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and
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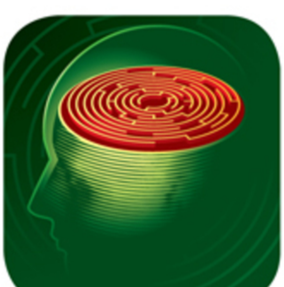
HANDBOOK OF ORTHOGNATHIC TREATMENT

A TEAM APPROACH



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Foreword

This new textbook on orthognathic surgery is to be commended for its holistic, or whole body, approach to the topic. Although there have been only relatively minor changes to the surgical techniques utilised in orthognathic surgery over the past 20 years, the recent past has seen dramatic changes in some of the psychological aspects of orthognathic surgery, some of the treatment planning techniques, and the overall concept of the team approach. These aspects are particularly well described in this textbook. The team approach for orthognathic surgery now involves the surgeon, an orthodontist (normally required for preparing the occlusion preoperatively and fine tuning the occlusion postoperatively), a restorative dentist (to restore missing or badly displaced teeth and perform cosmetic dentistry where required), laboratory staff (to carry out model surgery and prepare splints), psychologists (to evaluate the overall psychological indications for orthognathic surgery and the postoperative psychological changes that may occur), and of increasing importance someone to manipulate the software in the rapidly developing field of digital treatment planning. This textbook covers all these aspects in excellent detail.

Some of the most exciting developments in orthognathic surgery are in digital treatment planning with particular reference to three-dimensional planning. The ability to capture the patient's hard and soft tissues in three dimensions, manipulate them digitally on a monitor, and segmentalise the different components and simulate the surgery enables a new dimension in treatment planning. We are now able to accurately determine the effects of movement of the jaw in three dimensions with particular reference to areas like the mandibular angles and the lower borders of the mandible which have been somewhat difficult to predict previously. This is leading to added sophistication and changes in surgical techniques.

This textbook will appeal to those who are new to the field of orthognathic surgery as well as those who are experienced in orthognathic surgery.

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Preface

This handbook is our attempt to provide a short, contemporary textbook on the management of dentofacial deformities. There should be a chapter of interest to clinicians of all specialties and levels involved with orthognathic treatment, although we have written it with trainees particularly in mind.

Although there has been little change in the fundamentals of orthodontics, maxillofacial technology and orthognathic surgery over the past few decades, some important advances have occurred which have had a profound impact on our clinical practice. The most significant of these are:

1. An increasing awareness of the need to take the patient's psychological wellbeing into account as part of their journey through treatment. Psychological input to an orthognathic clinic should ideally not be limited to pre-treatment assessment, but also pre-surgical preparation and the provision of support at other times when needed, including post-operatively. We now consider this to be a key element of our inter-disciplinary approach.
2. The identification and analysis of the errors inherent to conventional face bow transfer records and articulators and their effect on the accuracy of model surgery. An understanding of these errors, their potential impact on treatment outcome, and how to eliminate them, is essential for all clinicians involved in delivering orthognathic treatment.
3. A paradigm shift from profile planning based on two-dimensional radiographs and photographs, to three-dimensional facial planning based on cone-beam computerised tomography and stereophotogrammetry. The 3D revolution is being fuelled by the rapid advance of image capture and computer technology and is increasingly becoming a routine part of our clinical practice.

In this book we aim to update the reader in these important areas of progress, in addition to covering the basic aspects of orthognathic treatment and describing the contribution of each team member within our integrated approach. We hope the content is clear and easy to read as well as thought provoking and, where possible, evidence based.

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We also owe a great debt of gratitude to our families for their continual patience and support.

1 Psychological considerations for the orthognathic patient

Chapter overview

Intended learning outcomes

By the end of this chapter the reader should:
- Understand the role of a clinical psychologist in an Orthognathic Service.
- Be able to explain the psychological impact of dentofacial anomalies.
- Be able to identify factors which may impact on patient satisfaction with treatment.
- Be able to identify psychological conditions which may not be helped by orthognathic treatment.

This chapter describes the role of a clinical psychologist, as an integral part of the multi-disciplinary team, in a dentofacial planning clinic. It covers:
- Psychological issues in facial appearance.
- Psychological assessment.
- Advice on the management of patients' psychological issues.
- Identification of patients with psychological problems which impact treatment.
- Psychological therapeutic input within this setting.

1.1 Psychological issues associated with facial appearance

A person's face is the most visible aspect of their appearance and is what other people focus on, during social interaction. Those with severe malocclusions may have been stared at, bullied, discriminated against most of their lives. Even when their condition may evoke a sympathetic response there may be an unintentional, negative non-verbal response from others which may be difficult for those people to suppress. As a result of these negative experiences, people with a facial deformity may go on to exhibit shyness and defensiveness in social situations, which compounds their social difficulties. Even those with more minor physical problems may be seen as less attractive, less socially competent and they may also have been subjected to teasing with resulting impact on their body image and self-esteem. MacGregor (1970) suggests that people with a minor anomaly such as "buck teeth" may evoke amusement, be a target of jokes and experience more actual direct

Handbook of Orthognathic Treatment: A team approach, First Edition. Ashraf Ayoub, Balvinder Khambay, Philip Benington, Lyndia Green, Khursheed Moos, and Fraser Walker.

comments about their appearance than those with more severe problems. Bull and Rumsey (1988) have conducted a number of experiments, in real life situations, which demonstrate the negative responses of others to a minor facial anomaly. Having an atypical facial appearance can therefore constitute a severe handicap in a wide range of situations and can affect social acceptance and social functioning in addition to the associated physical problems.

In addition to the objective features of the face, with its social implications, the psychological aspects of appearance also include the concept of body image. This is the person's subjective representation of their bodily experience and appearance. Cash (2006) has described body image as a multi-dimensional construct, encompassing both an individual's perception of and attitude towards their appearance. This involves their thoughts, feelings and behaviour in relation to their appearance. Their body image evaluation influences their level of satisfaction with appearance and will be influenced by cultural, ethnic and gender issues. The salience of attractive appearance, for that person, will also influence their associated distress with an objective or perceived anomaly. This helps explain why there is not a linear relationship between degrees of facial deformity and associated psychological disturbance.

Dental appearance plays an important part in body image assessment both in adolescence and adulthood. It is only one aspect of someone's face but it can independently influence how attractive a person is perceived to be. Both the individual themselves and other people rate someone with severe malocclusion as less popular and less sociable. Cunningham et al. (2000) found that orthognathic patients had poorer body image and facial body image than a matched non-clinical control group. Those most dissatisfied with their dental appearance are reported to be firstly those having an extreme overjet, secondly, an extreme deep bite and thirdly, space abnormalities (Helm et al., 1985). Combined orthodontic and orthognathic surgical treatment is now more readily available and there is more awareness of it. The majority of people undergo such treatment in order to improve function, but it also has an impact on the aesthetic appearance of their face. Indeed many people presenting for treatment in clinics do not have a severe malformation and are seeking treatment primarily for aesthetic reasons. In this situation, surgery is being carried out with the objective of improving the individual's body image. Even for those people who report a clear physical reason for undergoing orthognathic treatment, in a majority of cases, it is the aesthetic outcome from treatment that will determine their satisfaction with treatment.

Patients' expectation of orthognathic treatment is that it will improve both physical problems and their appearance, with resulting improvement in their body image, self-esteem and social functioning. In some cases the change in appearance can be quite marked, whereas in others the changes may be more subtle. Patients have to adapt to the change in their appearance and to deal with the response of others, or conversely the lack of response, to these changes. Most patients cope well with the treatment process and are happy with the outcome; for a minority however, treatment appears to have some negative psychological effects. Equally, psychological factors have an impact on physical response to treatment and to patients' level of satisfaction with it. There is therefore a complex interaction between oral functional and aesthetic factors in orthognathic treatment and between the physical and psychological aspects of treatment.

1.2 Psychological assessment

The psychological assessment takes place within the dentofacial planning clinic, before the patient is seen by the rest of the multi-disciplinary team. It is conducted in a one to one setting, in order to maximise the information obtained, as patients are much more likely to disclose information in that situation. The assessment does require a clinical psychologist with considerable experience of both psychological problems associated with appearance and also of the issues relating to the transitional period from late adolescence to adulthood (as the majority of patients seen are in this age group). It is a brief, focused psychological assessment covering the areas known to be relevant to patient satisfaction with the process and outcome of orthognathic treatment. The kind of information provided to the multi-disciplinary team includes:

- Patient's perception of the presenting problem and associated functional impact.
- Patient's motivation for and expectation of treatment.
- Patient's current psychological status and early identification of those patients who may need psychological support during treatment.
- Identification of those whose perceived problem is unlikely to be resolved by treatment.
- Assessment of risk factors predicting dissatisfaction with treatment.

1.2.1 Patient perception of the presenting clinical problem

Assessment of the patient's perception of the presenting clinical problem seeks to identify what exactly bothers them, how severe they perceive it to be and the impact it is having on their everyday life.

Patient's view of the clinical problem

It is important, at this initial stage, to understand what the patient thinks about the referred problem because a patient's perceived need for treatment may not always match the clinician's view. They may have a relatively uninformed view of the problem or they may be quite knowledgeable. Initially they are asked, irrespective of what they have been told or heard or read, what exactly bothers them and why. A more structured format follows the initial open ended questions in order to cover the relevant areas.

Functional and aesthetic concerns

It is important to understand the relative importance of physical functional problems and aesthetic concerns for the patient, associated with the malocclusion they present with. Patients may find it easier to discuss the functional concerns but may feel that their aesthetic concerns will be considered to be less important by clinicians. Jensen (1978) maintains that the evidence suggests that many patients conceal their aesthetic motivation for surgery. It may therefore be necessary to encourage patients to describe the aesthetic aspect of their concern. The relative importance of the functional and aesthetic concern, for the patient, is important when decisions are being made to proceed with treatment. If for example, the patient is primarily interested in aesthetic change and the team concludes that there is little chance of noticeable aesthetic change or the possibility of a negative effect then clearly the patient's concerns will not be met and they are likely to be dissatisfied with the outcome.

Perception of severity

The need to proceed with treatment is also influenced by the perceived severity of the problem both by the clinicians and the patient. The use of a Visual Analogue Scale, with defining markers at each pole, can be helpful in assessing the degree of concern a patient feels both about how severe they feel that the physical problem is and also the degree of distress they experience associated with the problem. There is no linear relationship between the degree of objective physical deformity and the severity of psychological disturbance associated with appearance reported by patients. So that someone presenting with marked facial problems may report little aesthetic concern, whereas others with some minor anomaly, which clinicians may consider to be within a normal range, may present with significant aesthetic concern. This latter group may require further more detailed assessment from a psychological perspective.

Not all patients who are offered surgery will accept this approach. In a study of patients with an equal objective need for surgery Bell et al. (1985) found that the patient's own perception of their face was a more important determinant of whether or not they accepted treatment. In general, lay people are more likely to judge a face as normal compared to surgeons and orthodontists. The authors of the study suggest that the patient's perception of their facial aesthetics should be of primary concern when alteration of facial aesthetics is being considered.

Impact on life

The reported impact that concern about appearance is having on the patient's everyday life is also assessed. This may require careful assessment in order to gain a realistic picture and to avoid both under-reporting and over-reporting of associated difficulties. Information about the onset of their concern, when this happened and if there were any particular triggers for it. Occasionally, patients may be referred who have not been aware of problems with their facial appearance prior to initial referral, but when the problem has been identified and named, may begin to become more self-conscious about their appearance. Equally, there may be patients who have been concerned about their facial appearance from an early age and this may have had a significant impact on their social and emotional development. The reported impact of the perceived problem is therefore assessed both in the past and on their current functioning.

Patients are asked if they have consulted anyone else in the past about the problem or had any previous treatment for it. A more general assessment of their body image is also made, asking for example, if there are other aspects of their face or body that they dislike and have considered changing by surgery or some other means. A history of any previous cosmetic type procedures undergone is also noted and this should include cosmetic dentistry.

In addition to the patient's description of the impact of their concern about their appearance, the psychologist will also observe their behaviour. For example, observing a patient automatically cover their mouth with their hand when smiling, gives important information about the behavioural aspects of their body image concern. Again, if a patient has problems establishing or maintaining eye contact then this may indicate a severe body image problem or a psychological condition such as social anxiety.

The assessment of the patient's perception of the presenting clinical problem is important for the team discussion and comparisons made with the clinical view of the problem, in order to avoid problems associated with disproportionate concern about appearance and dissatisfaction ultimately with treatment outcome.

1.2.2 Patient expectation of treatment

A second main area of the psychological assessment involves looking at the patient's expectation of treatment both from a physical and a psychological point of view. If patient's expectations are vague or unrealistic, it may be possible to alter those views by giving them very clear information during the multidisciplinary assessment, about what is possible from treatment. If their expectation about the effect that treatment will have on their lives is unrealistic, it may be possible to work with them psychologically in order to help them begin to make necessary changes in their lives, both prior to and following surgery, so that they can achieve a good outcome from treatment. If patients, however, continue to hold unrealistic views about what could be achieved both from a physical and a psychological point of view, despite input, then their expectations of surgery cannot be met and they are likely to be unhappy with the outcome from treatment.

1.2.3 Patient motivation for treatment

A third area of assessment is patient motivation both in relation to why they are seeking treatment and also to their likely adherence to what will be a long and demanding course of treatment. It is therefore important to establish if they have just agreed to be referred at the suggestion of their dental practitioner or another clinician and they are there unquestioningly. If this is the case, it is important to ask if they are keen to proceed once they have fully understood the nature of the clinical problem. This is particularly important if they are young or a vulnerable adult. If the referral was sought on their behalf primarily as a result of parental concern for example; it is important to establish whether they do actually share that concern and want to pursue treatment themselves. If they express a desire not to proceed, it is important to establish if this is because they have particular fears about the surgery (which may be inaccurate and change with reassurance) or do they simply have a different view from their parents. The maturity of this decision is also important to assess; for example to establish whether or not it is part of a more general oppositional stance with their parents or whether it is a considered view, taking into account the likely future impact of any facial anomaly they may have.

If the referral was primarily instigated by the patient themselves and is largely an aesthetic issue, the question of whether this is as a result of a sustained concern or one prompted by recent events (positive or negative) in the patient's life, is an important area of assessment. The recent event may be a negative one such as a relationship breakdown and the concern about facial appearance may just be part of a resulting general negative evaluation of self. There may be a more complex issue underlying patient motivation for treatment such as gender dysphoria or ethnic identity difficulties which may influence an aesthetic dissatisfaction with facial appearance. The question of why exactly the patient is seeking surgery, at this particular time in their life, is an important one because if surgery is in response to a more sustained concern, then they are more likely to be satisfied with the outcome of treatment.

Sarwer (2002) has described the concept of internal and external motivation for treatment. Internal motivation is driven by factors within the individual, for example, a wish to improve appearance or increase self-esteem. External motivation he suggests is concerned with factors external to the individual such as a desire to please others or the notion that if they changed their appearance they will get promotion at work and so on. The importance of the division between internal and external motivation has some relevance for patient satisfaction with outcome from treatment because it is suggested that more internally motivated patients are more likely to be happy with the outcome from surgery.

The likely motivation of a patient to continue with treatment through a relatively long treatment programme is also an important issue to explore. Patients are required to make frequent clinic visits, to adhere to an excellent standard of oral hygiene and to cope with many months of the initial treatment probably worsening their facial appearance, during the orthodontic preparation. The issue of motivation is more pertinent if they have a history of avoiding treatment offered or of defaulting from treatment. We know that past behaviour is the best predictor of future behaviour and therefore people who have not continued treatment in the past are more at risk of defaulting again, compared to those with no such history. It is therefore important to find out what the cause of the previous failure to complete treatment and if it is likely to recur in their current life situation. The patient's likely supportive network during treatment is ascertained, particularly for the immediate post-surgery period.

Motivation for treatment is affected both by the patient's perception of the problem and its relative importance to them and they need to make a very clear decision to proceed with treatment. If patients seem ambivalent about proceeding or if their motivation is questionable, then a delay in starting treatment is indicated. Those requiring additional support to attend, such as those with mental health problems, can be identified and the necessary support arranged.

1.2.4 Patient's psychological status

A psychological assessment, based on an expert knowledge of normal development, will also include taking a brief history of early childhood experience, their interpersonal relationships and of how they have functioned at school, work and in social settings. This will include some assessment of personality and the assessment of reported psychological difficulties currently or in the past.

A brief screening for a history of psychiatric illness is carried out and if such a history emerges then a more detailed assessment of current psychological status follows. This will include any history of alcohol or other substance abuse or of self-harm. If a significant psychological history emerges, a second assessment session may be required before the assessment is complete. This may include contacting the mental health professionals currently treating the patient, in order to obtain their opinion about any likely impact of the patient's illness on orthognathic treatment.

Finally to complete the assessment, a brief assessment of how patients have coped with illness, surgery or trauma in the past is made. There is some discussion about the patient's educational, work or family plans over the next two years because many patients seen in the dentofacial clinic are at a transitional stage of their lives and clearly this has to be taken into account when the treatment planning is being considered. An assessment of the social support available to them currently and any likely change to this, around the time of the surgery, is also carried out. The quality of social support has been found to be important for patient outcomes and it is important to try to identify patients who may need some additional support around the time of surgery.

1.2.5 Outcome from psychological assessment

At the end of the psychological assessment the psychologist has a discussion with the patient about relevant issues which have emerged during the assessment and informs them about issues which will be fed back to the rest of the clinical team. Some preparation for the rest of the assessment process is done, encouraging patients to ask questions or voice any concerns they may have during the process. If the patient indicates that they may have difficulty voicing their concerns they are reassured that they will have some help with that and they will also have a family member or partner or friend present with them. They are reminded that they have been referred for elective treatment and that they should only make the final decision to proceed, if treatment is recommended, after hearing all the risks and benefits of the treatment options. They are also reassured that they can take some time to make a decision as delay in starting treatment is better than withdrawing prematurely from treatment later.

Occasionally a recommendation will be made from the psychological assessment to delay the start of treatment because of the patient's current life situation, psychological difficulties or current mental health problems. For example if someone is suffering from post-natal depression and struggling to cope with a new baby, then a period of delay before embarking on treatment may be better. Sometimes patients may have difficulty in expressing concern about the timing of treatment because they think they will not be offered it again or they feel guilty that they have taken up an appointment slot. Postponement of the decision-making process may also be recommended if it emerges that the patient is under pressure, for whatever reason, to make a decision and they are not sure about it. This is particularly important if they are young, perhaps over-compliant or vulnerable in some way.

On rare occasions, the psychologist may recommend that treatment is not offered at all because there are contra-indicators for surgery from a psychological perspective (Red Flags) and these will be detailed in a later section. In addition, there may be other occasions where significant issues are identified by the psychologist (Amber Flags), which will influence the discussion and decision about whether or not to offer orthognathic treatment to particular patients. This may be particularly relevant in situations where the physical indicators for treatment are slight and the desire for treatment is primarily an aesthetic one. In some cases, the psychologist may arrange to see them again, contact the relevant mental health services for more information if necessary and carry out a more detailed assessment. If the patient agrees to appropriate treatment for the psychological condition identified, then a referral to the appropriate services is made.

Immediate feedback from the psychological assessment is given to the team prior to the orthodontic and surgical assessment of the patient. The feedback will also include recommendations about the patient's psychological needs during assessment and treatment. The psychologist takes part in the final discussion with the team after assessment of the patient is complete and during the discussion with the patient about treatment options, at the end of the multidisciplinary assessment.

1.3 Advice on management of patients following assessment

When the psychologist has identified patients with psychological difficulties or conditions during the initial assessment, some recommendations about management of the patient during treatment is made. The issues might be quite wide ranging but a few typical examples are patients who have:

- generalised anxiety;
- history of depression;
- learning disability;
- history of sexual or physical abuse.

If a patient is assessed as having generalised anxiety at assessment then clearly clinical settings and procedures are likely to evoke anxiety in such patients. Advice about their likely presentation at clinics, how to manage that and encouragement to use their anxiety management techniques should help to reduce the patient's anxiety.

A patient with a past history of depression will have been given advice by the psychologist at the initial assessment. In particular, patients are warned about the possibility of lowered mood following surgery and they are encouraged to report any symptoms of depression so that they can receive the appropriate input. The team is also advised about the previous history, or the current well managed depression so that they can refer the patient to psychology if they feel subsequently that the patient's mood is worsening. The exacerbation of depression may not just present as obvious low mood, but typically in increased irritability, change in treatment compliance or poorer self-care.

If a patient presents with a learning disability, then advice about the level of language use and how to structure information for that patient may be made. If the learning disability is severe and the patient is accompanied by their carer, attempts should still be made to ensure that communication is primarily with the patient and understood by them. Liaison with the family or carers will be essential if the patient has any likely difficulties in relation to treatment which they are unable to express.

If a patient has a history of sexual or physical abuse identified during assessment and patients feel uncomfortable with some procedures, the psychologist will have discussed what is going to be particularly difficult for them in clinical situations and be able to advise team members accordingly. For example, if a patient finds it particularly difficult to have someone standing behind them, out of sight, then care should be taken to minimise the time this happens. In general, it may be necessary to take more time to explain procedures before approaching the patient than would normally be necessary. Having various procedures or an anaesthetic may again be particularly difficult for patients with a history of abuse and particular care to support the patient at this time or devising procedures to increase the patients' sense of control in those situations may be necessary.

Advice may also be given about a variety of other relevant issues including gender, cultural or religious issues which may have been discussed at psychological assessment if this will have any implication for how the patient is managed during treatment. Understanding of psychological issues will contribute to better management of the patient.

1.4 Red flag and amber flag patients

The evidence suggests that most people being referred to orthognathic clinics do well with the treatment and are happy with the outcome. There are, however, a number who are not satisfied with the outcome of treatment and for some this will be due to psychological problems rather than any physical problem with their treatment. It is important that they are identified because in some cases orthognathic treatment may worsen their psychological condition. In other cases, it is important that they receive appropriate treatment for their psychological difficulties.

There is a generally held view, expressed in the orthognathic literature, that their patients are quite different from those seeking plastic surgery. In particular, they are said to be more psychologically stable and not dissimilar to the general population. There are however issues which should be noted in relation to this assumption of normality. Firstly these conclusions have often been based on average population scores rather than looking at the proportion of participants meeting "caseness" for psychological conditions which has not been considered in the past. Secondly, psychological "normality" is assumed because many are referred at the instigation of their general dental practitioner or orthodontist and have a clear physiological need for surgery. However, many studies show that aesthetic concern about facial appearance is a prime motivator for seeking orthognathic surgery and is also the main criterion for patient satisfaction with treatment. Thirdly, a sizable minority of patients are reported to have instigated the referral themselves and there is a suggestion that there is a change in the clinical population seeking orthognathic surgery since the 1990s, as more people have increased concern about appearance and are more aware of orthognathic surgery. Given that some people present in an orthognathic clinic with minor anomalies and an appearance within an average range, but reported associated psychological distress, may mean that this subgroup of orthognathic patients may be more similar to plastic surgery populations. Therefore some psychological issues, which have been more extensively researched in the plastic surgery literature, may be relevant to a sizeable minority of orthognathic patients and it is important to ensure that there are no conditions present which may make the surgery inadvisable. Finally it has to be remembered that "normal" or "average" populations will also include a percentage of people with psychiatric disorders and psychological problems; it does not mean that they are problem free.

Although patients described in the following sections are relatively rare, they may cause considerable disruption in clinical work, become more distressed following treatment and in rare cases, litigious. One way to think about the issue in relation to proceeding with treatment is a Red, Amber, Green flag system. The following section goes into some detail about those patients who:

- Have RED FLAGS and should generally not be offered surgery.
- Have AMBER FLAGS and treatment should go ahead only after very careful evaluation by the team.

1.4.1 Red flags

Body dysmorphic disorder

The essential criteria for a diagnosis of body dysmorphic disorder are:

- A preoccupation with a defect in appearance where the defect is imagined, or if a slight physical anomaly is present, the individual's concern is markedly excessive.
- The preoccupation must cause significant distress or impairment in social, occupational or other important areas of functioning.
- The preoccupation is not better accounted for by another mental disorder (DSM-IV-TR 2000).

The prevalence of Body Dysmorphic Disorder (BDD) in the general population is thought to be between 1%–2% but is known to be much higher in plastic surgery (5–5%) and dermatology (9–15%) clinical populations (Sarwer and Crerand, 2008; Phillips et al., 2000). The rate of BDD seen by orthodontists is reported as 7.5% of adult patients (Hepburn and Cunningham, 2006). The rate of BDD in orthognathic treatment clinics is not known, however given that the face is one of the main focuses of concern in BDD, it is highly likely that the rate is higher than in the general population. Veale et al. (1996) for example, found that 86% of their BDD sample mentioned their face as one focus of their concern. The average age of onset of the condition is late adolescence (Phillips et al., 1993; Veale et al., 1996) which is also the average age of those presenting in a dentofacial planning clinic. BDD is thought to be equally prevalent in men and women.

The key clinical features of people presenting with BDD are that they present with marked distress and intense pre-occupation with the imagined defect. They may try to camouflage the defect with their hairstyle, heavy makeup, and scarf or hat for example. They may spend long periods checking the imagined defect in a mirror or other mirrored surfaces and repeatedly check with family members about the appearance of the area involved. Alternatively, they may describe avoiding looking in mirrors and have them removed from their house; or never discussing their problem with anyone they know, to avoid drawing attention to it. There may also be marked avoidance of social and occupational settings and of forming relationships despite a wish to do all of those things. At the more extreme end of the spectrum, they may have dropped out of college or work and have become quite socially isolated.

There will inevitably be a marked difference between the objective evaluation of the patient with BDD and the patient's thinking about their perceived anomaly, which may be delusional or at a level of overvalued ideation. Phillips and McElroy (1993) maintain that although there may be a spectrum of severity along which the patient's beliefs may vary over time, they will continue to present with impaired insight about their condition. Clinical opinion and feedback about the essential normality of their appearance will not alter this.

Clearly patients with BDD will pursue treatment for the imagined defect persistently and put health professionals under great pressure to act on their behalf. They may have approached different clinics in different areas, to try to have the treatment they think they need and may well not disclose this when seen. Anyone presenting with excessive pressure to have surgery or treatment, needs to have a very careful assessment. The presence of BDD is considered a contra-indicator for surgery and indeed surgery can lead to an intensification of their symptoms or a symptom shift to another feature of their face or body (DSM-IV-TR). The NICE guidelines (2005) on obsessive compulsive disorder, which includes BDD, recommends that patients presenting with the condition should be assessed by a mental health professional with experience of the disorder. They should be referred on to an appropriate mental health clinician for treatment, preferably to a service which specialises in such conditions.

Psychotic disorders

a) Schizophrenia with delusional beliefs about facial appearance

There are a group of patients who may have delusional beliefs about their appearance which is secondary to a schizophrenic illness. They may at times become very preoccupied about their facial appearance for example, but at other times this preoccupation seems less intense, perhaps varying with an overall improvement in their mental state. Pruzinsky (2002) makes the point that very little is known about body image disturbance in psychotic disorders such as schizophrenia as there has been very little systematic investigation of it despite discussion of the phenomena in clinical case descriptions. Clearly, treatment would not be recommended for patients with such delusional beliefs, as it will not resolve their concerns.

On the other hand, if someone is referred with a schizophrenic illness with no delusional beliefs about their face they should be considered for treatment, if it is indicated. Contact with mental health services is essential, in order to obtain an opinion about the patient's current stability and ability to cope with treatment. An assessment of the support available to them should be made, in order to ensure that they are able to benefit from treatment.

b) Somatic delusions

The diagnosis of delusional disorder, somatic type (DDST):

> 'applies when the central theme of the delusion involves bodily functions or sensations'. (DSM-IV-R)

Occasionally someone may present with a single delusional belief about their face which does not seem part of any other psychotic condition such as schizophrenia. They may have normal appearance or at best some minor facial anomaly and their beliefs about their face are not consistent with an objective assessment. They may be quite insistent about the need for surgery and as the beliefs are delusional will not respond to reassurance about the essential normality of their face. The condition may vary, but tends to be chronic so they may repeatedly request treatment (Pruzinsky, 2002). Clearly surgery would not resolve their perception of the problem and surgery is therefore contra-indicated.

Under the current classification of Mental Disorder (DSM-1V-TR), BDD patients with delusional beliefs are also classified as having somatic delusions but experts in the field (e.g. Phillips, 2002) feel that they are actually one disorder with patients presenting with varying degrees of severity and are best thought of along a dimension of insight/delusion, rather than as discrete categories.

Major current depression

If patients present with current major depression, then it may be advisable to delay starting treatment, particularly if the prime reason for seeking orthognathic treatment is dissatisfaction with their facial appearance. In clinically significant depression, patients' mood symptoms affect their thinking and behaviour. There is a positive relationship between depression and body image problems and clearly any distress they may report in relation to their facial anomaly will be influenced by their current low mood. Their mental state may well be influencing their decision to seek surgery and when well, they may hold a different view. The depression will also affect their motivation and make it more difficult to cope with and adhere to a demanding treatment regime. Arrangements should be made to re-assess patients in several months, when the depression may have resolved.

Social phobia (Social Anxiety Disorder)

Some patients may present with marked social phobia or social anxiety and they identify their facial anomaly as the cause of the problem. In many cases their condition may not have been previously identified and they may have had no contact with mental health services.

The criteria for social phobia include:

> A marked and persistent fear of one or more social or performance situations in which the person is exposed to unfamiliar people or to possible scrutiny by others. The individual fears that he or she will act in a way (or show anxiety symptoms) that will be humiliating and embarrassing. (DSM-IV-TR)

Exposure to the feared situation invariably provokes anxiety and in some cases a panic attack. Patients with social phobia do have insight and recognise that the fear they experience is irrational, but they will have marked social withdrawal despite a desire for social interaction. Typically patients with a social phobia are hypersensitive to criticism or rejection. The condition may also have a significant impact on their work performance, social life and interfere with relationships. The prevalence rate in the general population of social phobia is around 2%. A much higher percentage of the general population will present with a degree of much milder social anxiety and this has been suggested to be as high as 40% (Edelmann, 1992).

Individuals, who have a history of extreme shyness in childhood or later have marked social anxiety, may focus on an aspect of their appearance as the reason for their difficulties. Clearly appearance can influence sociability, but where people are presenting with minor physical problems and seem to have marked social difficulties, then clearly an alternative explanation for their difficulties must be considered. This is important because their expectation of surgery will not be met (surgery will not bring about a transformation of their life) and this may precipitate a psychological crises when the expected result does not materialise or they may just shift the focus of their concern to some other aspect of their appearance.

Personality disorders

A personality trait has been defined as:

> An enduring pattern of perceiving, relating to and thinking about the environment and oneself that are exhibited in a wide range of social and personal contexts. Only when personality traits are inflexible and maladaptive and cause significant functional impairment or subjective distress, do they constitute a personality disorder. (DSM-IV-TR)

A number of personality disorders have been associated in the plastic surgery literature with poor outcome and may be problematic from a psychological perspective especially if the physical indications for orthognathic treatment were slight. An example would be Avoidant Personality Disorder.

A personality disorder which may sometimes be confused with social anxiety disorder is Avoidant Personality Disorder which has been defined as:

> A pervasive pattern of social inhibition, feelings of inadequacy and hyper sensitivity to negative evaluation, beginning by early adulthood and present in a variety of contexts. (DSM-IV-TR)

People with this diagnosis are typically shy, lonely and isolated because of their hypersensitivity to possible criticism or rejection. They frequently view themselves as inadequate or inferior to others. They may as part of the condition, assess their appearance as problematic and report embarrassment about some aspect of their face and fear rejection because of it. Orthognathic treatment is unlikely to change the patient's functioning, particularly if the physical indications are slight.

Self-harm

It is important to know if someone has a history of self-harm, whether this is recent and what form that has taken. There is a spectrum of severity, but some people, who harm their bodies, may interfere with wound healing or some other aspect of their treatment. A careful assessment of current stability and contact with mental health services, if they are being seen currently, is essential before considering treatment.

If patients are currently abusing alcohol or drugs significantly, then orthognathic treatment may not be appropriate currently. They would be unlikely to co-operate fully with treatment and may suffer trauma to their face, during for example binge drinking episodes.

Eating disorders

Current, severe eating disorders such as Anorexia Nervosa and Bulimia Nervosa would be a contra-indicator for treatment because of the physical effects of the conditions. In addition, the clinical priority in such cases would be to ensure that they are referred for appropriate treatment for their eating disorder if not currently in treatment.

1.4.2 Amber flags

Patients with amber flags are those patients whose presentation may give rise to some concern. These patients may not meet the formal criteria for psychiatric disorders but their presentation is suggestive of some psychological difficulty or a concern that they are at risk of being dissatisfied with the treatment outcome.

Preoccupation with minor defects

Patients who present at the clinic with pre-occupation with objectively minor physical problems or whose appearance can be considered to be within an average range of appearance, should be dealt with very carefully. They may engage in a very long and detailed history of their problem; have prolonged discussion about treatment options and may have researched treatment options extensively on the Internet. Typically they may also have difficulty in making a decision about whether or not to proceed with treatment. They may be exhibiting obsessional traits or even an obsessive compulsive disorder, which may involve having an extremely high level of expectation of their appearance. Given that their level of concern is not in keeping with objective assessment at the start, it may be impossible to achieve the standard of perfection they require and as a result, they may have difficulty accepting the outcome from surgery and request repeated surgery. They may also have some difficult adapting to changes in their appearance. Alternatively someone preoccupied with minor defects may have BDD.

Vague concerns with their appearance

If someone is unable to articulate their particular concerns about their face, after having been given plenty of time and encouragement to do so, then this is a cause for some concern. If they can only voice a vague notion of ugliness or a general unhappiness with their facial appearance this is equally problematic. It is not possible to establish their concerns or expectations accurately and therefore any subsequent surgery may not resolve their particular problem. It may also be indicative of a degree of BDD.

Use of extreme language

A patient who has a dramatic appearance and presentation and who describes any anomaly, even a minor one, in extreme language may have histrionic personality traits. They may appear to be very confident but be unusually demanding of attention and have some difficulty with the physical effects of surgery and recovery. Again, the use of extreme words such as ugly or repulsive, when describing a relatively minor anomaly, may be indicative of a degree of BDD.

Other body image problems

If a patient is seeking orthognathic surgery primarily for aesthetic reasons and they have very little physical indication for surgery it is important to know whether or not they have other body image problems. It is important to establish if they have other concerns about their face or concerns about other aspects of their body. They may have consulted other specialists about their presenting problem and perhaps been refused surgery. It is also important to know if they have had other cosmetic procedures such as plastic surgery, regular use of botulinum toxin injections, cosmetic dentistry and so on, in order to establish the extent of body image dissatisfaction. They may of course not reveal all their history and if this is the case, then it is a cause of some concern. Again they may be at risk of being unhappy with the outcome from treatment.

Complex identity issues

Dissatisfaction with facial appearance can occasionally be a manifestation of difficulties associated with more complex issues of identity for the patient. For example, particularly in adolescence when body image issues are especially in focus, an individual from a minority ethnic group in a society may want a particular aspect of their appearance to be more like the cultural ideal in the dominant ethnic group, in that society. This may be only a temporary attitudinal shift or part of the exploration of identity in adolescence and not a long term concern.

Again patients with gender dysphoria, may present with dissatisfaction with aesthetic aspects of facial appearance, often in situations where they are experiencing difficulties in adapting to living within their new gender and in particular, experiencing problems with the response of others to their change of identity. Orthognathic treatment is unlikely to resolve their difficulties and they may well as a result be unhappy with treatment outcome.

Undue pressure to have surgery

If clinicians feel under considerable pressure to go ahead with treatment, perhaps in situations where they feel that the clinical indicators for treatment are not compelling, this should raise some concerns. The pressure may come from parents who may be very anxious about the implications of their child not having treatment or from the patient themselves.

There may also be considerable pressure from parents to have their child undergo treatment earlier than the optimal age for treatment. This may be because the patient is quite distressed about their appearance or they are being teased or even bullied at school because of their dental anomaly. Clearly, if the latter is the case, then parents can be encouraged to approach the school, as there are support services in schools too (i.e. educational psychologists, school counsellors) who can help support the child and any bullying issues can be appropriately dealt with in the school.

Disproportionate social effects
If a patient describes quite disproportionate social effects of quite minor anomalies of appearance then this raises questions about their perception of the physical problem and of whether they will be happy with the outcome from treatment. It may also be indicative of a more general social problem which will not alter with orthognathic treatment.

Dissatisfaction with previous treatment
A patient's description of what they consider to have been previous failed treatment or poor relationships with clinicians which they have seen in the past, is of some interest, particularly if they have had a good objective outcome. Although undoubtedly some patients may have had poor experiences in the past, a closer investigation may suggest that there is a danger that they are likely to be unhappy with future treatment also.

Narcissistic traits
People who present with narcissistic traits (morbid self-admiration) are over-represented in those presenting for cosmetic surgery and cosmetic dentistry and may also present in a dentofacial clinic with perhaps minor physical anomalies. They may have unrealistic ideas about what can be achieved from treatment or attempt to make disproportionate demands on clinicians throughout treatment. They will be at risk of being dissatisfied with outcome from treatment, despite good outcomes and may put considerable pressure on clinicians for further treatment.

In summary, those patients presenting with red flags are unlikely to be helped by orthognathic treatment and should be referred for psychological treatment by a specialist service or referred to mental health services, if required. Patients presenting with amber flags should have a very careful assessment and a team discussion about whether or not the physical indicators for surgery are sufficient to outweigh the psychological concerns in a risk benefit analysis. If such patients proceed to surgery they may need some additional support or a particular management strategy as part of their care plan.

1.5 Psychological therapeutic input to patients during treatment

The majority of patients having orthognathic treatment will have no need for psychological input. However during treatment, a variety of stresses can occur and psychological issues may arise requiring some psychological input; during pre-surgical orthodontics, immediately prior to surgery or post-surgery.

1.5.1 Pre-surgical orthodontics

A number of brief interventions may be made with people, who have been identified at assessment, with particular psychological issues. Other problems may arise, during the fairly lengthy period of orthodontic treatment and which may be helped by further psychology assessment or intervention. For example patients may begin missing appointments which may be indicative of motivational issues, anxiety about the prospective surgery or ambivalence about completing treatment. Clinicians treating the patient may also become aware that the patient is exhibiting marked anxiety or low mood. The fact that the psychologist is seen as part of the team and has already spoken to them, makes the discussion about referral to psychology much easier and reduces any perceived "stigma". The patient themselves may ask to be seen as they have been told at the initial assessment that they can access further psychological input at any stage of treatment, if required. Some of the more common difficulties include the following:

a) Anxiety
If patients present with anxiety disorders such as generalised anxiety disorder or phobic anxiety, then a brief intervention may be offered which may typically involve relaxation training, anxiety management training or systematic desensitisation and use of coping self-statements.

b) Depression
If a patient becomes depressed during treatment, then a further psychological assessment would be carried out and depending on the severity of the problem would either refer them to mental health services or liaise with their general practitioner who may prescribe anti-depressant medication and they could then be seen by the psychologist for

cognitive-behavioural therapy or other appropriate intervention.

c) Unrealistic expectation of psychological effects

If a patient has been identified as having rather unrealistic expectations about the psychological impact of the treatment, but a decision has been made by the team to proceed with orthognathic treatment, then some brief therapeutic intervention, by the psychologist, may be helpful. The intervention would focus on helping the patient to assess the reality of some of their expectations, to emphasise that psychological change may take longer than the physical change in their appearance. It would also involve helping the patient to identify some changes that they could make in their functioning while undergoing orthognathic treatment so that the benefit from the later treatment is maximised. For example, if they are socially avoidant because of their concern about their appearance, encouraging them to begin to go into social situations they are currently avoiding, reminding them that the changes that will happen following surgery may not be particularly obvious to other people. Providing some training in coping strategies for any associated anxiety can also be helpful.

d) Support of patients with psychiatric conditions

A further role for the psychologist in the dentofacial clinic is to support those patients being treated who have stable mental illnesses but whose illness may still impact on the treatment process. Liaison with the mental health team can help resolve problems and ensure attendance for clinics. It will also be helpful in the period following surgery, to ensure that the patient manages to eat appropriately.

e) Patient changing decision to proceed with surgery

Patients may change their minds about proceeding with surgery after orthodontic decompensation has begun, despite it being emphasised at the start of treatment that the orthodontic and surgical treatment are a package and are co-dependent. If their decision is due to unrealistic fears about the surgery then a discussion with the psychologist and the surgeon may resolve some of the issues and fears that the patient has which would allow them to proceed as planned.

1.5.2 Surgical planning stage – patient preparation for surgery

Psychological factors have been shown to influence physical response to surgery, play an important part in surgical outcomes and contribute to patient satisfaction.

a) Communication

Communication between the surgeon and patient has been identified as a critical factor in the prediction of positive outcome following surgery. Typically patients will only retain a small amount of information given, be selective in what they attend to and anxiety in the clinical situation will affect recall. Lack of sufficient information about post-surgical adjustment problems is a frequent complaint of patients dissatisfied with their treatment. Written information can help, as can links to websites or with patients who have had similar surgery, but communication with the clinicians providing treatment, is particularly potent. Ensuring that a family member or partner has access to the information, at each stage of treatment, is also important.

b) Patient expectation of surgery

Prior to surgery, it is also important to re-iterate some of the issues which may not have been discussed since the initial assessment for example, eliciting again what patients are expecting from surgery and ensuring that these are realistic. At this time the orthognathic team should once again clearly express what is hoped to be achieved by surgery and the use of photographs or computer prediction software are particularly helpful. A reminder that desired changes in appearance may take some time and that they may experience a short-lived, negative emotional response immediately after surgery is important. They also need to be reminded that positive changes in self-esteem and interaction with others, if necessary, may take considerably longer to occur and require their own active participation in the process.

c) Patient preparation for surgery

Encouraging all patients to discuss their fears and anxieties, about the approaching surgery, will enable the clinician to provide relevant information about each of their concerns. There is considerable evidence in the pain literature that most patients cope better with a realistic description of likely discomfort following surgery, rather than simple reassurance and that this can have significant effects such as a decreased need for analgesics and earlier discharge from hospital. It is important that family members are also given information about the process of and effects of surgery; so that they are prepared for what they see when visiting the patient post-surgery, as their reaction may influence the patient's immediate post-surgical response.

d) Anxiety

Pre-surgical psychological distress has been shown to have a negative impact on post- surgical outcomes. Immediately prior to surgery a small number of patients may begin to exhibit considerable anxiety about it and they should receive additional support. In some cases information alone may not be enough to alleviate their anxiety and such patients may need some input from psychology focusing on the use of relaxation, coping self-statements and distraction techniques.

In summary, the issues of communication; realistic information giving; patient preparation; input to potentially vulnerable patients prior to surgery are all important issues because the patient's emotional state will not only determine their sense of well-being and satisfaction with surgery but also their physical response to the surgery.

1.5.3 Psychological input following surgery

The majority of patients adjust quickly to changes following orthognathic surgery but a number of psychological issues are known to influence the patient's progress after surgery:

a) Process of adaptation

After orthognathic treatment, patients have to adapt to changes in their appearance and oral functioning. If the alteration to a patient's facial appearance has been marked they may also have to adjust to change in how people respond to them. The majority of patients, however, appear to adapt quite quickly and are satisfied with the outcome of their treatment. However, not all patients adapt at the same pace and for example Kiyak et al. (2006) reported that men report less satisfaction with body image in the months following surgery compared to women. The suggested reason for this is that men may take longer to adjust to changes in their physical appearance. Adaptation is a process of change and it may be that psychological changes, associated with positive change in appearance, take longer than the physical changes.

b) Reaction of others

Social evaluation is a critical factor in a patient's adjustment to change after surgery. If a patient has had a severe disfigurement prior to surgery, then they are likely to receive considerable positive feedback from others about the improvement in their appearance (Kiyak, 1995). The change in social acceptance of their appearance will be obvious to them and will therefore have an impact on patient satisfaction with surgery. Conversely, patients may be disappointed if people in their social sphere do not notice any change to their appearance and may begin to feel that the treatment was not worthwhile.

The role of partners or families, providing the prime emotional support for a patient, is critical. They have a significant influence on a patient's original decision to opt for treatment and are an important, continuing influence on satisfaction with treatment.

There may be a mismatch between support and the patient's process of adjustment following surgery and particularly during the period when they are still adjusting to their changed appearance and responding to wider social reactions to their changed appearance. Family and friends may be supportive in the very early stages of surgical recovery, but may assume that the patient has no need for continued support beyond this and at a time when clinical input is also reduced. This may be a period when dissatisfaction with outcome from surgery will manifest itself, so that for example Kiyak et al. (1984) found that self-esteem scores were lower nine months after surgery but had improved again at 24 months after surgery. Kiyak et al. (1985) found that a subset of about 20% had increased mood disturbance and this group were more likely to experience significant life changes after surgery including divorce and family problems. The author suggests that social support, from significant others, is a continuing influencing factor for patient satisfaction with treatment for up to two years following surgery.

c) Mood disturbance

Immediately following surgery, patients typically have to cope with facial swelling, bruising, discomfort associated with the surgery and the orthognathic wafer. Patients vary considerably in how they cope with the immediate post-surgical period and may need reassurance about the temporary nature of the problems they are experiencing. Transient low mood following surgery is quite common and some have suggested that this may be linked to anaesthesia, steroid and analgesic drugs commonly prescribed at this time and to weight loss (Stewart and Sexton, 1987).

However, some patients appear to have a much more sustained low mood but little clear information is available, in the literature, about the proportion of patients involved. Derwent et al. (2001) reported that around 30% of parents and patients independently rated the patient as having depressed mood during the three months following surgery. Kiyak (1985) suggested that a 20% subset of patients have symptoms of depression. Kiyak (1981) found that low mood measured by questionnaire did not improve until about six months after surgery and not until the fixed braces were removed. A minority of patients may therefore have a more sustained depression and may require psychological support and treatment.

There is a consistently high correlation between low mood and dissatisfaction with the outcome of surgery (e.g. Kiyak et al., 1985). Depressed patients report more pain, post-surgical discomfort and poorer oral function. There appears to be a difference between the complaint of pain and other physical effects of surgery such as swelling and paraesthesia. This is thought to be due to the fact that there is an affective component in the pain experience which will be influenced by low mood.

d) Other problems

Relatives may identify ongoing problems both physical and psychological which the patient may not have reported themselves. A common example is a concern that the patient is not eating enough and this can be due to discomfort but some patients do see this period as an opportunity to lose weight and may become seriously underweight.

Functional improvement after surgery does not mean that associated psychological problems will improve at the same pace but may take much longer and involve a dynamic effect on the process of interpersonal relationships for example. Changes may still be taking place two years after surgery and some patients may require help to adjust to the changes. A clinical psychologist working within a dentofacial clinic can provide therapeutic input to deal with psychological difficulties associated with their treatment in the clinic.

1.6 Conclusion

Clinical experience and evidence from research suggests the need for systematic selection of patients, preparation for surgery and the careful management of the psychological aspects of patient care throughout the course of orthognathic treatment.

In summary clinical psychologist input to an orthognathic clinic will provide:

- Specialist assessment of all patients prior to treatment and early identification of potential problems from a psychological perspective.
- Advice on the psychological aspects of patient care.
- Input to patients at each stage of treatment when required.
- Reduced chance of problems associated with patients' psychological difficulties and therefore improved satisfaction with treatment outcome.
- Provide specialist psychological therapy for those not suitable for treatment or provide a signpost to appropriate mental health services when necessary.

The psychological aspects of patient care in orthognathic treatment needs to be recognised as an integral part of patient care.

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2 Dentofacial assessment

Chapter overview

Intended learning outcomes

By the end of this chapter the reader should:
- Understand the importance of taking a full history from the patient.
- Understand the importance of correctly positioning the patient's head prior to facial assessment.
- Be aware of the systematic approach required in carrying out a facial and intra-oral assessment of an orthognathic patient.
- Understand the function of the basic diagnostic records used in the management of orthognathic patients.
- Be aware of the commonly used objective soft tissue analyses.
- Be aware of the indications and purpose of three-dimensional imaging, including Stereophotogrammetry and Cone Beam Computerised Tomography.
- Be aware of the role of cephalometric analysis, including its limitations.
- Understand the importance of recognising progressive facial dysmorphology and the need for special investigations in some cases.
- Understand when referral to other medical and dental specialists is required.

2.1 Introduction

Assessment of the orthognathic patient should be carried out systematically to ensure that a complete picture of the presenting dentofacial dysmorphology

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is assembled. A pro-forma may be helpful in guiding the clinician through the assessment in planned sequence and documenting the findings in a structured manner. The purpose of this chapter is to describe the level of assessment that we consider to be essential on an inter-disciplinary planning clinic. Psychological assessment of the patient is an invaluable part of this and has been described in detail in Chapter 1. The procedure on our clinic is that all new patients are interviewed by the psychologist first and then progress to clinical examination only if given the 'green light'.

2.2 General assessment

2.2.1 Patient's concerns

Because orthognathic surgery is largely elective in nature, the patient's concerns are the main reason for pursuing treatment and must be carefully elicited from the outset. Whilst most patients will describe one or more clear problems, some will be more vague and will have to be probed more thoroughly to establish exactly what they are seeking to derive from treatment. In general, patients' concerns fall into the following categories:

1. Functional problems:
   a. Difficulty with biting and chewing.
   b. Discomfort due to the malocclusion:
      i. Palatal or gingival soft tissue trauma (e.g. deep overbite).
      ii. Dental trauma (e.g. limited tooth contact).
   c. Temporo-mandibular joint dysfunction.
   d. Speech difficulties.
2. Aesthetic problems:
   a. Facial appearance.
   b. Dental appearance.
   c. Gingival display.

If the psychologist can be present on the clinic when the patient is being examined, this is valuable in helping the patient to express their concerns and the clinicians to understand them.

2.2.2 Medical, dental and social history

As with any surgical or dental patient, a full medical history should be taken prior to clinical examination. It is not within the scope of this book to detail the medical conditions that will impact on the delivery of orthognathic surgery, but if the patient reports any significant illnesses at initial assessment it is prudent to contact the General Medical Practitioner or Consultant Specialist for clarification or further investigations prior to an appointment on the combined clinic.

It is important to establish the patient's level of dental motivation and ensure that they will have the ongoing support of a General Dental Practitioner for the duration of their treatment. If there is a history of dental anxiety it is important to make sure that the patient will be able to cope with the challenges of surgical orthodontic treatment.

A patient's social history should at least include questioning about home circumstances, smoking and alcohol consumption. It is also important to know about any history of mental health problems, but specialist questioning in this area is most appropriately undertaken at the psychology interview.

2.2.3 History of dentofacial dysmorphology

A history should be taken from the patient regarding the development of their dentofacial problems. This should include the following:

1. Congenital anomalies (e.g. growth abnormalities, condylar hypoplasia or agenesis, hemi-facial microsomia).
2. Familial traits (i.e. other family members with facial dysmorphology, such as class III jaw relationship).
3. Acquired anomalies:
   a. Traumatic (e.g. TMJ trauma, before and after cessation of growth).
   b. Pathology (e.g. pituitary adenoma).
4. Racial characteristics:
   a. Anterior bi-maxillary protrusion (Black African, Chinese).
   b. Zygomatico-maxillary hypoplasia (Asian).

It is important to recognise progressive facial dysmorphology, which most commonly manifests as follows:

1. Gradual increase in anterior open bite (e.g. idiopathic condylar resorption).
2. Progressive late mandibular growth (e.g. pituitary adenoma).
3. Progressive mandibular asymmetry:
   a. Unilateral condylar hyperplasia.
   b. Unilateral condylar resorption.
   c. Unilateral condylar tumour (e.g. osteochondroma).
   d. Hemi-mandibular elongation.
   e. Hemi-mandibular hypertrophy.

It is important to elicit the most accurate possible history regarding the progress of these conditions. Previous family or school photographs, if available, can be extremely helpful.

2.2.4 Stature and body form

The patient's height and general body shape should be noted early on in the assessment, since orthognathic treatment should be aimed at delivering facial proportions that are in keeping with the patient's build. A tall, lean patient is unlikely to suit a disproportionately reduced lower anterior face height and a short, broad patient is unlikely to suit an increased lower anterior face height. Similarly, a patient's stature may influence the surgical plan in the antero-posterior plane. For example, in certain class III patients, standing height might play a part in deciding whether surgical correction would be by means of a maxillary advancement or a mandibular setback.

Where a patient is clearly overweight this can be a contra-indication for elective orthognathic surgery. In such cases, the patient may be required to reduce their weight before they can be considered for treatment. The Body Mass Index (BMI) is helpful as a guide.

2.3 Facial assessment

The following is a suggested systematic approach to clinical assessment of facial dysmorphology. See also Tables 2.1a and b.

2.3.1 Lateral view

The patient should be seated comfortably with their back in an upright position and asked to adopt their natural head posture (NHP), in which they are generally viewed in everyday life. This can be made easier by asking them to look in a mirror mounted straight ahead of them. The alternative method of positioning the Frankfort Plane (FP) parallel to the floor may place them in an artificial position, since this not a reliable horizontal reference plane in patients with significant facial skeletal discrepancies. It has been shown that NHP is more reliable than FP for orientation of the head. Inappropriate head positioning can result in a false perception of the antero-posterior jaw relationship (Figure 2.1).

Habitual tilting of the head to the left or right side should be avoided. However, for patients that have a condition that produces involuntary tilting, such as tortocollis (due to shortening of one of the sterno-mastoid muscles), this should be accepted as their normal posture, as it is unlikely to improve as a result of surgery.

It is important for the peri-oral soft tissues to be relaxed, particularly in patients with increased vertical proportions, who may have incompetent lips and will tend to habitually posture them together through mentalis muscle hyper-activity.

Table 2.1a Soft tissue profile cephalometric landmarks

Landmark	Definition
Tr	**Trichion:** the anterior hairline in the midline.
G	**Glabella:** the most anterior point on the soft tissue outline of the brow ridge.
N′	**Soft tissue nasion:** the deepest point on the soft tissue outline below glabella.
Prn	**Pronasale:** the most anterior point on the outline of the nose.
Cm	**Columella:** the most anterior point on the columella of the nose.
Sn	**Subnasale:** the junction of the upper lip and the columella.
A′	**Soft tissue A point:** the deepest point on the anterior outline of the upper lip below Sn.
Ls	**Labrale superius:** the muco-cutaneous junction of the upper lip.
Sts	**Stomion superius:** the lowermost point on the vermillion of the upper lip.
Sto	**Stomion:** the point of contact, in the midline, between the upper and lower lips, where the lips are competent.
Sti	**Stomion inferius:** the uppermost point on the vermillion of the lower lip.
Li	**Labrale inferius:** the muco-cutaneous junction of the lower lip.
B′	**Soft tissue B point:** the deepest point on the anterior outline of the lower lip, above Pg′.
Pg′	**Soft tissue pogonion:** the most anterior point on the soft tissue outline of the chin below B′.
Me′	**Soft tissue menton:** the most inferior point on the soft tissue outline of the chin.

Viewing the face from the lateral aspect allows the assessment of:

- Jaw relationship and facial convexity.
- Forehead.
- Infra-orbital rims.
- Nose.
- Para-nasal region.
- Upper lip.
- Lower lip and chin.
- Lower lip to sub-mental plane angle.
- Mandibular plane angle.

Jaw relationship and facial convexity

The left and right sides of the head should be examined separately, since characteristic differences will be detected in asymmetric faces.

Table 2.1b Summary of soft tissue variables

Variable/ analysis	Type	Description	Function	Mean value(s)
Angle of facial convexity (Figure 2.2)	Angular	The small angle between the lines G-Sn and Sn-Pg′.	Measures the convexity or concavity of the profile, excluding the nose.	12 ± 4° indicates a normal profile.
Full soft tissue convexity (Figure 2.2)	Angular	The angle between the lines N′-Prn and Prn-Pg′.	Measures the convexity of the profile, including the nose.	137° for Males & 133° for Females indicates a normal profile.
Naso-labial angle (Figure 2.4)	Angular	Three angles can be measured separately between: **1.** A tangent to the columella and the line Sn-Ls. **2.** A tangent to the columella and horizontal. **3.** The line Sn-Ls and horizontal.	**Angle 1** measures the angle of the upper lip to the columella, but is affected by the slope of the columella, which can vary greatly between patients. **Angle 2** gives an indication of the angle of the columella to horizontal (or the Frankfort Plane). **Angle 3** measures the angle of the upper lip to horizontal (or Frankfort Plane).	Angle 1 = 90–110° Angle 2 = 25° Angle 3 = 85°
Labio-mental angle (Figure 2.5).	Angular	The angle between lines Li-B′ and B′-Pg′.	Measures the degree of curvature of the lower lip.	120 ± 10°
E-plane “Esthetic” Plane (Figure 2.6).	Linear	Line tangential to the chin and tip of the nose.	Provides a reference line from which to assess the positions of chin, lips and nose with respect to profile balance.	Li 2 ± 2 mm behind E-plane. Ls 4 mm behind E-plane
H-line “Harmony” line (Figure 2.6).	Linear	Line tangential to the chin and upper lip.	Provides a reference line from which to assess the positions of the chin and lips with respect to profile balance.	Li should lie on the H-line ± 1-2 mm.
Zero-degree meridian (Figure 2.7)	Linear	A line dropped perpendicular to the Frankfort Plane (or horizontal) from soft tissue Nasion.	Provides a vertical reference line from which to assess the A-P position of the chin point (Pg′).	Pg′ 0 ± 2 mm from line measured parallel to FP.
Lip-chin – submental plane angle (Figure 2.8)	Angular	The angle between the line Li-Pg′ and a tangent to the submental plane.	Tends to be increased with mandibular retrusion and increased with mandibular prominence.	100 ± 10°
Submental plane - neck angle (Figure 2.8)	Angular	The angle between tangents to the submental plane and the anterior border of the neck.	Will tend to be increased with mandibular retrusion and/or the presence of submental/ cervical adipose tissue.	Males: 126° Females: 121°
Frankfort – Mandibular Planes Angle (FMPA) (Figure 2.9)	Angular	The angle between the clinical Frankfort Plane (tragus of ear to infra-orbital rim) and mandibular plane.	Gives an indication of the inclination of the lower border of the mandible, located by palpation using an index finger or ruler.	25–30° (the lines should meet just behind the back of the head).

(*Continued*)

Table 2.1b (*Continued*)

Variable/ analysis	Type	Description	Function	Mean value(s)
LAFH/TAFH ratio (Figure 2.10)	Proportional	The ratio of the distance Sn-Me′ to G-Me′.	Gives a measure of the lower anterior face height in comparison to the total anterior face height as seen clinically. The points selected are intended to give equal upper and lower face height dimensions to make clinical assessment easier.	LAFH/TAFH = 50%
Upper lip length (Figure 2.11)	Linear	The distance from Sn to Sts	Gives an indication of the length of the upper lip.	Males: 24 ± 1.5 mm Females: 21 ± 1.9 mm
Lower lip length (Figure 2.11)	Linear	The distance from Sti to Me′	Gives an indication of the length of the lower lip.	Males: 50 ± 4.5 mm Females: 46.5 ± 3.4 mm

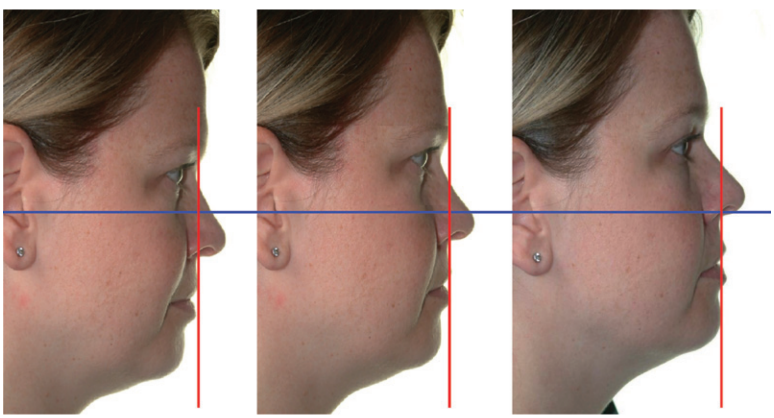


Figure 2.1 The patient's head posture can affect the clinical impression of their antero-posterior jaw relationship.

The relative antero-posterior positions of the maxilla and mandible, as well as the convexity of the profile, can be assessed subjectively by looking at the patient's profile in natural head position. The facial convexity can also be measured objectively on a profile photograph, including or excluding the nose, as illustrated in Figure 2.2a. A class II jaw discrepancy will generally manifest as a convex profile (Figure 2.2b), while a class III profile will be concave (Figure 2.2c).

In some class III cases, the drape of the upper lip can mask the underlying maxillary deficiency to a large extent and present a deceptively normal soft tissue profile. This is most likely in high angle cases where there is a degree of bi-maxillary retrusion owing to the downward and backward position of the chin.

In class II cases, maxillary protrusion is uncommon, relative to the patient's racial norm, but it is not uncommon to see bi-maxillary retrusion, particularly in patients with long facial types. In such cases, the telltale signs of maxillary deficiency will be present, such as para-nasal hollowing (Figure 2.3). In

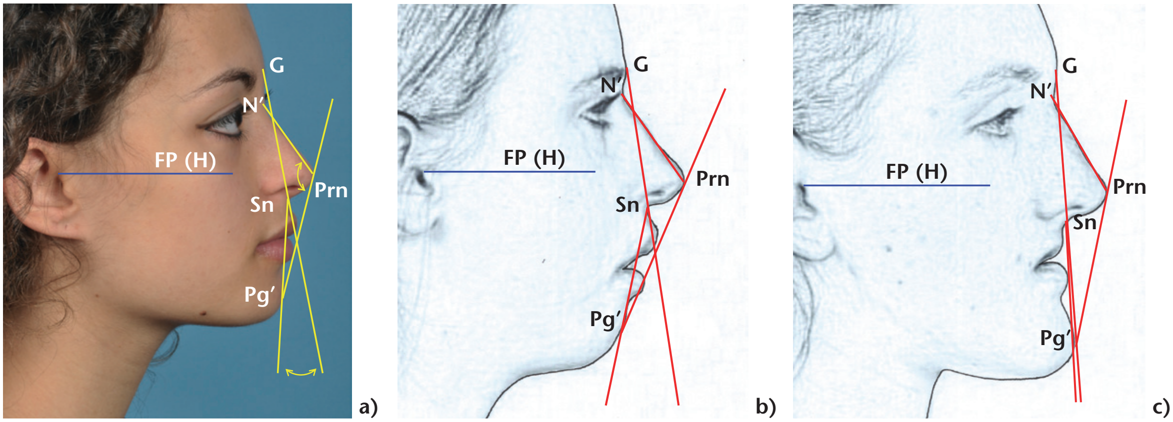


Figure 2.2 **(a)** Angle of facial convexity (the small angle between G-Sn and Sn-Pg′) excludes the nose, while the angle of total facial convexity (the small angle between N′-Prn and Prn-Pg′) includes the nasal tip. These angles tend to be increased in class II cases **(b)** and reduced in class III cases **(c)**.

class III cases, maxillary deficiency is common but again, in high angle cases, bimaxillary retrusion with retrogenia can be present.

Forehead

It is important to note the position and shape of the forehead, since it is one of the parts of the face that will remain completely unchanged by orthognathic surgery. If frontal bossing is present or the forehead is flat, this should be taken into account when assessing the jaw positions and the effects of surgery, such that harmonious facial balance will be achieved.

Infra-orbital rims

The antero-posterior position of the infra-orbital rim can be assessed relative to the globe of the eye and the supra-orbital ridge. A deficient infra-orbital rim will tend to accompany high-level deficiency of the maxilla and is usually a part of mid-face hypoplasia.

Nose

The shape of the nasal dorsum and the angle of the nasal tip may be affected by maxillary osteotomy and it should be carefully noted whether or not such changes are likely to be favourable. For example, a patient with maxillary deficiency who already has an up-turned nasal tip is likely to experience a worsening of this feature with a Le Fort 1 advancement osteotomy. On the other hand, a patient with a long facial type and a down-turned nasal tip may well experience an improvement in their nasal profile as a result of Le Fort 1 impaction osteotomy.

In addition, an assessment of the prominence of the nose in relation to the forehead and chin is essential, in diagnosing the jaw discrepancy and planning the required surgical correction (Figure 2.2).

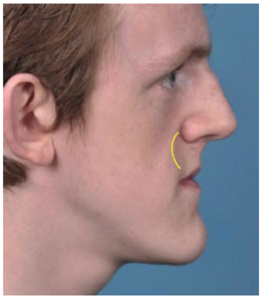


Figure 2.3 This patient with maxillary deficiency exhibits para-nasal hollowing, indicated by the yellow line.

Para-nasal region

The contour of the skin overlying the area just lateral to the alar base can be seen from the side view. A lack of bony support for the soft tissues in this region will produce a depression described as para-nasal hollowing, which is indicative of low level antero-posterior maxillary deficiency (Figure 2.3). Although most commonly associated with class III jaw discrepancies, it can also be present in class II cases with bi-maxillary retrusion.

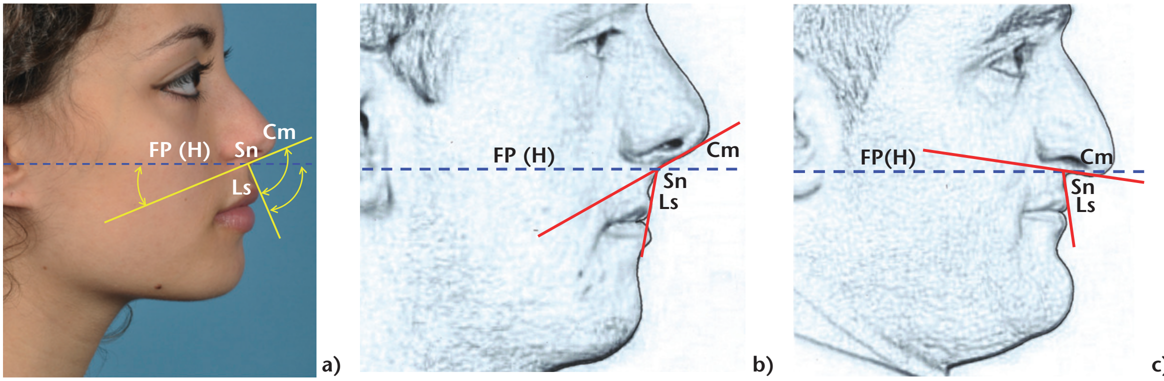


Figure 2.4 **(a)** The naso-labial angle is measured between Sn-Cm and Sn-Ls. The angles between these lines and the Frankfort Plane (or horizontal reference line) allow the slope of the columella to be accounted for. **(b)** In this class III case the naso-labial angle is increased. **(c)** This class III patient's naso-labial angle is reduced due to a down turned columella, but the angle of the upper lip to horizontal is within the normal range.

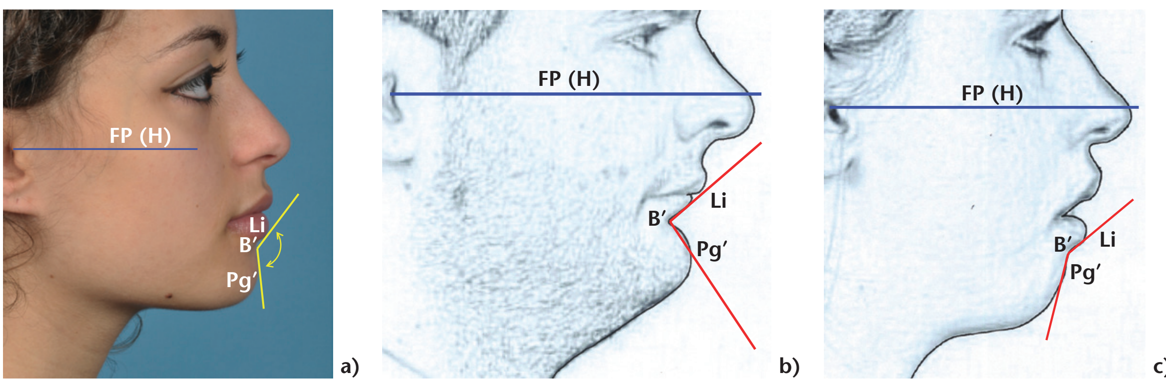


Figure 2.5 **(a)** The labio-mental angle (between Li-B′ and B′-Pg′) gives a measure of lower lip curvature. It is reduced in the short-faced patient shown in **(b)**, and increased in the long-faced patient shown in **(c)**.

Upper lip

It is important to assess the form and angle of the upper lip. The naso-labial angle is often taken as an indication of the position of the underlying maxilla and incisors. However, it is prone to variation according to the slope of the columella and the curvature of the upper lip and the angle can be measured in a number of different ways (Figure 2.4a). A patient with maxillary deficiency will tend to show an increased naso-labial angle (Figure 2.4b). However, an unusually short upper lip may be more furled than average, or the columella may be down turned, giving rise to an acute angular measurement, even in the presence of maxillary deficiency (Figure 2.4c). Conversely, some patients present with a deficient maxilla but the proclined upper anterior teeth support the upper lip.

Lower lip and chin

The curvature of the lower lip is dependent mainly on the depth of the labio-mental fold (Figure 2.5a), which in turn, tends to reflect the inclination of the lower incisors, the antero-posterior position of the chin point (soft tissue pogonion) and the lower anterior face height. As a general rule, a reduced lower anterior face height, with accompanying progenia, will produce an accentuated labio-mental fold (Figure 2.5b), whilst a flat lower lip will be associated with retrogenia and increased vertical dimensions (Figure 2.5c).

The profile balance of the lips in relation to the chin and nose can be assessed using various indicator lines, including the 'Esthetic' or E-plane and the Holdaway Harmony or H-line (Figure 2.6). The antero-posterior position of the chin should be assessed in relation to the forehead and the upper face. The zero-meridian line (Figure 2.7a) is helpful in clinically identifying mandibular retrognathism (Figure 2.7b) and prognathism (Figure 2.7c), but particular attention must be paid to the patient's head posture since the position of the vertical line at the level of the chin will vary significantly with any upward or downward tilting (Figure 2.1).

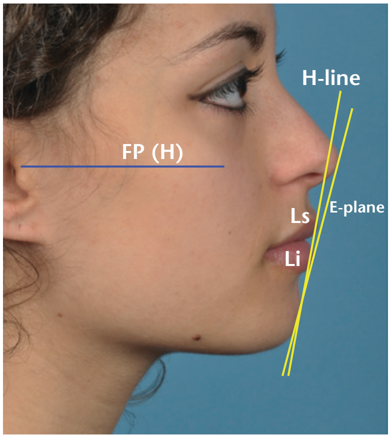


Figure 2.6 The Ricketts "E" Plane is tangential to the chin and nasal tip. The Holdaway "H" line is tangential to the chin and upper lip.

Lower lip to sub-mental plane angle

The angle of the lower lip to the sub-mental plane (throat) is important for pleasing facial aesthetics and it should be close to a right angle in an average face (Figure 2.8a). In addition to the inclination of the lower lip, the angle is equally dependent on the slope of the sub-mental plane, which varies with the degree of mandibular prognathism, the chin position and the vertical dimension of the face, as well as the presence of sub-mental adipose tissue (Figure 2.8b,c). The appearance of excess tissue in this region can be unaesthetic, particularly if the throat length is short, and it is important to note how this might be affected by surgical changes to the position of the mandible and the chin.

Mandibular plane angle

The angle of the mandibular plane can be assessed by placing an index finger or a ruler along the lower border of the mandible and the Frankfort Plane. The point of intersection of the two planes should be just behind the back of the head where the angle is average. The effect on this point of intersection can be seen in low and high angle cases in Figure 2.9. In the presence of facial asymmetry, the right and left mandibular planes may differ and must be assessed separately.

It must be remembered that the Frankfort Plane can deviate from normal and, as mentioned previously, may not be horizontal with the head in NHP. If there is any doubt then it is advisable to position the patient correctly and then use a true horizontal line as a reference.

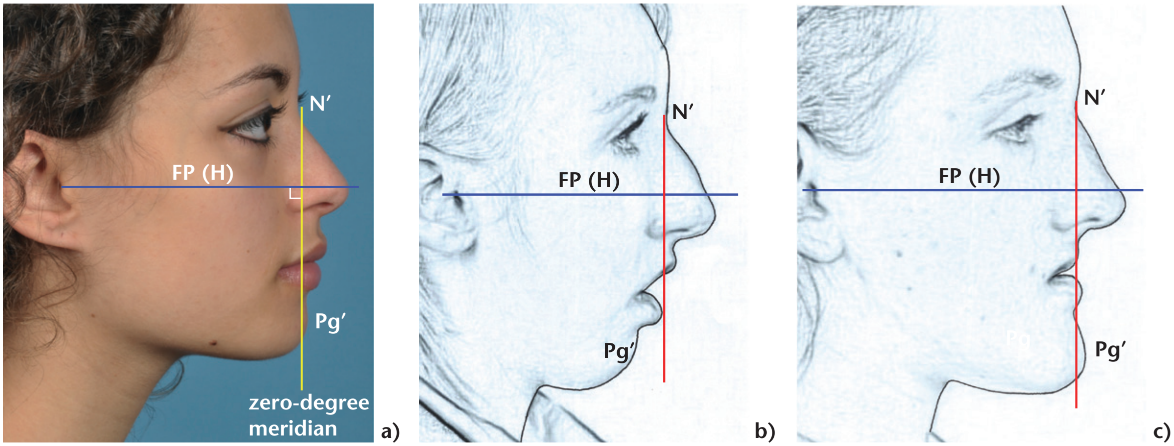


Figure 2.7 **(a)** The Ricketts zero-meridian line is a constructed vertical line dropped perpendicular to the Frankfort Plane (or horizontal) from N′. It gives an indication of the antero-posterior position of Pg′, which will lie behind the line in class II cases with mandibular retrusion **(b)** and in front in cases with mandibular prognathism **(c)**.

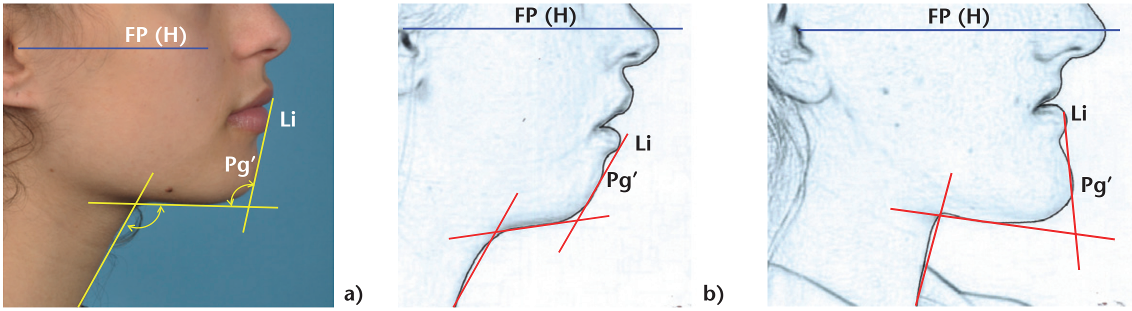


Figure 2.8 **(a)** The lower lip to sub-mental plane angle is measured between the lines Li-Pg′ and a tangent to the submental plane. **(b)** A class II case with increased vertical dimension and retrogenia, in which the angle is increased and **(c)** A Class III case, in which the angle is reduced.

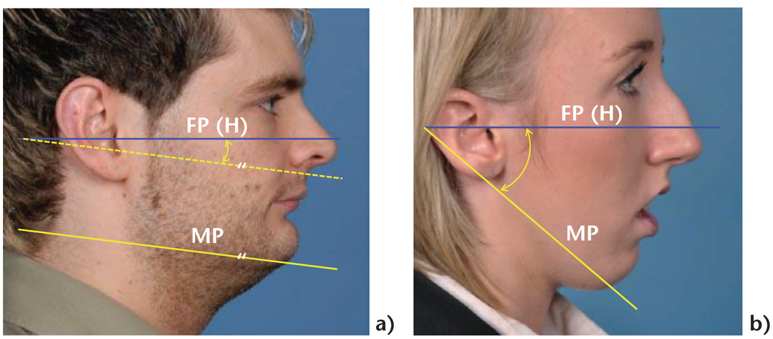


Figure 2.9 The clinical Frankfort-mandibular planes angle is reduced in short-faced patients **(a)** and increased in long-faced patients **(b)**.

2.3.2 Frontal view

Viewing the face from the front allows assessment of:

- Vertical proportions.
- Vertical asymmetries.
- Transverse proportions.
- Transverse asymmetries.
- Ear shape and position.
- Scleral show and eye lid shape.
- Upper incisor show.
- Lip form and symmetry.

Vertical proportions

Viewed from the front, the face can be divided vertically into thirds and the dimensions of the upper, middle and lower facial heights compared. The vertical distance from subnasale (Sn) to soft tissue menton (Me′) represents the lower anterior face height (LAFH) and this can be compared to the total anterior face height (TAFH), represented by the vertical distance from glabella (G) to Me′. These landmarks are used so that the proportions of the upper and lower anterior facial heights are approximately equal in an average facial type. The ratio of LAFH:TAFH is reduced in short-faced patients and increased in long-faced patients (Figure 2.10).

Within the lower anterior facial third, further subdivisions allow the vertical proportions of the upper and lower lips to be assessed. The upper lip length is measured from subnasale to stomion superius, which is normally 50% of the length of the lower lip, measured from stomion inferius to soft tissue menton (Figure 2.11). Where the lips are incompetent, it is probably most valid to measure the heights of the upper and lower lips individually along with the overall lower face height proportions.

Vertical asymmetries

Upper facial asymmetry. The evaluation of vertical asymmetries is usually carried out with reference to the inter-pupillary line. Occasionally the orbits may be at different levels (dystopia) and, if this is the case, judgement will be required to identify a horizontal plane that allows meaningful assessment of structures lower down the face. Vertical asymmetry of the zygomatic bones is usually associated with traumatic injuries, which have not been corrected appropriately.

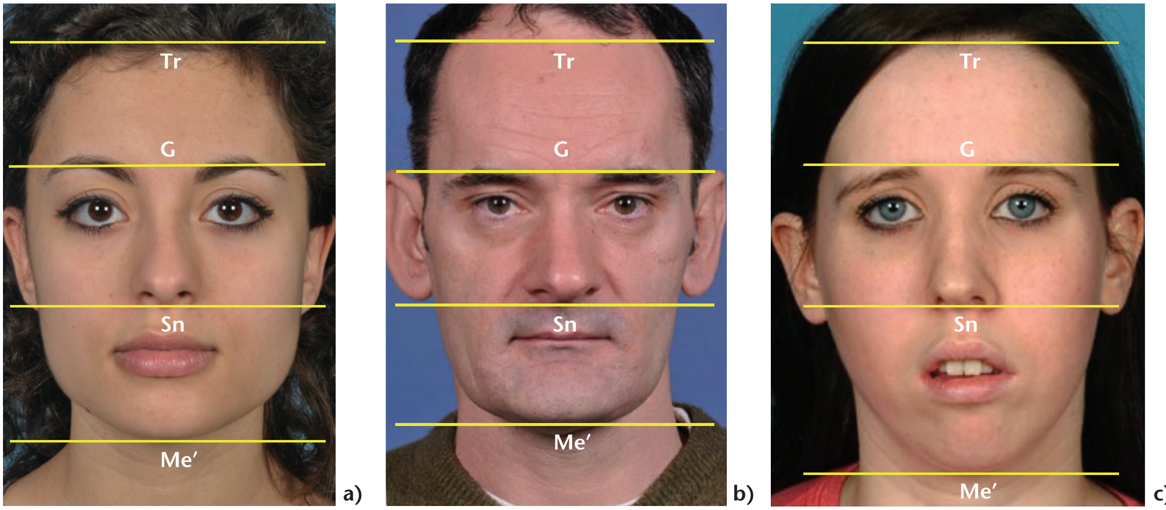


Figure 2.10 **(a)** Normally proportioned face divided into equal vertical thirds (Tri-G′, G′-Sn and Sn-Me). Lower anterior face height reduced in a short-faced patient **(b)** and increased in a long-faced patient **(c)**.

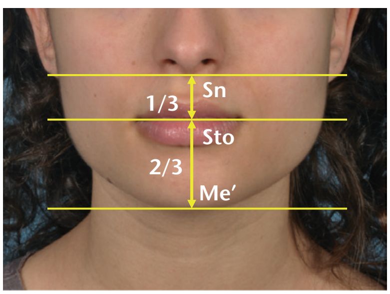


Figure 2.11 Vertical sub-divisions of lower anterior facial third, showing normal ratio of upper and lower lip lengths.

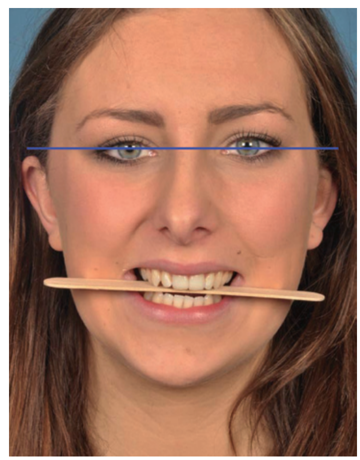


Figure 2.12 A tongue spatula is useful in assessing canting of the maxillary occlusal plane.

Canting of the maxillary occlusal plane. A common method of assessing canting of the maxillary occlusal plane is by placing a wooden tongue spatula across the premolars and relating it to the inter-pupillary line (Figure 2.12). Care should be taken to avoid being misled by over-erupted teeth or canine cusps of different lengths, which may tip the spatula in a way that does not accurately reflect the skeletal base.

Vertical mandibular asymmetry. Vertical mandibular asymmetry is evident in patients with unilateral condylar hyperplasia, hypoplasia or agenesis, which affects the height of the rami. Hemi-mandibular hypertrophy causes a downward bowing of the lower border on the affected side, with increased depth of the body. If there is an accompanying cant of the mandibular occlusal plane with any of these conditions, then this should be assessed using a tongue spatula in the same way as for the maxillary plane.

Transverse proportions

The face can be divided into fifths to allow transverse proportions to be assessed (Figure 2.13). This is particularly relevant in patients planned for Le Fort I advancement or impaction osteotomy, where the alar base is prone to flaring. A narrow alar base may well improve in appearance through surgery, while a broad one may be at risk of looking overly flared. Procedures available to the surgeon for controlling this are described in Chapter 7.

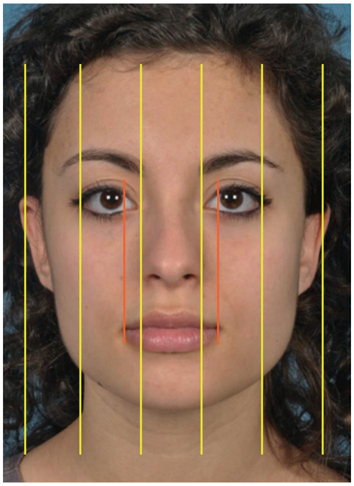


Figure 2.13 A normally proportioned face can be divided into equal fifths (long lines). The middle fifth should equal the width of the alar base and the inter-canthal distance. Further sub-divisions (short lines) illustrate that the width of the stoma should be approximately equal to the inter-iris distance.

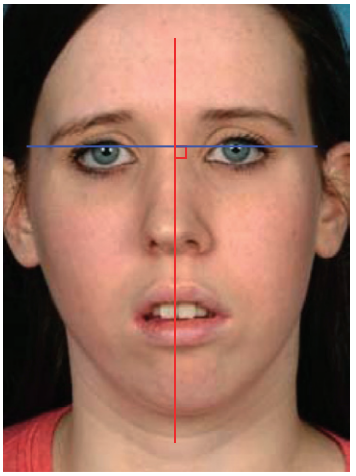


Figure 2.14 The facial midline is dropped perpendicular to the inter-pupillary line, provided the orbits are level. In this patient, there is deviation of the nasal tip to the right and a shift of the upper dental centreline and the chin point to the left.

Transverse asymmetries

Before assessing the transverse symmetry of the face it is essential to check that the patient is holding their head level, without any side-to-side tilting. The base of the neck and clavicles should be exposed, with the patient's consent, to allow full assessment of the neck and head posture.

Envisaging the facial midline. Every face has subtle asymmetries and only significant asymmetries require assessment. Before attempting to assess any transverse asymmetry it is necessary to envisage the facial midline. If an asymmetry involves just the mandible then it is usually straightforward to establish a reference line running down the middle of the forehead, bisecting the inter-pupillary line and continuing down through the middle of the dorsum of the nose and philtrum of the upper lip. Where more complex asymmetries are present higher up in the face, for example, in cases with dystopia, this is less straightforward and an element of judgement is required to envisage a reference line that most accurately represents the midline. The nose can also exhibit asymmetry of both the dorsum and the tip. It is essential to identify any nasal asymmetry and ensure that it is not influencing the position of the facial midline, before assessing the symmetry of the lower facial structures. Otherwise the extent of an asymmetry lower down the face could be either accentuated or diminished.

Upper facial asymmetry. In the upper face, it is mainly the lateral projection of the zygomatico-orbital complex that needs to be assessed for symmetry.

Dental centrelines. The upper centreline should first be assessed in relation to the facial midline (Figure 2.14). The exact upper centreline position can be difficult to determine, particularly in cases where there are other asymmetries present. Again, holding a ruler along the envisaged facial midline is a useful aid. The middle of the philtrum is also an important reference for the position of the upper centreline, particularly where nasal deviation is present. The position of the lower centreline should then be noted relative to the upper centreline and to the midpoint of the chin, as well as to the facial midline. Where there is a shift of the lower centreline relative to the facial midline, but not relative to the midpoint of the chin, it is important to determine whether it is due to a true mandibular asymmetry or a displacement on closure due to an occlusal interference, particularly if a unilateral buccal segment cross-bite is present (see also Section 2.4).

Transverse mandibular asymmetry. In evaluating transverse mandibular asymmetry, the position of the chin point relative to the facial midline must be carefully assessed. As mentioned above, it is important to take into account any nasal deviation as well as any asymmetry of the lips. Marking a dot where the middle of the soft tissue chin point is thought to be and then holding a ruler along the facial midline is helpful in trying to quantify the extent of any deviation (Figure 2.14).

Ear shape and position. Any abnormal shape or position of the ears should be noted during clinical assessment. Unilateral abnormalities of the ear shape may be part of hemi-facial microsomia and various cranio-facial syndromes.

Scleral show and eye lid shape. The lower eye lid should normally rest at the inferior border of the iris, with no sclera on display. Scleral show is a tell-tale sign of infra-orbital rim deficiency, which usually accompanies maxillary deficiency in class III cases (Figure 2.15). Anti-mongoloid slanting of the palpebral fissures and clobomata of the lower eyelids are manifestations of various craniofacial anomalies and should be taken into consideration during clinical assessment of dentofacial deformities.

Upper incisor show. Because orthognathic surgical planning usually starts with a decision regarding where to position the maxillary incisors, a key feature in the assessment of the orthognathic patient is the vertical relationship between the upper lip and the upper central incisors at rest and on smiling. Variation in the height of the maxilla and/or the length of the upper lip, as well as the length of the upper incisor crowns, will directly affect these measurements. It is essential that the patient's head posture is correct and that the lips are fully relaxed for the resting lip line (Figure 2.16a). Equally, it is important to ensure that the patient performs a full smile to allow the lip to rise to its maximum height before assessing the incisor show on smiling (Figure 2.16b). Asking the patient to smile voluntarily may not be reliable, particularly in the environment of a busy clinic and it is important to watch for genuine involuntary smiles, which are more fully expressive.

Lip form and symmetry. The shape of the vermillion border and the symmetry of the Cupid's bow should be assessed. The line between the lips (the inter-labial line) must be assessed in relation to both vertical and horizontal reference lines. The philtrum of the upper lip can deviate to one side, often in

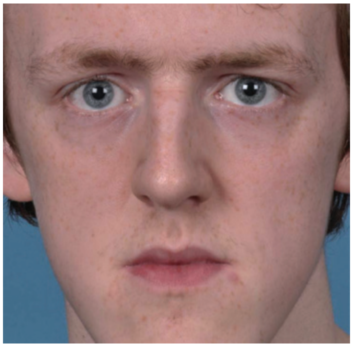


Figure 2.15 Display of the sclera of the eye below the iris is a sign of high-level maxillary antero-posterior deficiency, including the infra-orbital rims.

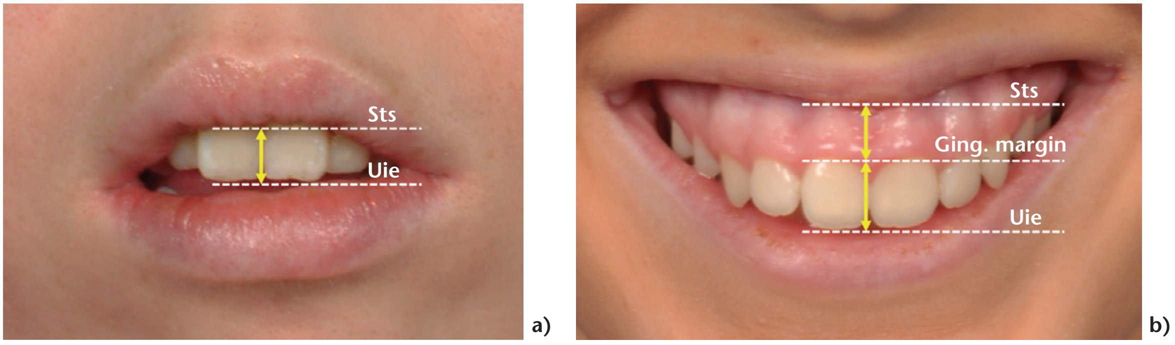


Figure 2.16 **(a)** Increased vertical display of the upper central incisors with the lips at rest. The average is approximately 2–3 mm, or about 1/3 of the clinical central incisor crown. **(b)** Increased gingival display on smiling in a patient with a combination of vertical maxillary excess and a short upper lip.

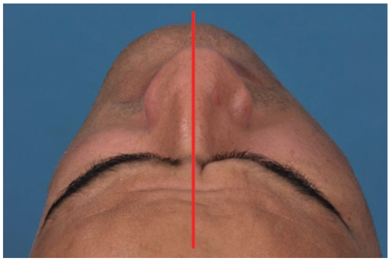


Figure 2.17 Bird's eye view in a patient with a mandibular asymmetry, showing deviation of the chin point to the left. The nasal tip is also deviated slightly to the right.

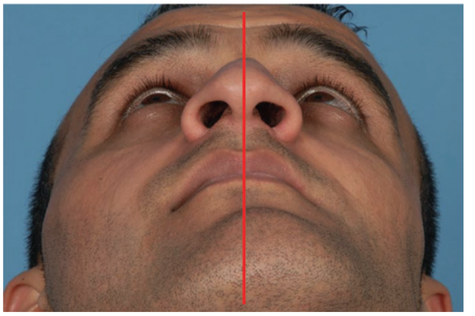


Figure 2.18 Worm's eye view of patient with mandibular asymmetry. The medio-lateral shift of the chin is clearly seen and it is also possible to see the vertical asymmetry of the gonial angles.

association with a cant of the inter-labial line or an asymmetry of the nose. The lower lip can also be displaced to one side, usually as a result of a mandibular asymmetry. Asymmetry of facial animation should also be taken into consideration.

2.3.3 Bird's eye view

Viewing the face from above (Figure 2.17) allows assessment of:

- Orbital rims.
- Antero-posterior asymmetries.
- Nasal deviation.
- Upper dental centreline.
- Transverse mandibular asymmetry.

Orbital rims

The view from above helps to assess the antero-posterior position of the supra- and infra-orbital rims. Deficiency of the infra-orbital rims will usually accompany zygomatico-orbital deficiency, which is usually a manifestation of mid-face deficiency and can also be seen from this angle.

Antero-posterior asymmetries

When viewing the face from above, it is possible to assess the presence of any antero-posterior asymmetries of the forehead and the supra- and infra-orbital rims, as well as the zygomatico-orbital complex and para-nasal regions. This will need particularly careful scrutiny in cases where an asymmetry is not just confined to the mandible and the lower face, but affects the whole face. Such patients may have a mild expression of a cranio-facial syndrome, such as hemi-facial microsomia and will require careful three-dimensional surgical planning. Patients suffering from plagiocephaly would also exhibit antero-posterior asymmetries of the craniofacial skeleton.

Nasal deviation

The bird's eye view allows the dorsum and tip of the nose to be assessed for transverse deviation. As with the frontal view, it is important to envisage the facial mid-line as a reference and care must be taken to account for any deviation of the chin point. If both the nose and the mandible are asymmetric, an element of judgement may be necessary to identify which structure is most at fault.

Upper dental centreline

This view is also valuable in confirming the position of the upper dental centreline with reference to the midline of the face, taking care to account for any deviation of the nose, philtrum and mandible.

Transverse mandibular asymmetry

The bird's eye view is essential for assessing the position of the chin point relative to the facial midline. As with the frontal view, it is useful to mark the midpoint of the chin and then use a ruler on the facial midline as a reference.

2.3.4 Worm's eye view

Viewing the face from below (Figure 2.18) allows assessment of:

- Asymmetries of the mandible.
- Asymmetries of the alar base.

Asymmetries of the mandible

Vertical and transverse asymmetries of the mandibular inferior borders or gonial angles are only fully appreciated from the worm's eye perspective.

Asymmetries of the alar base

Any asymmetry of the nares, or deviation of the columella, can be clearly identified.

2.4 Intra-oral assessment

Before assessing the dental arches and occlusion, it is important to carry out a routine clinical examination of the oral hard and soft tissues, which should be supplemented with any necessary radiographs. Active caries will require restoration by the General Dental Practitioner and periodontal disease should be controlled prior to definitive treatment planning, with specialist input if necessary. Any areas of gingival recession should be carefully documented, since these may worsen with orthodontic treatment. Clinical photographs are an essential pre-treatment record in this regard, as well as recording any marks on the teeth that may later be attributed to the iatrogenic effects of fixed appliances. In most cases one would expect that these problems will have been identified and resolved prior to the patient being referred to the combined planning clinic, but the clinicians should be vigilant at all stages of the patient journey to ensure that no relevant disease remains undiagnosed. The patient's role in maintaining good oral health and plaque control should be emphasised from the outset.

As with facial assessment, intra-oral examination should be carried out systematically.

2.4.1 Dental arches

The key features of the dental arches to note are:

- Dentition.
- Arch forms.
- Incisor inclinations.
- Crowding and spacing.
- Curves of Spee.
- Oclusal plane canting.

Dentition

The standing teeth should be charted accurately and any teeth of possible poor prognosis noted. If extractions are required as part of orthodontic treatment or even segmental surgery, it may be beneficial to remove teeth that may cause long-term problems. For example, poor quality lower first molars might usefully be extracted to allow lower incisor decompensation in a class II case prior to mandibular advancement, or a setback mandibular body osteotomy in a class III case. Equally, edentulous spans in patients with incomplete dentitions, whether due to hypodontia or previous tooth loss, may present either a problem or an opportunity to the clinicians depending on the planned orthodontic and surgical objectives.

Arch forms

The width and shape of both dental arches determine the degree of arch coordination that can be achieved and should be noted. If the upper arch is narrow it is important to assess whether this is due to a genuinely narrow maxilla or just the result of upright molars. Looking at the inclination of the buccal segments gives a guide as to the degree of flaring present and palpating the alveolar bone over their roots gives an indication of the width of the maxillary apical base.

If there is a narrow maxilla and surgical widening is a possibility, the palatal contour should be noted, since a high vaulted palate is more favourable for "tenting" of the muco-periosteum following a midpalatal split.

If the mandibular arch is particularly broad or narrow, a similar assessment of the skeletal and dental contributions should be made to give an indication as to how much orthodontic adjustment of the arch width is likely to be possible in the effort to achieve arch coordination.

Incisor inclinations

The inclinations of the upper and lower incisors tend to be determined by a combination of skeletal and soft tissue factors and will often differ from average in orthognathic patients as a result of dento-alveolar compensation. The lower incisors will tend to be proclined in class II cases and retroclined in class III cases as a result of the action of the tongue and lower lip respectively. The lower incisors should be assessed with reference to the clinical mandibular plane, which can be represented by a finger or ruler held against the lower border of the mandible.

The upper incisors may be proclined in class II cases where a lower lip trap is present but, where the skeletal discrepancy is marked and the lower lip is retrusive, they will often be close to normal. In class II, division 2 cases they may be severely retroclined as a result of the high lower lip line. In class III cases the upper incisors will generally be proclined under the influence of the tongue, although this will not always be the case in severe malocclusions where the resting tongue posture is below the upper occlusal plane. The upper incisor inclination should be assessed with reference to the clinical Frankfort Plane (tragus of ear to orbitale).

The normal Caucasian values for incisor inclination are approximately 90° for the lowers and 110° for the uppers. Cephalometric analysis should normally be available to confirm the clinical findings (see Section 2.6).

Crowding and spacing

An estimate of the degree of crowding or spacing present in each arch can readily be made on intra-oral examination, but more objective assessment or "space analysis" is more appropriately carried out on study models (see Section 2.5). Any rotated or misaligned teeth should be noted.

Curves of Spee

Orthognathic patients frequently exhibit curves of Spee on their occlusal planes as a result of their underlying skeletal jaw discrepancies. Class II patients with deep overbites and reduced vertical dimensions will tend to have an accentuated curve on the lower arch (Figure 2.19a), whilst patients with an anterior open bite and increased vertical dimensions will often present with a curve on the upper arch (Figure 2.19b).

Occasionally reverse curves of Spee are seen. In the lower arch this is usually due to impaired eruption of the lower incisors during growth, possibly due to an extreme digit sucking habit or endogenous tongue thrust (see also Section 2.4.3). In the upper arch, it is usually over-eruption of retroclined upper incisors in class II, division 2 cases that produces the reverse curve effect, due to the increased inter-incisal angle.

The more severe a curve of Spee is in either arch, the more challenging it will be to level orthodontically. It is therefore important to quantify the depth of curve present and, whilst an estimate can readily be made clinically, study model analysis will allow more accurate measurement. The relevance of the curve of Spee for orthognathic treatment is explained more fully in Chapters 3 and 4.

Occlusal plane canting

See Section 2.3.2.

2.4.2 Teeth in occlusion

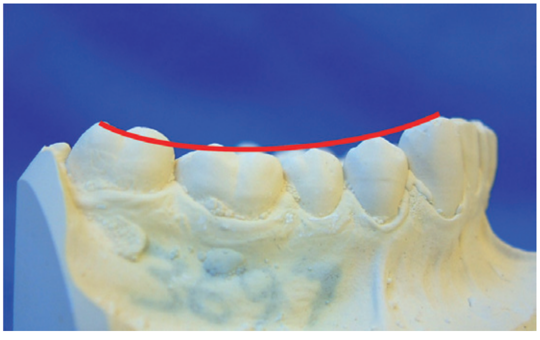
The main occlusal features to be noted are:

- Incisor relationship.
- Cross-bites.
- Centrelines.

Incisor relationship

The incisor classification should be assessed with reference to standard definitions, which are readily available in basic orthodontic texts. The features that contribute to the patient's incisor relationship are: the incisor inclinations (see Section 2.4.1), the overjet and the overbite.

Overjet. The overjet normally measures 2–4 mm but will be increased in class II division 1 patients and decreased or negative in class III patients. In class II, division 2 patients the overjet will usually be minimal but can occasionally be increased in the presence of a severe class II jaw relationship. Particular care should be taken when recording the overjet in class II orthognathic patients, particularly those with backward mandibular rotations. This is because they tend to have short mandibular rami with skeletal anterior open bites, which require them to posture their man-


a)


b)

Figure 2.19 Lower arch **(a)** and upper arch **(b)** showing accentuated curves of Spee, associated with a deep overbite and an anterior open bite, respectively. The open bite is also accompanied by a narrow maxillary arch, which has resulted in bilateral buccal segment cross-bites.

dible forwards on order to gain a functional occlusion. It is therefore essential to coax the mandible into its retruded contact position (RCP). This can usually be achieved by asking the patient to extend their neck backwards, which stretches the suprahyoid muscles, and curl their tongue to the back of the mouth, before guiding the mandible into occlusion with light pressure on the chin. This will often unmask a larger than expected overjet and anterior open bite, which might otherwise have gone undetected, resulting in erroneous planning.

Class III cases with vertical maxillary deficiency and over-closure of the mandible also present a problem when measuring the reverse overjet. This is because the measurement obtained with the mandible in rest position can be significantly smaller than that obtained when the mandible is rotated upward and forward to bring the posterior teeth into occlusion. An overjet measurement recorded with the mandible in rest position is probably more valid from the point of view of surgical planning. An example of this is illustrated using two pre-surgical lateral cephalograms in Figure 6.4.

Overbite. The overbite should be assessed as the vertical overlap of the upper central incisors over the lower incisors, both as a percentage and in millimetres. The average overbite, as viewed along the occlusal plane, should be approximately one third of the lower incisors, or 2–3 mm. An increased overbite in a class II orthognathic patient will often mean that the lower incisal edges are occluding on the palatal mucosa, distal to the upper incisors, and this area should be scrutinised clinically for any signs of trauma. This may manifest as grooving or gingival recession. Similarly, in severe class II, division 2 cases the retroclined upper central incisors may cause trauma to the labial gingival margins of the lower incisors (Figure 2.20). In extreme cases, both problems may co-exist. Traumatic overbites often present a compelling need for treatment, particularly if the patient is complaining of long standing symptoms.

Anterior open bite. Where an anterior open bite is present, the amount of vertical separation between the upper and lower incisors should be recorded, perpendicular to the occlusal plane, as well as its extent on both sides (see Figure 2.19b). As already mentioned, the presence of a curve of Spee on the upper or lower arch often contributes to an increased overbite or anterior open bite. In the case of anterior open bite, it is important to assess whether the problem is primarily dental or skeletal in origin. An open bite localised to the labial segments with an accentuated upper curve of Spee and a good buccal segment occlusion most likely indicates a dental origin. Flat dental arches with occlusal contact limited to the terminal molars, on the other hand, will generally point to a skeletal origin. The skeletal features that tend to accompany these occlusal traits have already been discussed under "Facial assessment".

Figure 2.20 Trauma to the labial gingival margins of the lower incisors caused by a deep overbite.

Cross-bites

Cross-bites involving only one or two teeth are often the result of local dental irregularity or crowding and are usually straightforward to deal with. Cross-bites involving whole segments of teeth, either anterior or posterior, usually occur either as a result of an underlying antero-posterior or transverse skeletal jaw discrepancy, or because of a mismatch in the widths of the dental arches and tend to be more common in orthognathic patients. In some cases, both problems may be contributing factors to a greater or lesser extent. In all cases it is essential to not only record the presence of any cross-bites, but also be clear as to their aetiology and whether or not they are causing any mandibular displacement on closure.

Anterior cross-bites. Anterior cross-bites usually reflect an underlying class III skeletal pattern. Where there is only a minimal reverse overjet and a positive overbite it is important to check whether the patient is able to achieve an edge-to-edge contact between the incisors with the mandible in RCP (using the same method as above). If a forward displacement is occurring from an initial incisal contact, then it is wise to take clinical measurements and diagnostic records with the mandible in RCP or rest position, rather than with the posterior teeth in occlusion, which may give a false impression of the class III skeletal pattern.

Posterior cross-bites. Posterior cross-bites can be either unilateral or bilateral. In orthognathic patients with significant antero-posterior jaw discrepancies a buccal segment cross-bite can result from the dental arches occluding in a mismatched position, even thought there is no true transverse arch width discrepancy. The more severe the antero-posterior discrepancy, the more likely it is that a cross-bite will result. In class III patients in particular, the true arch coordination is best checked on the study models (see Section 2.5).

- **Unilateral cross-bites.** Unilateral cross-bites result from a relatively mild underlying transverse arch width discrepancy. If a mandibular asymmetry is also present in inter-cuspal position (ICP) it is important to establish whether this is a true skeletal asymmetry or the result of a displacement of the mandible from RCP to ICP, due to an occlusal interference (Figure 2.21).
- **Bilateral cross-bites.** Bilateral cross-bites are usually the result of a more severe transverse arch width discrepancy and are less likely to be accompanied by a mandibular displacement because the patient is able to bite directly into an inter-cuspal occlusion without the need for the mandible to shift to one side (Figure 2.19b).

Figure 2.21 A unilateral buccal segment cross-bite caused by a true mandibular asymmetry. Note the shift of the lower centreline to the left.

Centrelines

The assessment of the dental centrelines relative to the facial and mandibular midlines has already been described. Intra-orally, the dental cause of any centreline shift within the arches should be noted. This may be previous unilateral loss of a permanent tooth or asymmetric crowding. If there is a unilateral cross-bite present with an associated displacement on closure then the extent of this, and its effect on the position of the lower centreline in occlusion, should be noted.

2.4.3 Soft tissues

Assessment of the tongue

The shape, size and movement of the tongue should be assessed to identify any abnormalities. Where an anterior open bite is present with the characteristic signs of soft tissue aetiology, the resting posture and activity of the tongue should be observed, although it can be difficult to distinguish between a true endogenous tongue thrust and tongue posture that is simply adaptive to a pre-existing open bite (Figure 2.22). Where the tongue's position, its size (e.g. macroglossia) or activity is thought to be abnormal, its possible role in post-treatment relapse will have to be carefully evaluated.

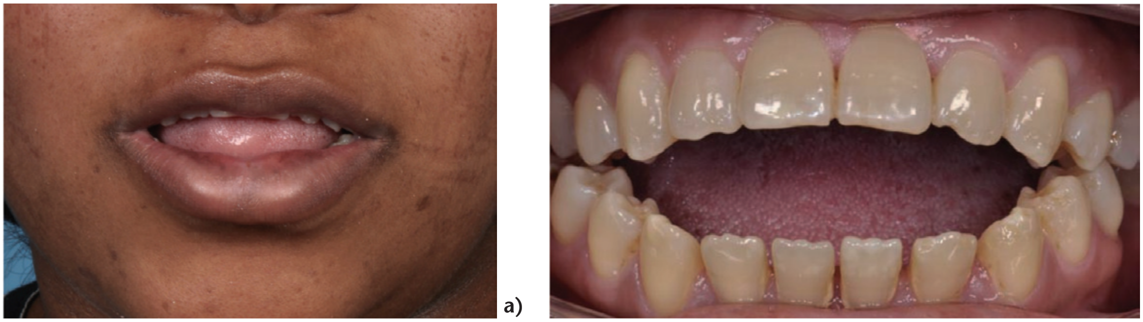
2.5 Diagnostic records

2.5.1 Protocol for collection of basic records

The treatment of orthognathic patients requires numerous diagnostic records and it is important to have a protocol in place that provides a guide as to which basic records should be collected and when. There will be a need for supplementary records and investigations as the need arises for individual patients but Table 2.2 shows the basic minimum dataset that the authors aim to collect for each patient.

2.5.2 Role of diagnostic records

The longitudinal management of orthognathic patients usually extends over a prolonged period, starting from the initial referral, often as a child, and finishing with their discharge after several years of post-operative follow-up. The various diagnostic



a) b)

Figure 2.22 Typical habitual tongue posture in a patient with an endogenous tongue thrust **(a)**. The associated anterior open bite caused by divergent upper and lower curves of Spee **(b)**.

Table 2.2 Protocol for basic orthognathic record collection

Record type	Pre-ortho planning	Pre-surgery planning	1 wk post-op	Post debond	6 months post-op	1 yr post-op	2 yr post-op	3 yr post-op	4 yr post-op	5 yr post-op
SMs	*Yes*	*Yes*	–	*Yes*	–	–	–	–	–	–
Clinical photos	*Yes*	*Yes*	–	*Yes*	–	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
DPT	*Yes*	–	*Yes*	–	–	–	–	–	–	–
Lateral ceph.	*Yes*	–	–	–	–	–	*Yes*	*Yes*	*Yes*	*Yes*
CBCT	–	*Yes*	–	–	*Yes*	–	–	–	–	–
3D capture	*Yes*	*Yes*	–	–	*Yes*	–	–	–	–	–
4D capture	*Yes*	*Yes*	–	–	*Yes*	–	–	–	–	–

SMs	Study models
DPT	Dental Panoramic Tomogram
CBCT	Cone Beam Computerised Tomogram
3D capture	3D static stereophotogrammetry
4D capture	3D motion capture

records that are collected at different times along the patient's journey have specific purposes as follows.

Study models

Orthodontically trimmed study models are an essential basic record of the arrangement of a patient's teeth and their occlusion and are taken at all the key stages of treatment. They can either be physical plaster models or digital e-models. In orthognathic patients the occlusion will sometimes be difficult to accurately record and a careful occlusal registration is required. A conventional modelling wax wafer is usually adequate, but more sophisticated silicone based materials are useful in cases where the occlusion is particularly awkward and there is limited contact between the teeth. As with the clinical examination, it is also essential to ensure that the bite registration is recorded with the mandible in the desired position. In most cases this will be with the teeth in ICP, but where there is a displacement on closure associated with a cross-bite, it may be more helpful to record the occlusion in RCP. Study models have the following applications:

Monitoring occlusal change. Many patients are referred to the orthognathic team as adolescents and still have growth left to complete, or they have mandibular asymmetries that may be progressive. Study models that are correctly bench-trimmed, or articulated if necessary, allow longitudinal change of the occlusion to be monitored and measured. In the case of anterior open bites, it is essential to obtain an accurate occlusal registration, which will allow the models to be correctly articulated at a later date, for comparison.

Checking arch coordination. Hand held study models allow the 'best fit' of the dental arch to be assessed both at the patient's initial assessment and throughout pre-surgical orthodontic treatment. Objective measurements can also be made of the extent of any arch expansion required and the approximate size of surgical movement needed to correct the malocclusion in advance of definitive laboratory-based planning. If necessary, the initial models can be sectioned to simulate the effect of segmental surgery. For this reason it is advisable to have two sets of models available at the initial assessment stage.

Space analysis and orthodontic planning. The amount of dental crowding or spacing can be measured from study models to aid orthodontic planning and in particular the decision regarding extractions. Diagnostic set-ups, where teeth are repositioned on the models in wax to simulate the result of orthodontic treatment, can be a useful planning aid, although care must be taken to ensure that any simulated tooth movements are realistic and within the confines of the alveolar bone (Figure 2.23).

Clinical photographs

All patients being seen on an orthognathic clinic should have a series of clinical photographs available that adequately records their presenting dentofacial problems. It is important that the facial views are taken in natural head position with the lips at rest and, if there is a tendency to over-closure, with the mandible in rest position. As mentioned previously, the right lateral view is conventionally used to carry out any objective soft tissue analysis. Our standard series is as follows:

Facial views:

- Frontal, with lips at rest and smiling.
- Right and left profile.
- Right and left ¾ profile.
- Bird's eye.
- Worm's eye.

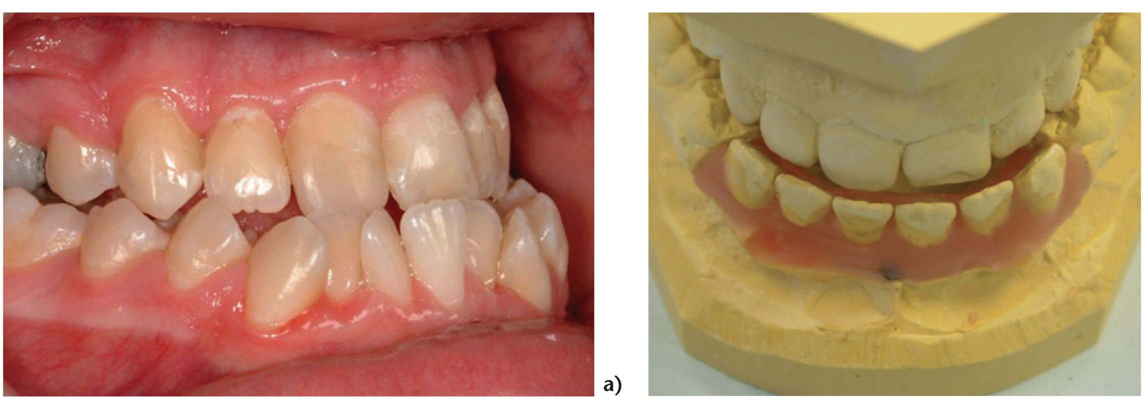
Intra-oral views:

- Upper and lower occlusal.
- Front and sides of teeth in occlusion.
- Overjet (or reverse overjet).

As well as providing a basic record and aiding assessment, photographs are valuable in monitoring facial change. However, they have the limitation of being only two-dimensional.

Stereophotogrammetry

Conventional photographs do not record the 3D morphology of the face and are associated with magnification and positioning errors. Stereophotogrammetry provides 3D, photorealistic images of the patient using specialised equipment. This is the only method of accurately recording the patient's true appearance and is invaluable in monitoring soft



a) b)

Figure 2.23 Planning decompensation of the severely crowded lower incisors in this class III patient **(a)** is helped by a diagnostic setup of the teeth **(b)**. It is clear that premolar extractions will be required to avoid excessive proclination.

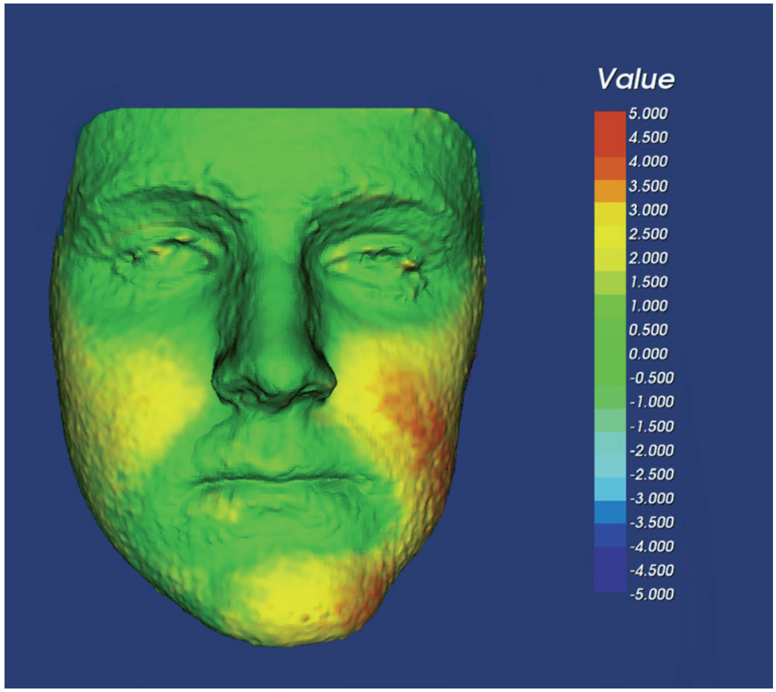


Figure 2.24 Two sequential stereophotogrammetric images, superimposed on the forehead. Asymmetric mandibular growth has produced significant unilateral left sided changes (red = 5.0 mm difference).

tissue changes over time, particularly in cases of asymmetry (Figure 2.24). There is evidence in the literature that orthognathic surgery affects facial animation and 4D imaging (3D with movement) is a potentially valuable tool for recording the dynamics and quantifying changes in facial animation before and after surgery.

Dental Panoramic Tomogram (DPT)

The panoramic tomogram allows a basic radiographic assessment of the teeth and jaws and is required for all patients as part of the initial orthognathic assessment. The DPT yields the following diagnostic information:

Dental and related pathology. Apart from checking for incidental pathology, an account of which is beyond the scope of this book, an accurate assessment of the patient's dental and supporting tissues is essential prior to definitive treatment planning. With orthognathic patients being primarily adults, many will have multiple restored teeth and some may have periodontal disease, which requires attention prior to definitive treatment planning. The morphology of the roots of the teeth and any dental anomalies should be noted. The image resolution of modern digital machines often obviates the need for supplementary intra-oral views, but these may still be required in some situations.

Mandibular morphology. It is essential that the full mandible is included in the exposure, rather than the truncated option that modern machines offer for dental assessment, which often excludes part of the ramus and the condyles. The DPT allows gross assessment of the morphology of the following mandibular structures:

- **The condylar neck and head.** If the condyle is particularly small or flattened, this may indicate under-development or lytic disease and may warrant further investigation. Condylar hyperplasia can manifest as an enlarged condyle or elongated condylar neck and might require further investigation. The angle of the condylar neck also tends to reflect the morphology of the mandible, sloping back in the case of backward growth rotation and vice versa.
- **The ramus.** The height of the ramus can vary significantly depending on the patient's facial morphology, with a small, short ramus tending to accompany a backward mandibular growth pattern and a long facial type, whilst the short-faced patient tends to possess a longer and wider ramus.

- **The ante-gonial region.** In backward mandibular growth rotations, short rami, ante-gonial notching is usually evident, whereas a forward rotation tends to be accompanied by a rounded lower border.
- **The body.** The shape and depth of the bodies can be assessed, as well as the distance between the apices of the teeth and the lower border. Significant asymmetry of the mandible can also be detected using comparative measurements between left and right sides.
- **The inferior dental canal.** It is important to note the course of the inferior dental nerve in relation to other skeletal and dental structures. However, the two dimensional nature of the image gives no information regarding its transverse position, which is of relevance for mandibular surgery.

Other features. Features of the middle and upper face that can be assessed are as follows:
- The shape and vertical extent of the maxillary air sinuses.
- The relationship of the roots of the posterior teeth to the air sinuses.
- The depth of the maxillary alveolar processes.

Peri-apical radiographs

Peri-apical radiographs can be useful in checking the clearance between the roots prior to segmental surgery. However, it must be remembered that the images are only two-dimensional and may not accurately portray the true spatial position of adjacent roots.

Cone Beam Computerised Tomography (CBCT)

This radiographic scanning technique provides simultaneous 3D hard and soft tissue imaging of the face and skull. As with any radiographic investigation, the radiation dose associated with CBCT must be justified by its diagnostic yield. Its applications in orthognathic treatment are as follows:

Assessment and diagnosis of complex dentofacial problems. The majority of orthognathic patients can be adequately assessed and diagnosed using plain radiographs. Even in those with facial asymmetries, an initial combined orthodontic and surgical plan can usually be formulated with the aid of two-dimensional images. However, there may occasionally be cases whose asymmetries are more complex, which warrant CBCT imaging at the initial assessment stage, in order to arrive at a satisfactory diagnosis before any provisional treatment planning can be carried out. An example of such a case is illustrated in Figure 2.25.

Three-dimensional orthognathic prediction planning. Orthognathic surgery involves jaw movements in all three planes of space and it is essential to know their starting positions and the movements required to achieve the planned result. This is particularly the case with facial asymmetries and the advent of Cone beam CT, in conjunction with specialised software, has made 3D planning a recent reality, albeit in its early stages of development (see Chapter 6).

Anatomical information. Accurate information regarding the relative spatial positions of anatomical structures can only be obtained from a CBCT image. The following are of relevance in surgical planning:
- The position and course of the inferior dental nerves. This is important in reducing the risk of nerve damage for all of the mandibular ramus and body procedures (Figure 2.26).
- The position of the teeth adjacent to a planned segmental osteotomy in order to minimise the risk of root damage.
- The position of the infra-orbital nerves, to minimise the risk of damage during higher level Le Fort I osteotomies.
- The morphology of the maxillary sinuses and any associated radio-opacities.
- The orientation and structure of the mandibular rami. It is helpful to be able to assess the thickness of the cancellous bone space, which may affect the success of a sagittal split, and also the angle of the rami in assessing suitability for vertical sub-sigmoid osteotomies.

Fabrication of three-dimensional models. Stereo lithographic models or, more recently, 3D printouts of the patient's skull, jaw bones and dentition, can be produced from CBCT data. These are particularly useful where a physical, anatomically realistic plan is required, such as in the correction of an asymmetry. Note that the dentition is subject to magnification and artefacts and should ideally be replaced prior to planning to ensure accuracy (see Chapters 5 and 6).

Post-surgical evaluation. If orthognathic surgery is planned and executed in three dimensions, then ideally its outcome should also be evaluated in three dimensions. This is only possible if a CBCT scan is taken post-operatively, although the exact timing of the second scan is open to debate. If taken six months after surgery, as is the routine on our clinic,

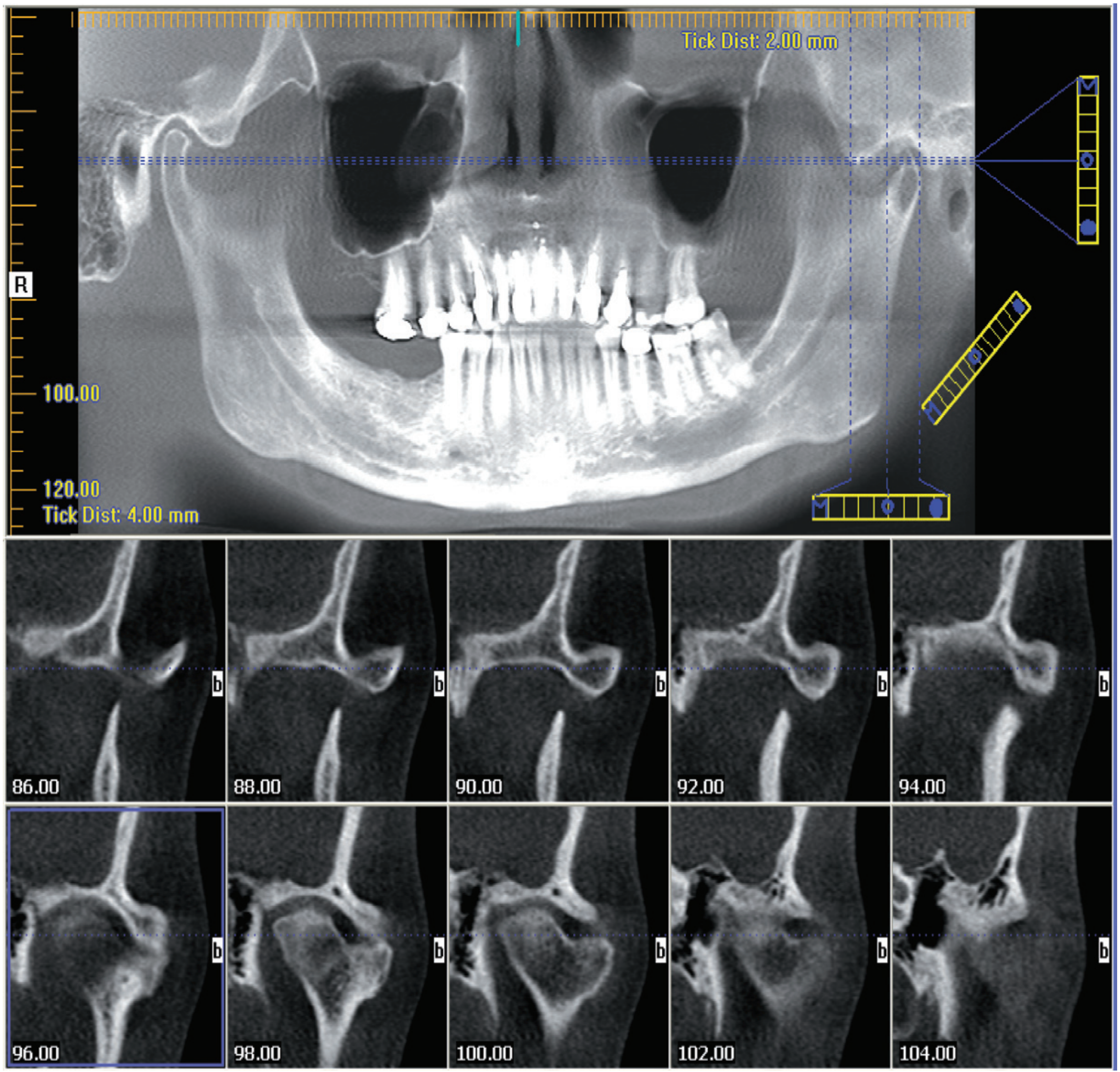


Figure 2.25 A case with mandibular asymmetry. The assessment of the left temporo-mandibular joint morphology is greatly aided by cone beam CT (screen capture from iCATvision™).

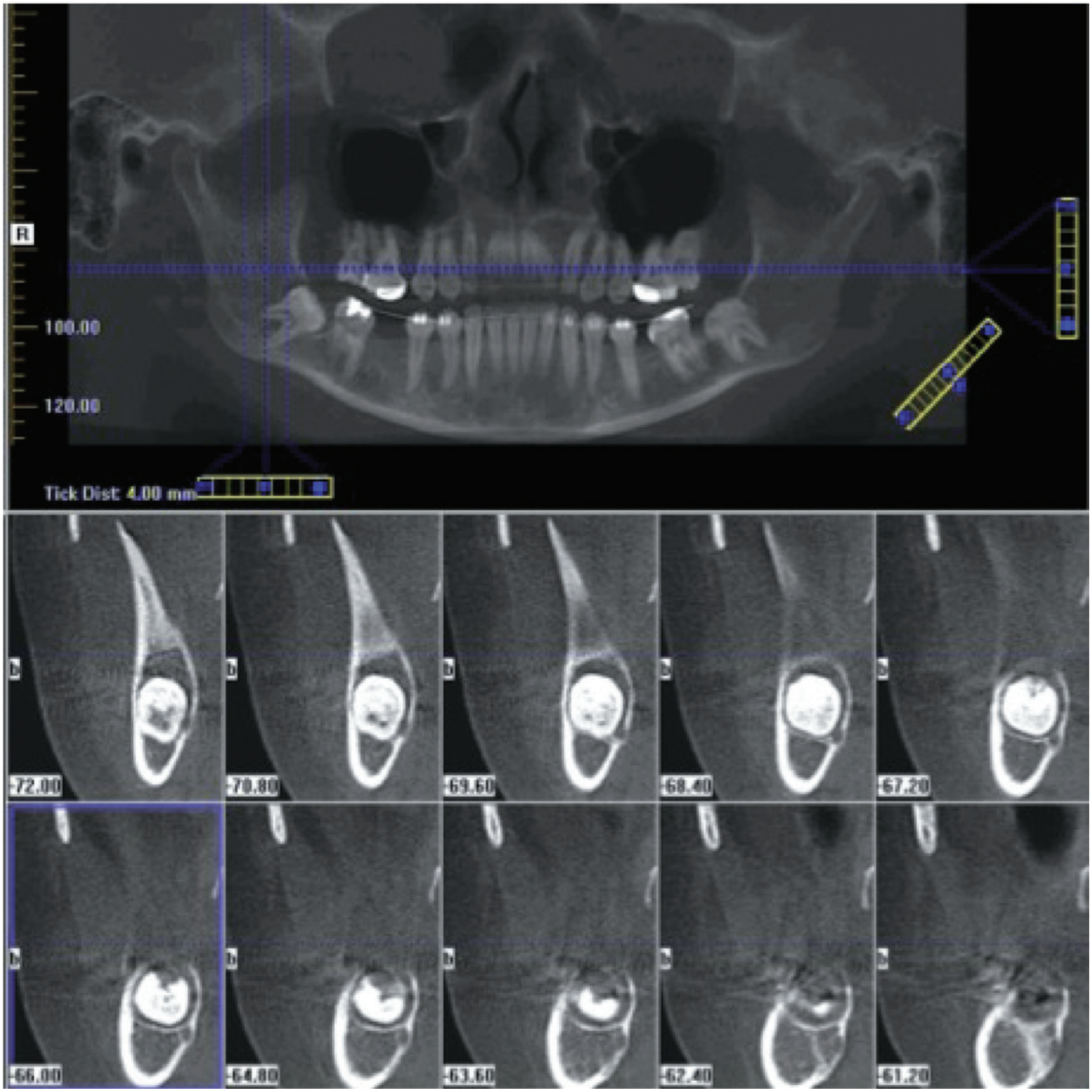


Figure 2.26 Screen capture from iCATvision™ showing the intimate relationship between the ID nerve and the unerupted LR8 in a patient scheduled for bilateral sagittal split osteotomy.

there will have been adequate resolution of soft tissue swelling, but the position of the surgical segments may reflect a degree of early relapse in some cases. As a compromise, we consider this to be the optimal time to capture both hard and soft tissues simultaneously, whilst minimising exposure to ionising radiation.

The three-dimensional position and orientation of the condylar segments, in sagittal split osteotomy cases, can be assessed using CBCT. The presence of condylar torqueing can be evaluated and addressed as deemed appropriate.

The position of plates and screws, and their proximity to anatomical structures, can be identified on a post-operative scan.

Lateral cephalogram

See Section 2.6.

PA skull radiograph

This view can also be classed as a cephalogram, in that it is standardised and can be analysed using linear and angular variables. It is commonly used to assess facial asymmetries, but lacks the 3D information that a CBCT scan is now able to provide. In the authors' clinical practice, the PA skull view has now been entirely replaced by the CBCT scan.

2.6 Cephalometrics for orthognathic patients

Lateral cephalograms have the following applications in the management of orthognathic patients:

- Assessment and diagnosis of dento-skeletal dysmorphology.
- Monitoring of jaw growth and occlusal change prior to surgery.
- Monitoring of orthodontic treatment progress.
- Surgical profile prediction planning (see Chapter 6).
- Assessment of surgical change.
- Monitoring of skeletal and occlusal relapse.

It must be remembered that a cephalogram is a two-dimensional representation of a three-dimensional object that has several bilateral structures. That said, for patients without significant asymmetries, lateral cephalometry remains a useful tool, which is a routine part of orthognathic patient management for most clinical teams. It cannot be over-emphasised, though, that cephalometric findings should always be interpreted against the background of an adequate clinical assessment and are only an adjunct to clinical judgement, rather than a stand-alone definitive assessment. There are a number of ways in which lateral cephalograms can be analysed in order to fulfil the applications listed above.

2.6.1 Gross inspection

An experienced clinician can derive a good deal of information regarding a patient's dentofacial dysmorphology simply by viewing the image, without the aid of any objective analysis. A general impression of the size and shape of the jaws, the approximate incisor inclinations and dento-alveolar heights, as well as the form and thickness of the soft tissues can be gained, at a glance.

Certain anatomical features do not lend themselves easily to measurement, but are none-the-less important to assess, such as the morphology of the mandible, which in patients with extreme vertical dysplasias, will exhibit the characteristic features of a growth rotation. For example, it can quickly be seen in Figure 2.27a that:


a)


b)

Figure 2.27 Lateral cephalograms of patients showing the typical features of **(a)** short-face syndrome and **(b)** long-face syndrome.

- The lower mandibular border is flat or rounded.
- The gonial angle is rounded with little ante-gonial notching.
- The course of the ID nerve is curved.
- The condyle is angled forwards.
- The ramus height is increased.
- The mandibular symphysis is upright with accompanying progenia.
- The lower molars have a forward path of eruption.
- The anterior vertical dimensions are reduced.

These are the classic cephalometric features of short-face syndrome and are only fully appreciated on gross visual inspection.

The cephalogram shown in Figure 2.27b shows all of the converse features associated with long-face syndrome and it can be readily seen how dramatically different the two images are in their overall vertical proportions.

In addition, the clinician should be alert to signs of possible pathology of the base of the skull, such as enlargement of the Sella Turcica in an acromegaly patient, which should be picked up early on initial inspection.

2.6.2 Qualitative analysis

The use of average templates derived from normal populations, such as the Bolton templates, allows for quick confirmation of the key areas of dysmorphology (Figure 2.28). There are potential problems with superimposing the tracings on the SN line, if the patient's cranial base differs from average and also with the scaling of the templates, which will not always be accurately matched to the patient.

Drawing the key horizontal reference planes on a cephalogram, allows better visual appreciation of the patient's vertical skeletal relationships, with the position of the convergence point indicating any variation from normal (Figure 2.29).

2.6.3 Quantitative analysis

Numerous cephalometric variables and analyses have been developed, with the aim of measuring different aspects of the dentofacial complex. The values obtained quantify how the patient's face varies from average, based on published 'normal' values. However, it is important to remember that the population from which the reference values are derived may differ from the patient's own local population, even within the same racial group. Standard racial values should be referred to, wherever they are available. Quantitative analysis can also be used to monitor antero-posterior and vertical change in the dentofacial complex.

The clinician must be aware of the limitations of cephalometry with regard to the accuracy and

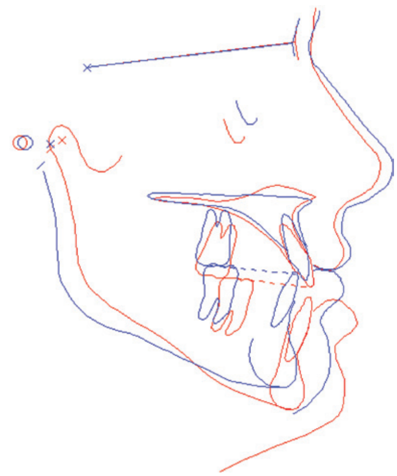


Figure 2.28 Lateral cephalogram of a class III patient (red) superimposed on a Bolton normal template (blue), using the S-N line as the reference, holding at Sella. It is immediately apparent that the patient has a mild degree of maxillary deficiency, a greater degree of mandibular prognathism and an increased lower anterior face height.

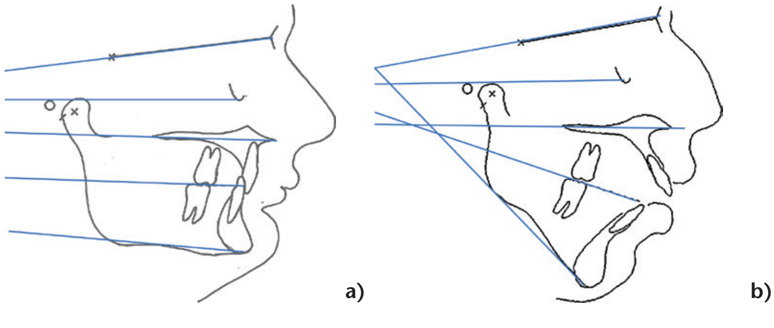


Figure 2.29 Drawing the horizontal reference planes (after Sassouni) helps the clinician to assess vertical dysmorphology on the lateral cephalograms of a short-faced patient **(a)** and long-faced patient **(b)**.

Table 2.3a Hard tissue cephalometric landmarks

Landmark	Definition
S	**Sella:** the centre of the sella turcica, determined by inspection.
N	**Nasion:** the most anterior point of the frontonasal suture.
Or	**Orbitale:** the lowest point on the infraorbital margin.*
Po	**Porion:** the uppermost point on the outline of the bony external auditory meatus.*
Ar	**Articulare:** the point of intersection between the outlines of the posterior cranial base and the dorsal condyle.*
ANS	**Anterior nasal spine:** the tip of the anterior nasal spine.
PNS	**Posterior nasal spine:** the tip of the palatine bone in the hard palate.
A	**Point A (subspinale):** the deepest point on the anterior outline of the maxilla below ANS.
B	**Point B (supramentale):** the deepest point on the anterior bony outline of the mandibular symphysis.
Uia	**Upper central incisor apex:** the apex of the root of the most prominent upper central incisor.
Uie	**Upper central incisor edge:** the tip of the crown of the most prominent upper central incisor.
Lie	**Lower incisor edge:** the tip of the crown of the most prominent lower central incisor.
Lia	**Lower incisor apex:** the apex of the root of the most prominent lower central incisor.
UM	**Upper molar cusp:** the tip of the mesiobuccal cusp of the upper first molar.*
LM	**Lower molar cusp:** the tip of the mesiobuccal cusp of the lower first molar.*
Pg	**Pogonion:** the most anterior point on the outline of mandibular symphysis below B point.
Me	**Menton:** the lowest point on the outline of the mandibular symphysis.
Go	**Gonion:** the most inferior and posterior point on the outline of the gonial angle of the mandible. Constructed point, found by bisecting the angle formed by tangents to the posterior and inferior borders of the mandible.*

*Bilateral structures may project a double image on the cephalogram, with two identifiable landmarks. In such cases the convention is to use a point midway between the two.

Table 2.3b Cephalometric reference lines

Line	Definition
SN	**SN line:** Line through Sella and Nasion. Represents the anterior cranial base.
FP	**Frankfort Plane:** Line through Porion and Orbitale. Also termed "Frankfort horizontal".
Max	**Maxillary Plane:** Line through PNS and ANS.
FOP	**Functional Occlusal Plane:** Line through the tips of cusps of the lower first molars and premolars.
Mand	**Mandibular Plane:** Line through Go and Me.

reliability of the landmarks and measurements. The values obtained from any analysis must be interpreted with caution and only as an adjunct to a thorough clinical assessment. As a general rule, it is unwise to fully trust any single variable or analysis and it helps to measure the same feature using two or more contrasting variables, particularly where the figures obtained are surprising or at odds with the clinical impression.

Tables 2.3a and 2.3b list a number of basic landmarks and reference lines, along with their definitions. Tables 2.4a, 2.4b, and 2.4c list some of the more commonly used variables, along with their values and some notes of caution regarding their application. These are also illustrated in Figure 2.30.

Antero-posterior jaw relationship

The antero-posterior position of the maxilla and mandible, and their relationship to each other, are commonly measured in relation to the SN line, which represents the anterior cranial base (Figure 2.30a). For SNA and SNB, values above or below their normal range will tend to indicate prognathism or retrognathism of the maxilla or mandible, respectively. However, for the angles SNA, SNB and ANB to be reliable, the SN line must be angled normally. If

Table 2.4a Antero-posterior jaw relationship

Variable	Type	Description	Value(s)	Potential problems
SNA (Angle between lines SN and NA)	Angular	Relates the maxilla to the anterior cranial base in the A-P plane.	81 ± 3°	Prone to unreliability due to variation in the angle of the SN line and the A-P position of Nasion. A-point can sometimes be difficult to locate.
SNB (Angle between lines SN and NB)	Angular	Relates the mandible to the anterior cranial base in the A-P plane.	78 ± 3°	Relies on the SN line and N-point, as for SNA.
ANB (Angle between the lines AN and NB)	Angular	Relates the maxilla to the mandible in the A-P plane with reference to N point.	3 ± 2°	Prone to error due to variation in the angle of the SN line and the SNA angle. The Eastman correction can be applied to compensate for an SNA value out with its normal range, but only if the SN-Max angle is normal (8° +/- 3°).
BO-AO (Relative positions of B-point and A-point along the FOP)	Linear (Wit's appraisal)	Relates the maxilla to the mandible parallel to the Functional Occlusal Plane using perpendicular lines from A and B point.	Females: 0 ± 1.8 mm Males: 1 ± 1.9 mm (i.e. in males BO meets the FOP 1 mm ahead of AO)	Very dependent on the inclination of the FOP, which can be greatly affected by the curve of Spee. Variation in the occlusal plane directly affects the relative positions of A and B points.
A-N perpendicular	Linear	Relates the maxilla to a line dropped perpendicular to the Frankfort Plane from Nasion.	Females: 0.4 ± 2.3 mm Males: 1.1 ± 2.7 mm	Measurements to both A and Pg are very sensitive to any variation in the orientation of the Frankfort Plane, since this directly affects the position of N perpendicular.
Pg-N perpendicular	Linear	Relates the mandible to a line dropped perpendicular to the Frankfort Plane from Nasion.	Females: −1.8 ± 4.5 mm Males: −0.3 ± 3.8 mm	

Table 2.4b Vertical jaw relationship

Variable/analysis	Type	Description	Value(s)	Potential problems
FMPA (Frankfort-mandibular planes angle)	Angular	Relates the inclination of the mandibular plane to the Frankfort Plane.	27 ± 4°	Relies on the Frankfort Plane as a horizontal reference. Anatomic Porion can be difficult to identify.
MMA (Maxillary-mandibular planes angle)	Angular	Relates the inclination of the mandibular plane to the maxillary plane.	24 ± 4°	Relies on the maxillary plane as a horizontal reference, which can be tipped backwards or forwards.
SN-Max (SN- maxillary plane angle)	Angular	Relates the SN line to the maxillary plane. Measured prior to carrying out the Eastman correction to confirm that the angle of the SN line is normal, (Figure 2.31).	8 ± 3°	Can be unreliable if the angle of the maxillary plane is abnormal (see Figure 2.2.).
UAFH (Upper anterior face height)	Linear	The distance between Nasion and ANS measured perpendicular to the Frankfort Plane (or true horizontal).	55 ± 8 mm	Both measurements may vary with any error in the angle of the Frankfort plane as well as with any tip of the maxillary plane.
LAFH (Lower anterior face height)	Linear	The distance between ANS and Menton measured perpendicular to the Frankfort Plane (or true horizontal).	68 ± 8 mm	
TAFH (Total anterior face height)	Linear	The sum of UAFH and LAFH.	124 ± 8 mm	
LAFH percentage (Lower anterior face height percentage)	Proportional	The ratio of LAFH to TAFH expressed as a percentage. Intended to show any disproportion between the lower and total anterior face heights.	55 ± 2%	
UPFH (Upper posterior face height)	Linear	The distance between Sella and PNS measured perpendicular to the maxillary plane.	45 ± 5 mm	
LPFH (Lower posterior face height)	Linear	The distance between PNS and Gonion measured perpendicular to the maxillary plane.	34 ± 5 mm	
TPFH (Total posterior face height)	Linear	The sum of UPFH and LPFH.	79 ± 6 mm	
LPFH percentage (Lower posterior face height percentage)	Proportional	The ratio of LPFH to TPFH expressed as a percentage. Intended to show any disproportion between the lower and total posterior face heights.	44 ± 1%	
Ar-Go (Mandibular ramus length)	Linear	The distance between Articulare and Gonion.	Females: 55.6 mm Males: 62.0 mm	Ramus length should ideally be measured to Condylion but this point is difficult to identify and Articulare is probably more reliable.
Ar-Go-Me (Gonial angle, between lines Ar-Go and Go-Me)	Angular	The angle between the posterior border of the ramus and the lower border of the body of the mandible.	128 ± 7°	

Table 2.4c Dento-alveolar dimensions

Variable	Type and origin	Description	Value(s)	Potential problems
Ui-Max (or Ui-FP) (Upper incisor to maxillary or Frankfort plane angle)	Angular	The angle between the long axis of the upper central incisor and the maxillary plane or Frankfort plane.	109 ± 6°	Upper incisor apex can be difficult to locate. Maxillary plane may not be horizontal.
Li-Mand (Lower incisor to mandibular plane angle)	Angular	The angle between the long axis of the lower central incisor and the mandibular plane.	92 ± 6°	Lower incisor apex is particularly difficult to locate.
Ui-Li Inter-incisal angle	Angular	The angle between the long axes of the upper and lower incisors.	130 ± 6°	As above.
UADH (Upper anterior dental-alveolar height)	Linear	The distance between the upper central incisor edge and the maxillary plane, measured perpendicular to the maxillary plane.	33 ± 3 mm	
LADH (Lower anterior dento-alveolar height)	Linear	The distance between the lower central incisor edge and menton, measured perpendicular to the maxillary plane.	Females: 40 ± 2 mm Males: 44 ± 2 mm	Will vary with the way in which the mandibular plane is constructed.
UPDH (Upper posterior dento-alveolar height)	Linear	The distance between the upper first molar mesial cusp and the maxillary plane, measured perpendicular to the maxillary plane.	28 ± 3 mm	
LPDH (Lower posterior dento-alveolar height)	Linear	The distance between the lower first molar cusp and the mandibular plane, measured perpendicular to the mandibular plane.	38 ± 3 mm	Will vary with tipping of the maxillary plane.

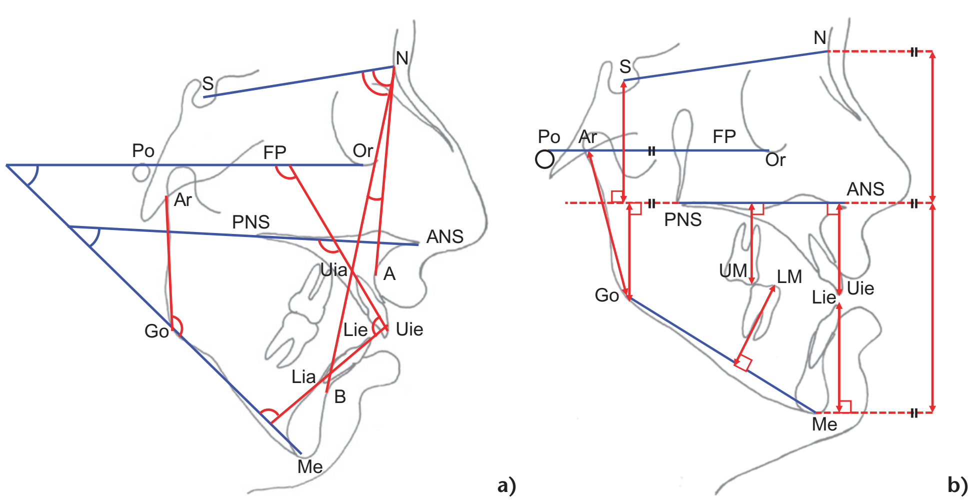


Figure 2.30 (see also Tables 2.4a-c) **(a)** Angular cephalometric variables, describing the horizontal and vertical jaw relationship. **(b)** Linear and proportional variables, describing the vertical facial dimensions.

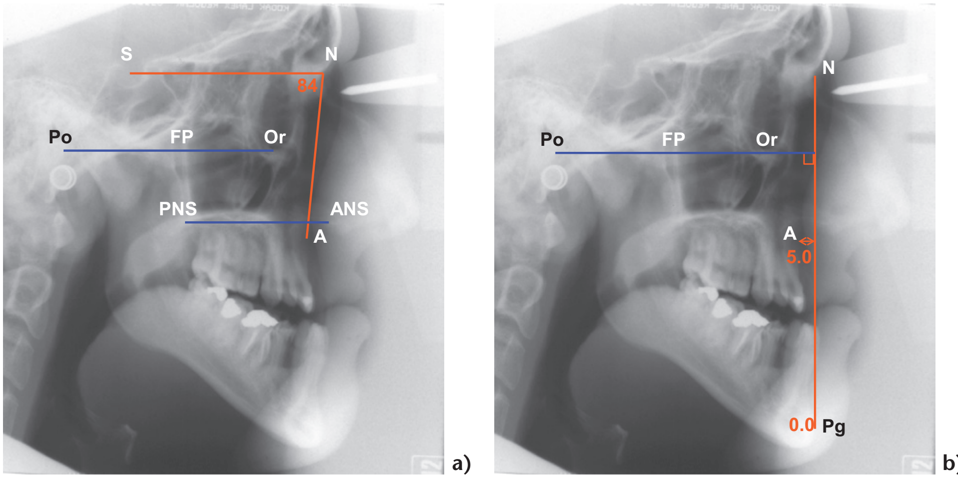


Figure 2.31 **(a)** Lateral cephalogram of a patient with clinical maxillary deficiency. The SNA angle is deceptively large, due to a flat anterior cranial base (S-N line). **(b)** The maxillary position relative to the Nasion perpendicular line (McNamara analysis) is more in keeping with the clinical impression (A-point 5.0 mm behind).

either Sella or Nasion is significantly out of position, or the jaws are bi-maxillary protrusive or retrusive, this will affect the values obtained. In orthognathic patients, this is often the case and the clinician should be aware of the potential problems that can be encountered.

The unreliability of SNA. Figure 2.31a shows the cephalogram of a patient, who had clinical signs of antero-posterior maxillary deficiency. A reduced SNA value would have been anticipated, but in this case it is increased. The clinician would clearly be misguided to accept this figure as an indication of maxillary prognathism, since it can be explained by the flatness of the anterior cranial base (SN line) along with an SN-Max angle below the normal range. When the McNamara analysis is applied, which relies on the Frankfort Plane, a value more in keeping with the clinical impression is obtained (Figure 2.31b).

The Eastman correction. Where the SNA angle is outside its normal range, this can result in a change in the ANB angle, which is not a true reflection of the jaw relationship. The Eastman correction is intended to compensate for this and is illustrated in Figure 2.32.

Whilst the Eastman correction is valuable in many cases, the clinician must be aware of its limitations. A scenario is illustrated in Figure 2.33 in which a class II patient has an SNA value of 85° and an ANB value of 8°, which is consistent with the clinical impression. If the Eastman correction was to be applied, ANB would be reduced to 5°, which would indicate only a mild class II skeletal jaw relationship and would be misleading. However, the value of the SN-Max angle is outwith its normal range of 8 +/- 3° due to the flatness of the SN line, so the correction is contra-indicated (see also Figure 2.32c).

The effect of the vertical dimension on ANB. Patients with increased vertical proportions can present a problem when using the cranial base as a reference, since their mandibular and occlusal planes are usually rotated downwards and backwards, thus increasing or reducing the ANB angle, in class II and III cases respectively. For the high angle patient in Figure 2.34a, ANB is surprisingly large, given the clinical impression of a significant class III jaw discrepancy. Applying the 'Wits' appraisal removes the cranial base as a reference and measures the jaw relationship parallel to the occlusal plane (see Table 2.4a), yielding a result more in keeping with the clinical picture (Figure 2.34b).

Vertical skeletal dimensions

Mandibular plane angle. The vertical jaw relationship is described by a combination of angular, linear and proportional variables (Figure 2.30), which are aimed at describing a patient's vertical facial type (normal, long or short) and the growth pattern and morphology of their mandible (normal, backward or forward). The inclination of the lower border of the mandible is described by both the FMPA and MMA. Values above and below the normal range will be

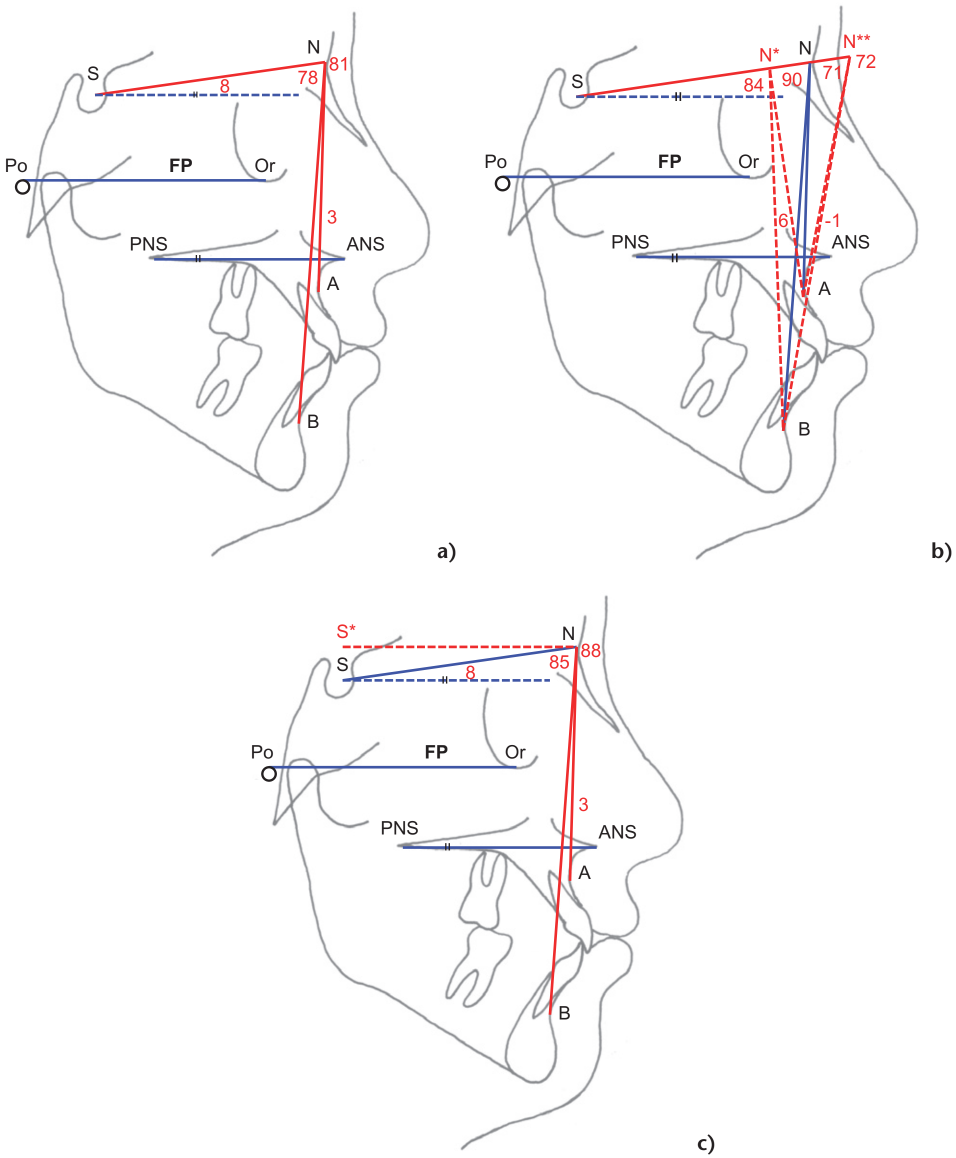


Figure 2.32 The Eastman correction explained: **(a)** When the SNA angle is within normal limits (81 +/– 3°) and the angle of the S-N line is normal, the ANB angle will accurately reflect the antero-posterior jaw relationship. **(b)** If Nasion is positioned too far forward or back relative to the jaws, the ANB angle will change and become inaccurate. To compensate for this, subtract 0.5° from ANB for every 1.0° of increase in SNA, and vice versa. **(c)** The Eastman correction should only be carried out if the SN-Max angle is within normal limits (8 +/– 3°) because, if the angle of the S-N line is too steep or too shallow, this alters the SNA angle without any corresponding change in the ANB angle.

expected to accompany a backward or forward mandibular growth rotation respectively. However, the Frankfort and maxillary planes are not always parallel and the maxillary plane is particularly prone to variation in orthognathic patients. It is therefore advisable to measure both angles together for increased reliability and look for the cause of any unexpected values.

Face height proportions. The linear and proportional variables describe the effect of the growth pattern of the mandible on the heights of the anterior and posterior facial skeleton. A patient with a short face will be expected to show reduced ratios of LAFH:TAFH and LAFH:LPFH (Figure 2.35a), while the opposite will be the case in a long-faced patient (Figure 2.35b).

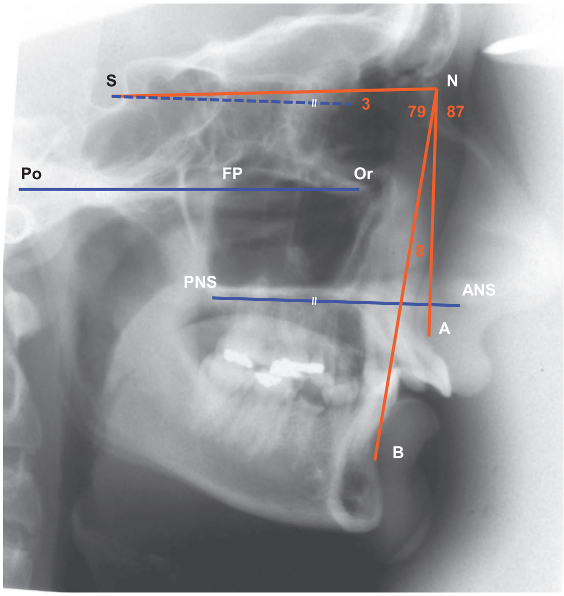


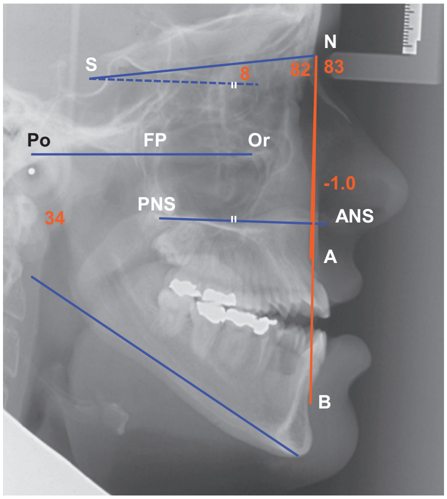
Figure 2.33 In this class II patient, the Eastman correction is contra-indicated due the value of the SN-Max angle lying outwith its normal range.

Dento-alveolar dimensions

Incisor inclinations. Cephalometric analysis is helpful in confirming the inclinations of the incisors, particularly where they appear compensated clinically. Figure 2.36a shows the tracing of a class III case, which confirms that the upper incisors are proclined and the lowers retroclined beyond their normal ranges, as expected. The tracing in Figure 2.36b confirms that the lower incisors are proclined in compensation for the class II skeletal pattern, but the upper incisors are also markedly proclined due to the presence of a lower lip trap. In the class II, division 2 patient in Figure 2.36c, the upper incisors are confirmed as being severely retroclined, under the action of the upper lip and the lowers are mildly retroclined.

Upper incisor inclination is commonly measured relative to the maxillary plane, but this is not always reliable in orthognathic patients, particularly those with vertical dysplasias where it is often tipped forwards or backwards. It may also be altered through maxillary surgery. It is therefore also advisable to measure the upper incisor inclination relative to the Frankfort Plane (or true horizontal), since this remains constant throughout treatment and may be more relevant in assessing the inclination of the incisors from an aesthetic standpoint.

Lower incisor inclination and the mandibular plane. There is a school of thought that the assessment of lower incisor inclination should take account of the FMPA, since a mandibular growth rotation will



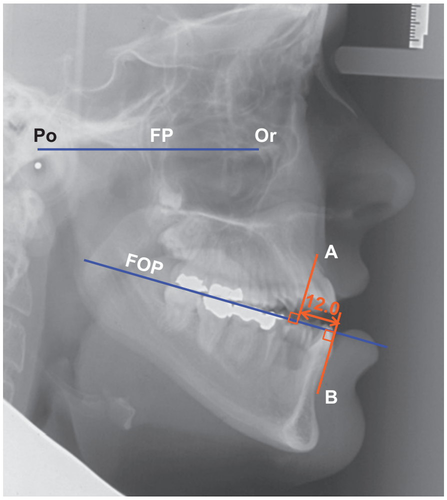


Figure 2.34 **(a)** In this class III case with a high FMPA the ANB angle is only slightly reduced. **(b)** The “Wits” appraisal gives a value of –12 mm between BO and AO, measured along the Functional Occlusal Plane (FOP).

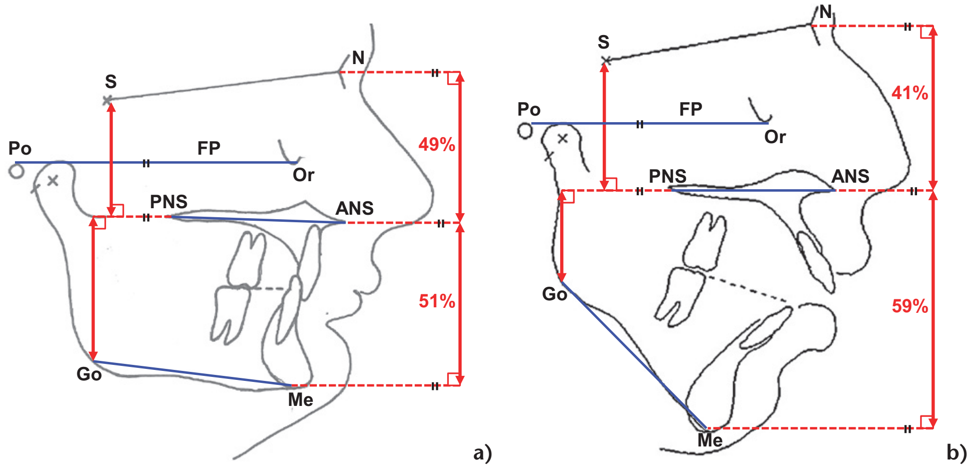


Figure 2.35 **(a)** In short-faced patients, the lower anterior face height (LAFH) is reduced and the lower posterior face height (LPFH) is increased, reflecting a forward mandibular growth rotation. The converse is true for long-faced patients **(b)**.

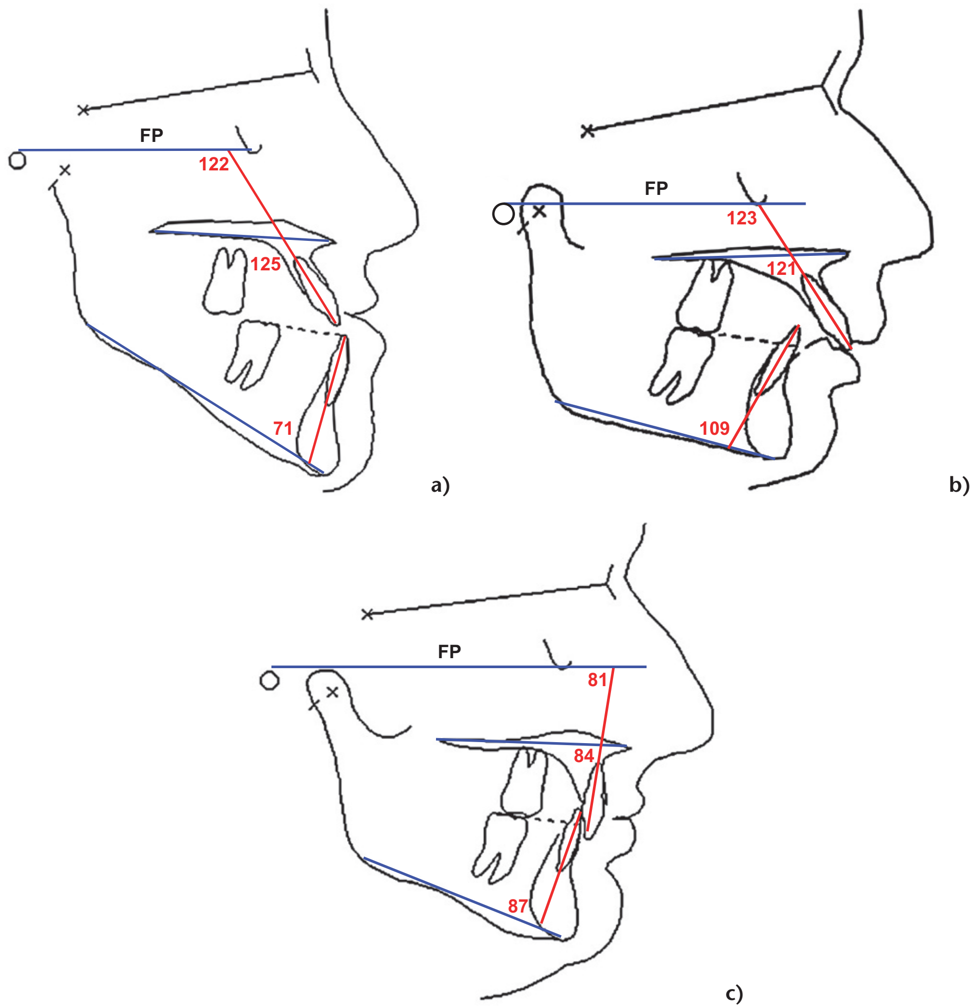


Figure 2.36 Cephalometric diagrams illustrating incisor compensations in the main malocclusion types. It is useful to measure the upper incisor inclinations to the Frankfort horizontal as well as the maxillary plane: **(a)** Class III, with retroclined lowers and proclined uppers. **(b)** Class II, division 1, with a lower lip trap and bi-maxillary proclination. **(c)** Class II, division 2, with bi-maxillary retroclination.

tend to alter the inclination of the lower incisors within their soft tissue envelope. Hence, if the FMPA is 5° greater than average, the inclination of the lower incisors would be expected to be 5° less than average and visa versa, such that the FMPA and lower incisor inclination values add up to 120°. This can have implications for the planning of pre-surgical orthodontics (see Chapters 3 and 4).

Dento-alveolar heights. The heights of the posterior dento-alveolar processes tend to reflect the mandibular growth pattern. In a short-faced patient with a deep overbite, the posterior dento-alveolar heights are usually reduced (Figure 2.35a), while in a patient with a long facial type and a skeletal open bite they are usually increased in (Figure 2.35b).

The relationship between the anterior dento-alveolar heights and the mandibular growth pattern is not so straightforward because the extent of incisor eruption is determined by a combination of their inclinations and occlusal relationship, and the action of the lips and tongue. For example, in a class III case with vertical maxillary deficiency, the upper dento-alveolar height will invariably be reduced, but in a class II, division 2 case, with an increased inter-incisal angle, the upper incisors are free to over-erupt. Conversely, in a high angle case with anterior open bite, the upper anterior dental height would usually be increased, but it may be reduced if a long-standing digit sucking habit has impeded vertical dento-alveolar development.

In summary, it is essential to appreciate that cephalometric findings are only a guide and that all analyses have their strengths and weaknesses. At the end of all of the diagnostic and planning appointments it is a patient, and not a radiograph, that the team is delivering treatment to and clinical impression and judgement should always take precedence over numerical values.

2.6.4 Superimposition

Superimposition is a technique that readily allows differences between two or more cephalograms to be identified graphically by over-laying them. This may be required to monitor facial growth, assess treatment changes, or quantify relapse.

Monitoring growth

Serial cephalograms are useful in assessing whether jaw growth is ongoing prior to surgery. Figure 2.37 shows an example of progressive mandibular growth between the ages of 17 and 20 years of age in a male with a class III jaw relationship and increased vertical dimension.

Figure 2.37 Class III growth shown using superimposed sequential lateral cephalometric tracings.

Where idiopathic condylar resorption is suspected as the cause of progressive anterior open bite, superimpositions will reveal decreasing ramus height.

Assessment of treatment change

Cephalograms can also be used to assess the dental changes produced by pre-surgical orthodontics and the skeletal changes produced by surgery. Because orthognathic patients are usually adults who have stopped growing, the SN line can be used reliably as the reference plane for superimpositions, such that any changes observed are entirely the result of movement of the dentofacial components.

Assessment of relapse

It is not our routine to take an immediate post-operative cephalogram because a second CBCT scan is taken six months after surgery for every patient in order to allow assessment of surgical change in three dimensions as required. It is usually at the two-year post-operative review appointment that the first conventional cephalogram is taken. If any signs of relapse are seen clinically a superimposition can be carried out of this image onto a cephalometric view derived from the CBCT data. Relapse can be due to skeletal and/or dentoalveolar changes and cephalometric superimposition allows this to be analysed and quantified, at least in the antero-posterior and vertical planes. Subsequent follow-up cephalograms are taken annually, up to five years post-operatively.

2.7 Special investigations

There are some progressive conditions that require additional special investigations for adequate assessment and diagnosis. The most common of these are:

2.7.1 Condylar hyperplasia

Where the patient reports or shows signs of a progressive mandibular asymmetry, this will require monitoring. It may be appropriate to consider radio isotope (technetium[99]) scanning in an attempt to confirm the over growth of the suspected condyle in comparison to the opposite side. Negative findings are inconclusive as excessive growth tends to occur in phases, so that the scan may take place during a period of quiescence.

The diagnosis of hemi-mandibular hypertrophy and condylar hyperplasia can be readily confused and they can co-exist in the same patient. The hallmarks of hemi-mandibular hypertrophy are bowing of the inferior border of the mandible and inferior displacement of the ID canal on the affected side, which helps with the diagnosis and treatment plan.

2.7.2 Acromegaly

Acromegaly is caused by excessive growth hormone production in adulthood, usually due to pituitary adenoma. Initial diagnosis is likely to be through patient history and clinical signs, which are as follows:

- Late mandibular growth, typically causing a class III malocclusion with spacing of the lower incisors.
- Thickening of the facial skin and lengthening of the lips.
- Thickening of the fingers.

Previous family or school photographs of the patient are particularly valuable in identifying the soft tissue changes, which will tend to cause lengthening of the lips and a reduced display of the upper incisors. Reported increases in glove and ring size are typical complaints. Where suspected, referral to an endocrinologist will be required for assessment of growth hormone levels and appropriate management.

2.8 Summary

- Prior to dentofacial assessment, a thorough history should be taken from the patient regarding their presenting problem, their general and dental health.
- A social history is important, although this is primarily be the remit of the psychologist, if one is available.
- A full facial assessment should be carried out systematically from the lateral right and left, frontal, bird's eye and worm's eye views.
- Correct positioning of the head is essential in assessing the jaw relationship and any facial asymmetry.
- Objective soft tissue analysis, carried out on correctly orientated photographs, can be a valuable adjunct to clinical assessment.
- Assessment of the dental arches should include a basic space analysis and measurement of the depth of the curves of Spee.
- Assessment of the occlusion should include the incisor relationship and extent of dento-alveolar compensation in all three planes, as well as any transverse arch width discrepancy.
- The dental centrelines should be assessed in relation to their respective jaws, as well as the facial midline.
- If a mandibular asymmetry is present, it is essential to determine whether it is truly skeletal in origin, or the result of a displacement due to occlusal interference.
- Study models and photographs are essential in monitoring progressive conditions such as class III, asymmetry and anterior open bite.
- Stereophotogrammetry is the only method of recording a patient's true 3D facial characteristics, quantifying 3D soft tissue growth changes and monitoring asymmetries.
- Cephalometric analysis is a valuable adjunct to clinical assessment, but the clinician must be aware of its limitations, particularly in assessing the antero-posterior jaw relationship un relation to the anterior cranial base.
- Cone beam CT imaging is not usually required at the initial assessment stage, except for patients with complex asymmetries.
- The routine capture of CBCT, pre- and post-operatively, allows surgical intervention to be planned appropriately and gives the opportunity to evaluate and measure surgical changes in 3D.

2.9 Recommended further reading

Jacobson, A. and Jacobson, R.L. (2006) *Radiographic cephalometry: From Basics to 3D Imaging*, 2nd edn. Quintessence Publishing Co, Inc.

Naini, F.B. and Gill, D.S. (2008) Facial aesthetics: 2. clinical assessment. *Dent Update*, **35** 159–170.

Proffit, W.R. Fields, H.W. and Sarver, D.M. (2013) *Contemporary Orthodontics*, 5th edn. Sections II and III. Elsevier.

3 The treatment planning process

Chapter overview

Intended learning outcomes

By the end of this chapter the reader should:
- Understand the three fundamental steps in orthognathic treatment planning.
- Understand the four keys to hard tissue planning.
- Understand the difference between initial, combined treatment planning and final surgical planning.
- Understand the interaction between pre-surgical orthodontic planning and provisional surgical planning.

3.1 Introduction

Treatment planning for the orthognathic patient should be an inter-disciplinary process, carried out between the team members, with the patient present. Following appropriate diagnosis the clinicians will be able to discuss the proposed dental and skeletal movements, taking the patient's concerns into account.

No individual part of the plan can be made in isolation and a continuous, interactive thought process is required to arrive at the optimal combination of orthodontic and surgical movements.

3.2 Three fundamental planning steps

The planning process typically involves three basic steps:
1. Envisaging the main soft tissue changes required to produce harmonious facial aesthetics.
2. Deciding the approximate skeletal jaw movements required to produce the desired aesthetic result.
3. Planning the pre-surgical orthodontics, such that correcting the occlusal disharmony will result in the required jaw movements.

3.2.1 Envisaging the desired aesthetic changes

This relies on the experience and judgement of the clinicians to a large extent and, even between

Handbook of Orthognathic Treatment: A team approach, First Edition. Ashraf Ayoub, Balvinder Khambay, Philip Benington, Lyndia Green, Khursheed Moos, and Fraser Walker.

experienced clinicians, there can be disagreement regarding the facial aesthetic goals. Where this occurs, it is particularly important to ensure that planning remains focused on the patient's concerns. Guidelines can help in determining the site and magnitude of the discrepancy and have been discussed in Chapter 2.

Photo-cephalometric planning may be required at this stage when maxillo-mandibular disharmony is mild and it is not clear which single jaw correction would produce the best results, or in borderline cases where it is not clear if single or bi-maxillary surgery is required.

3.2.2 Deciding on the required jaw movements

The soft tissue changes, in response to surgical movement of the underlying bones, vary depending on the anatomical level (see Chapter 6). This is not an exact science, since the evidential basis for hard-to-soft tissue movement ratios is limited and there is considerable individual and racial variation.

In addition, soft tissue changes occur not just in profile, but in three dimensions and the clinicians should be mindful of potentially adverse effects. In particular, with Le Fort I osteotomy:

- The alar base has a tendency to flare, even where there is no vertical impaction of the maxilla (Figure 3.1).
- The nasal tip turns upwards with maxillary advancement and impaction.
- Correction of severe maxillary deficiency, accompanied by zygomatic and infra-orbital deficiency, can leave the patient with an unattractive appearance of bi-maxillary protrusion and enophthalmos.

These effects are not entirely predictable and can be controlled by the surgeon to some extent (see Chapter 7), but they will tend to be greater with larger maxillary movements. Care must be taken to formulate a plan that will adequately correct the jaw disharmony, but also limit the unaesthetic side effects. It is important to take into account the shape of the nose and the alar base width, in proportion to the rest of the face, along with the upper facial morphology, particularly where a large maxillary advancement will be required.

3.2.3 Planning orthodontics to allow the required jaw movements

Pre-surgical orthodontics should be aimed at placing the teeth in a position that allows the jaws to be surgically moved by the amount estimated to produce the desired facial aesthetic changes. A key feature of this approach is that the degree of incisor decompensation should be tailored to allow the planned surgical movements, which involves setting a target overjet (class II cases) or reverse overjet (class III cases). This is conceptually different to an approach where the primary aim is to set the incisor inclinations to their cephalometric norms, with the resulting overjet then dictating the size of the surgical correction (see also Chapter 4).

The amount of incisor decompensation that will be required can be aided by profile cephalometric planning at this stage, but its validity may be limited until the final tooth positions are known at the end of pre-surgical orthodontics.

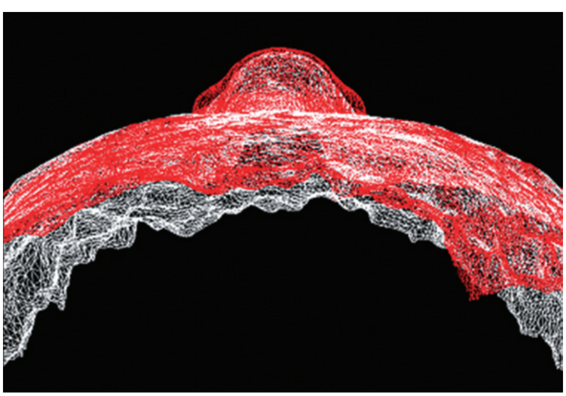


Figure 3.1 Superimposition of mean pre-surgical (white) and post-surgical (red) three-dimensional mesh diagrams of Le Fort I advancement osteotomy patients showing flaring of the alar base.

3.3 Four keys to dento-skeletal planning

Whilst the initial step in the planning process is envisaging the final aesthetic outcome, the delivery of treatment usually takes place in the reverse sequence. The teeth are orthodontically positioned first, then the jaws surgically moved to produce the soft tissue changes. The orthodontic tooth movements and the surgical jaw movements are interdependent and must be planned together. In most cases the major orthodontic tooth movements will be carried out first but, at the initial planning stage, it can be difficult to predict how accurately the orthodontist will be able to achieve the desired tooth positions. The initial surgical plan can therefore only be approximate and it is not until the patient is seen again following the completion of pre-surgical orthodontics, that the definitive surgical plan can be finalised.

The following four keys should be considered in planning the dento-skeletal movements:

1. Upper incisor and maxillary position.
2. Occlusion and mandibular position.
3. Maxillo-mandibular complex rotation.
4. Chin position.

3.3.1 Upper incisor and maxillary position

The first step is deciding where to place the upper incisors in all three planes of space, and their final position will be the net result of both orthodontic and surgical movements.

Antero-posterior positioning

Planning the optimal antero-posterior position for the upper incisors must take into account their position in the horizontal plane as well as their inclination. Antero-posterior orthodontic adjustment of the incisors pre-surgically has two objectives:

1. To help achieve the target overjet or reverse overjet as part of incisor decompensation.
2. To ensure that they are left at the most aesthetically pleasing inclination following orthognathic surgery.

These objectives are inter-linked and must be considered simultaneously. There are specific planning considerations that relate to the different malocclusion groups.

Class II skeletal pattern. In many class II, division 1 cases, the upper incisors will be at an aesthetically acceptable inclination and will require minimal adjustment. If they are proclined and the plan is to retract them to a more average inclination, it must be borne in mind that the upper lip will drop back in response to this, which can accentuate any underlying deficiency of the maxilla. In Class II, division 2 cases the upper central incisors will require proclination and this will result in some increase in lip support.

Where a degree of maxillary deficiency does accompany the mandibular deficiency (bi-maxillary retrusion), a decision must be made as to whether the position of the maxilla also warrants surgical correction to bring the upper incisors into an aesthetically pleasing position. In cases where the maxillary deficiency is mild, leaving the upper incisors slightly proclined may allow adequate advancement of the mandible, whilst avoiding the need for maxillary osteotomy. However, in cases where this may leave the maxilla looking slightly deficient, para-nasal augmentation using bone grafts can be considered as a surgical adjunct.

Where the degree of maxillary retrusion is considered severe enough to require surgical advancement, it is important to ensure that the target overjet is sufficient to allow the maxilla to be advanced by a worthwhile amount (i.e. at least 4mm), whilst still keeping the mandibular advancement to within an achievable surgical limit (i.e. approximately 10mm maximum with a sagittal split osteotomy). An overjet of 8mm is therefore about the maximum that will be compatible with bi-maxillary advancement osteotomy in a class II patient. An adjustment to this calculation will be necessary where the maxilla also needs to be impacted, allowing a degree of mandibular advancement through autorotation. In some cases, with severe mandibular deficiency, other surgical techniques, including inverted 'L' osteotomy with bone graft, or distraction osteogenesis, may be considered.

In cases where prominence of the anterior part of the maxilla (pre-maxilla) has resulted in dento-alveolar protrusion, an anterior maxillary osteotomy may be required. This is often carried out in conjunction with extraction of upper first premolars and may be a more predictable and quicker alternative to orthodontic retraction of the teeth.

Class III skeletal pattern. In class III cases, where maxillary deficiency has been diagnosed, the plan will involve advancement of the maxilla. This has two specific objectives:

1. To produce the envisaged mid-facial soft tissue aesthetics.
2. To place the upper incisors in the most aesthetically pleasing position.

The upper incisors will often be proclined in compensation for the underlying skeletal discrepancy and may need to be orthodontically retroclined to place them at the most aesthetically pleasing inclination.

Anterior open bite. Where an anterior open bite requires correction by posterior impaction of the maxilla, surgery will have a retroclining effect on the upper incisors, which should be compensated for in the pre-surgical orthodontic preparation (Figure 3.2). Where segmental osteotomy is required to level the maxillary arch, due to a severe curve of Spee, the upper incisor inclination will be determined by the positioning of the anterior segment to a large extent. This may be amenable to some post-surgical adjustment.

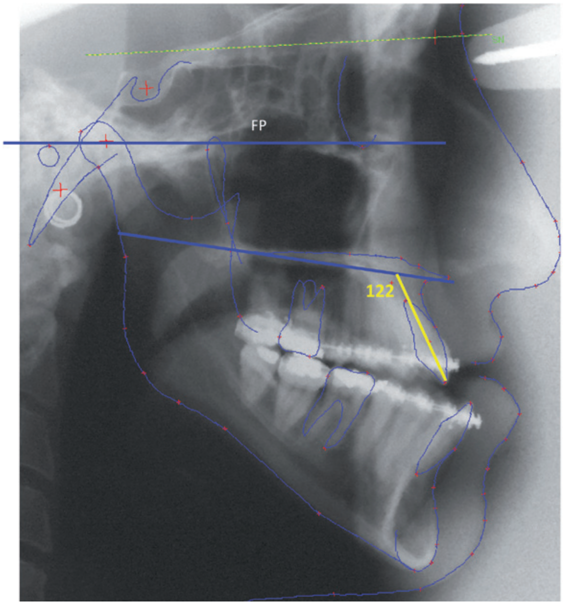


Figure 3.2 Pre-surgical cephalometric tracing of a class III patient with an anterior open bite. The proclination of the upper incisors has been maintained during pre-surgical orthodontics to allow for the retroclining effect of the planned posterior maxillary impaction.

Vertical positioning

Canting of the occlusal plane. Canting of the maxillary occlusal plane can be levelled surgically and this must be planned to achieve the correct vertical position of the upper incisors on both sides. Where no other movement of the maxilla is required and the discrepancy is mild, it may be acceptable to leave the cant uncorrected. Where it is part of a lower facial asymmetry involving the mandible, adequate surgical correction of the overall bi-maxillary vertical asymmetry will depend on achieving a level maxillary occlusal plane.

Excessive incisor show – the 'gummy' smile. Where the vertical display of the upper incisors (at rest and on smiling) is significantly increased, it must be decided whether or not this requires surgical correction. This will be largely driven by the patient's concerns, as well as their malocclusion. In patients with a short upper lip and a 'gummy smile', it may be that full correction of the vertical incisor-to-lip relationship will be unrealistic without impacting the maxilla excessively and compromising the overall vertical facial proportions. In such cases, leaving a small amount of gingival display on smiling will have to be accepted, but this will usually be aesthetically acceptable. An adjunctive surgical lip lengthening procedure, such as a 'V-Y' closure of the incision of the muco-buccal fold and the mucosa of the lip will usually be beneficial in such cases.

Reduced vertical incisor display. In class III patients with a reduced lower anterior vertical dimension, the maxilla will often be vertically deficient and the upper incisor show will be reduced. The patient will often exhibit over-closure of the mandible with their posterior teeth in contact. This is because the freeway space is increased and it is important that planning is carried out with the mandible in its rest position (see Figure 6.4). This gives an indication of the amount of vertical space available for maxillary down-grafting, as well as giving a more accurate impression of the antero-posterior jaw relationship.

Incisal show may also be reduced in class II cases due to restriction of the vertical development of the anterior maxilla because of para-functional habits i.e. tongue thrust or digit sucking. The uppper curve of Spee will be accentuated and the decision to level this surgically (by a segmental approach) or orthodontically, will depend on the severity of the curve and operator preferences (see Chapters 4 and 7).

Borderline cases. In cases where the vertical incisor position is only mildly abnormal, the possibility of correcting it may depend on the rest of the surgical plan. For example, if the maxilla is to be advanced, there will be an opportunity to simultaneously adjust its vertical position in order to achieve the most ideal result possible. On the other hand, if the maxilla is already in the correct position antero-posteriorly, it may not be warranted to perform a Le Fort I procedure for the sake of a relatively minor discrepancy that the patient is not overly concerned about.

Transverse positioning

Where the upper dental centreline is displaced to one side, it should ideally be a goal of pre-surgical orthodontics to correct it (see Chapter 4). If a Le Fort I osteotomy is planned, there may be some scope to rotate the maxilla to correct the centreline surgically, but, this movement can potentially disrupt the transverse buccal segment occlusion.

Where there is a transverse arch discrepancy, the maxillary dental arch is most commonly too narrow. Hand-articulating the study models, or requesting some preliminary model surgery, can often be helpful in assessing the amount of expansion that would be required to achieve arch coordination. The commonly used techniques for widening the maxillary arch are outlined in Chapter 4 and the surgical techniques are described in Chapter 7. In the more severe cases, accepting a bilateral buccal segment cross-bite may be the most sensible approach, particularly if the patient is not greatly concerned about the aesthetics of their narrow upper dental arch.

3.3.2 Occlusion and mandibular position

Antero-posterior correction

Having planned the upper incisor and maxillary position, the antero-posterior mandibular position can be addressed. In cases where mandibular surgery only or bi-maxillary surgery is planned, the mandible is moved to set the teeth into the planned post-surgical occlusion, through either setback or advancement.

As previously stated, incisor decompensation should be tailored to deliver optimal aesthetics. Another aspect of this concept is that the amount of decompensation carried out could, in some cases, mean the difference between single and double jaw osteotomy. Although the attainment of ideal aesthetics is important, the risks of bi-maxillary osteotomy must be carefully weighed up in cases where a single jaw procedure would still be estimated to produce a satisfactory result (Figure 3.3).

In more severe cases, where bi-maxillary osteotomy is inevitable, partial decompensation may be planned to limit the size of the jaw movements, thereby reducing surgical complexity and relapse tendency, whilst still achieving satisfactory aesthetics.

Vertical correction

Deep overbite. Class II patients sometimes present with a reduced lower anterior face height and a tendency to parallelism of the jaws (see Chapter 2). In such cases, treatment will be aimed at increasing the lower anterior face height. A common approach to achieve this is to plan to maintain the lower curve of Spee until after mandibular advancement surgery, in order to produce a ‘three-point landing’ (occlusal contact between the incisors and terminal molars only). The resulting lateral open bites must then be closed orthodontically after surgery (see Chapter 4).

In cases with a severe lower curve of Spee, where orthodontic levelling is unlikely to be achievable, it may be necessary to plan for a sub-apical procedure or body osteotomy, to set down the lower anterior labial segment. Which procedure is selected will depend on whether or not an increase in lower anterior face height is required (see Chapter 7).

Anterior open bite. Where an anterior open bite is due to posterior vertical maxillary excess or vertical deficiency of the mandibular ramus, this is commonly corrected through posterior maxillary impaction which allows the mandible to auto-rotate into the correct vertical position, bringing the incisors into occlusion (Figure 3.4).

Asymmetry. Where a vertical asymmetry of the mandible is present, there will usually be a cant of the mandibular occlusal plane. If this has developed during facial growth, the maxillary plane will usually be canted as well and the plan will already include its correction (see previously). If the mandibular asymmetry has developed after the cessation of normal facial growth, then there may be a lateral open bite on the affected side. In either case, the mandibular occlusal plane will require surgical levelling, in order to correct the occlusion. Where the problem is due to excessive ramus length on one side, this will require surgical reduction of the affected side, or lengthening of the opposite side, or a combination of both. Where there has been restriction of vertical growth on one side, it may be necessary to consider a ramus lengthening procedure (see Chapter 7). In cases where there is no significant disparity of the ramus lengths, vertical mandibular asymmetry can be corrected using sagittal split osteotomy.

Angle of the mandibular plane. It is important to take the mandibular plane into account at the planning stage, because its angle can affect the objectives of both pre-surgical orthodontics and surgery. Post-surgical profile balance may be improved where the lower incisor inclination has been adjusted to compensate for the mandibular plane angle being outside its normal range. Figure 3.5 illustrates a class III patient with an increased FMPA and correspondingly retroclined lower incisors. Surgical correction was carried out by means of a Le Fort I maxillary advancement and a bilateral sagittal split mandibular set back. No vertical change of the maxilla was required and so the FMPA remained largely unchanged as a result of surgery. The lower incisors were only partially decompensated, such that a balanced profile would be achieved. Had full decompensation been carried out, the result would have been over-correction and a convex profile, due to the backwardly angled

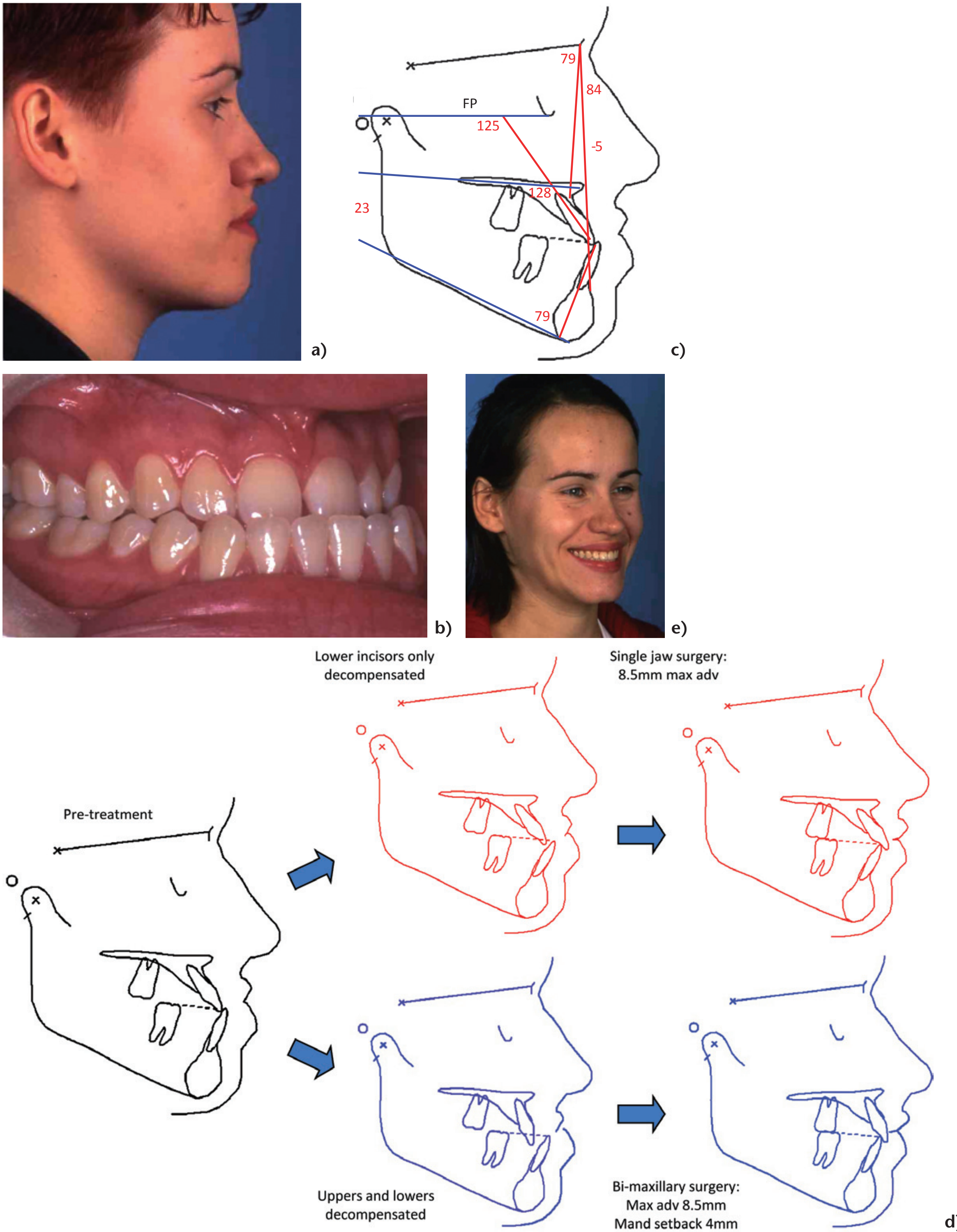


Figure 3.3 Class III patient with compensated upper and lower incisors **(a, b, c)**. Initial cephalometric planning **(d)** revealed that complete upper incisor decompensation (requiring extractions), would result in bi-maxillary osteotomy. Accepting the upper incisor proclination allowed occlusal correction with maxillary osteotomy only, which produced a satisfactory aesthetic result **(e).** Tracings produced using OPAL (British Orthodontic Society).

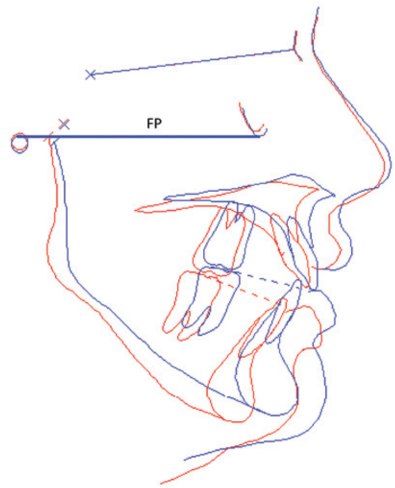


Figure 3.4 These superimposed pre- (red) and post-surgical (blue) cephalometric tracings demonstrate closure of an anterior open bite by mandibular autorotation, following posterior maxillary impaction. Produced using OPAL (British Orthodontic Society).

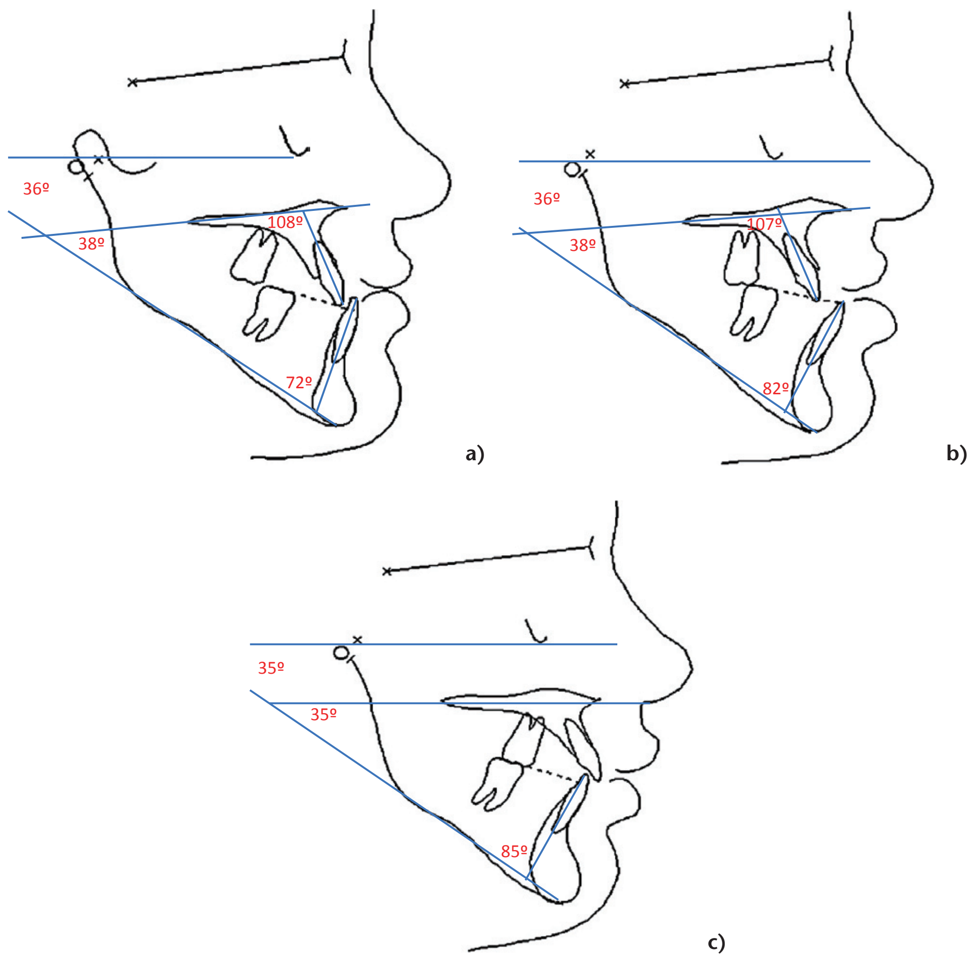


Figure 3.5 Cephalometric tracing of a class III patient with increase FMPA and retroclined lower incisors, planned for bi-maxillary osteotomy **(a)**. Because surgery was not expected to correct the FMPA, the lower incisors were only partially decompensated **(b)**. This allowed satisfactory profile balance to be achieved without resort to an advancement genioplasty **(c)**. Produced using OPAL (British Orthodontic Society).

symphysis, which might then have required an advancement genioplasty.

The converse is true for low angle cases where leaving the lower incisors proclined, in anticipation of a reduced post-surgical FMPA, will help to compensate for the progenia that tends to accompany forward mandibular growth rotation.

Transverse positioning

If there is a significant medio-lateral mandibular asymmetry, with a corresponding dental centreline displacement, then surgical correction will be achieved through asymmetric mandibular osteotomy, which will correct the centreline along with the chin point. This will allow the ideal planned occlusion to be achieved with the maxillary centreline in harmony with the middle of the face.

If the mandibular centreline is not coincident with the chin point and cannot be easily corrected orthodontically, the following two scenarios may occur:

1. If maxillary surgery only is planned, the upper centreline will finish off-centre, assuming that the planned occlusion has coincident centrelines.
2. If mandibular or bi-maxillary surgery is planned, it will be necessary to carry out asymmetric mandibular osteotomy to leave the upper and lower centrelines coincident. This will then result in the chin point being off-centre.

In the first case, one option is to compromise the planned occlusion by leaving the centrelines non-coincident. In the second case, the resulting mandibular asymmetry can potentially be addressed with a lateral sliding genioplasty (see Chapter 7).

3.3.3 Maxillo-mandibular complex rotation

The morphology of the mandible varies considerably between patients with extremes of vertical jaw growth, according to its direction of growth rotation (see Chapter 2). A shallow or steep mandibular plane often contributes to the poor aesthetics that short- and long-faced patients complain about and seek correction of. Whilst it is not always possible, or indeed necessary, to surgically correct the rotation of the jaws as part of orthognathic treatment, it should be considered in certain situations.

Clockwise rotation

In class II cases with reduced vertical dimensions, carrying out a mandibular advancement to a three-point landing will increase the lower anterior face height through downward and backward rotation of the mandible (Figure 3.6). There will also be a corresponding increase in the gonial angle and the mandibular plane will steepen to a certain extent (see also Case Report 1). In extreme cases, where correction of the angles of both the occlusal and mandibular planes together is required, it may be appropriate to carry out bi-maxillary osteotomy to rotate both jaws downward and backward (clockwise) (Figure 3.7b).

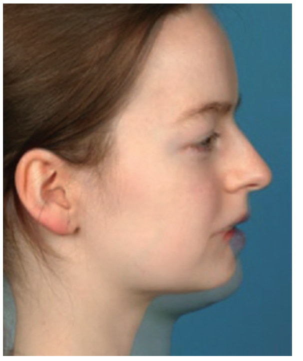


Figure 3.6 Superimposition of pre- and post-surgical profile photographs showing the increase in lower anterior face height achieved as a result of the 'three-point landing' approach to correcting a deep overbite in a class II patient.

Anti-clockwise rotation

In severe anterior open bite cases with an extreme backward rotation of the mandible, the mandibular plane will be steep and the ramus short, with an obtuse gonial angle. Closing the anterior open bite through posterior impaction of the maxilla alone will allow a certain amount of upward and forward (anti-clockwise) auto-rotation of the mandible, with a corresponding flattening of the mandibular plane. In cases where greater rotation is required, an option may be to increase the ramus heights through an 'inverted 'L' osteotomy or distraction osseogenesis, producing an anti-clockwise rotation of the mandibular and occlusal planes and a reduction of the gonial angle (Figure 3.7a). The risks of these procedures must be carefully evaluated against the anticipated benefits (see also Chapter 7).

3.3.4 Chin position

The final part of the provisional surgical plan is the positioning of the chin, which must be considered in all three planes of space (see also Chapter 7).

Adjusting chin prominence

Following correction of a sagittal jaw discrepancy there may be a need to adjust the antero-posterior position of the soft tissue chin point to achieve the best possible profile balance. Advancement genio-

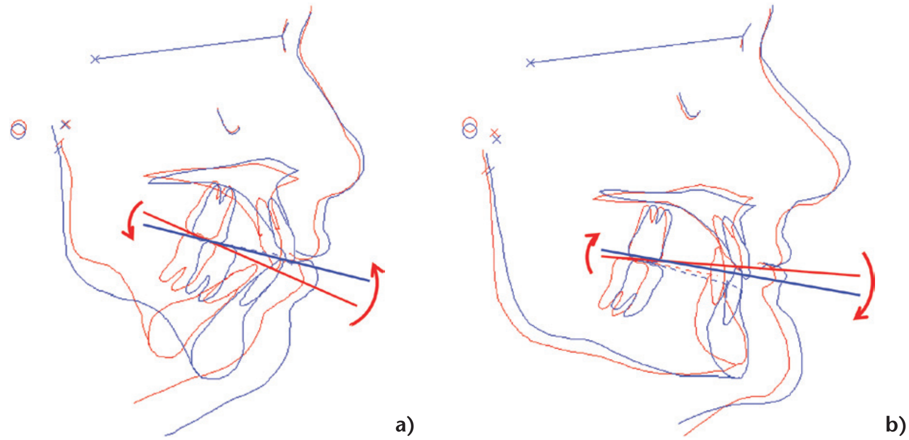


Figure 3.7 Superimpositions of pre-surgical (red) and post-surgical (blue) cephalometric tracings illustrating rotation of the maxillo-mandibular complex. **(a)** Anterior open bite case in which the mandibular and occlusal planes were rotated anti-clockwise with anterior maxillary impaction and inverted 'L' ramus lengthening. **(b)** Deep overbite case in which the occlusal and mandibular planes were rotated clockwise with bi-maxillary osteotomy. Produced using OPAL (British Orthodontic Society).

plasty is most often required to compensate for the backward slope of the mandibular symphysis, in cases where the mandibular plane angle will still be increased following surgery. Predicting the soft tissue movement that will be achieved through an advancement genioplasty is usually straightforward since there is a one-to-one ratio of hard-to-soft tissue movement at the level of pogonion (see Chapter 6).

A set-back genioplasty is potentially required where progenia is predicted after surgical jaw correction in low angle, deep bite cases. In isolation, it tends to result in a poor lower lip form (see below) and is not commonly performed by our team, but it may produce a satisfactory result when combined with a vertical augmentation. Correcting the mandibular plane angle in a short-face patient will also help to reduce post-surgical progenia by rotating the chin downwards and backwards (see Section 3.3.3).

Adjusting lower anterior face height

In cases where the lower anterior face height is predicted to be deficient or excessive following surgical jaw correction with Le Fort I osteotomy, there may be a need to carry out a vertical augmentation or reduction genioplasty to achieve the correct vertical facial proportions. This also normalises the lower lip length and the proportions of the lower anterior facial height.

Improving lower lip curvature

One of the aesthetic features that orthognathic treatment should aim to correct is the labio-mental fold, or lower lip curvature (see Figure 2.5). The post-surgical shape of the lower lip and the competence of the lips are closely linked to the inclination of the lower incisors, the lower anterior face height and the prominence of the mandibular symphysis. Normal lip curvature and competence should therefore result from placing the chin or the mandible in its correct antero-posterior and vertical positions, as described above. Carefully planned decompensation of the lower incisors will also improve the curvature or the lower lip and this should be considered when planning pre-surgical orthodontics.

Disguising mandibular asymmetry

In some cases, a mild medio-lateral mandibular asymmetry may have to be accepted as part of the surgical plan and may require disguising in order to optimise the overall aesthetic result (see Section 3.3.2). In such situations a sliding genioplasty can be planned to adjust the chin point in either direction. This is an easy manoeuvre to add if a genioplasty has already been planned to adjust the chin point in the antero-posterior or vertical dimensions.

3.4 Final surgical planning

For most patients, pre-surgical orthodontics will be required and this will be carried out according to the prescribed initial plan. When the orthodontic preparation is complete, the patient is seen again on the combined clinic for final surgical planning. At this stage, it is essential to reassess the patient's dento-

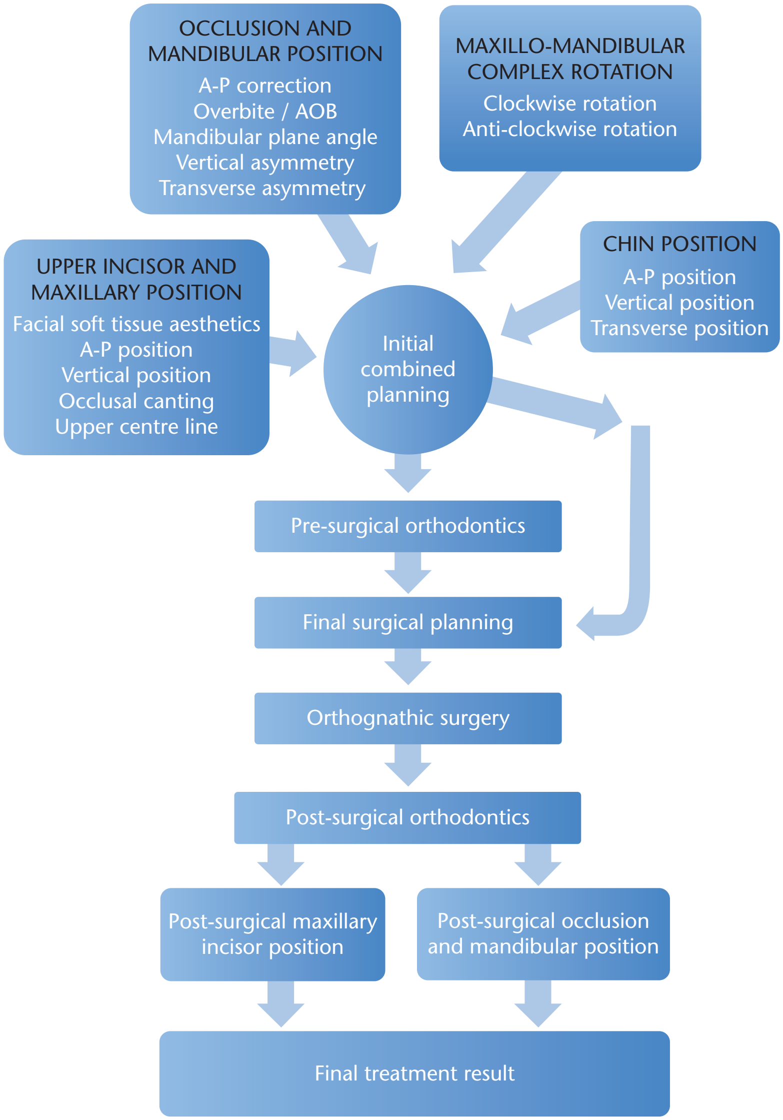


Figure 3.8 Flow diagram of the treatment planning process.

facial dysmorphology and ensure that their concerns are fully taken into account.

3.4.1 Final planning steps

The final planning steps are then as follows:

1. Envisage the soft tissue changes required for optimal facial aesthetics.
2. Plan the surgical movements required to:
   a. Produce the desired soft tissue changes.
   b. Place the teeth in the most aesthetic position.
   c. Achieve the optimal occlusion.

3.4.2 Photo-cephalometric prediction

Photo-cephalometric profile planning or if available, three-dimensional virtual planning, (see Chapter 6) is mandatory at this stage to:

- Assist with planning the magnitude of the jaw movements. This is particularly important where the patient is on the borderline between one- or two-jaw surgery and where the correct ratio of bi-maxillary jaw movements is difficult to envisage.
- Help decide whether or not a genioplasty is needed to improve profile balance.

- Provide the patient with a graphic depiction of the soft tissue changes that surgery is predicted to achieve.

3.4.3 Model surgery

The next stage is the technical planning, ideally carried out on an orthognathic articulator (see Chapter 5). It is essential that the model surgery and the photo-cephalometric prediction are well matched, to ensure that the planned surgical movements produce a harmonious profile in addition to achieving the planned occlusion.

In cases involving correction of facial asymmetries, three-dimensional hard tissue planning, based on a CBCT-derived model of the skull, is extremely useful and a technique for this is described in Chapter 5.

3.5 Summary (Figure 3.8)

- Combined surgical orthodontic treatment planning involves three fundamental steps:
  - Envisaging the desired dentofacial aesthetic changes.
  - Deciding on the jaw movements required to produce those aesthetic changes.
  - Planning the pre-surgical orthodontics such that correcting the occlusal disharmony will result in the required jaw movements.
- Execution of the treatment plan takes place in the reverse direction, with the pre-surgical orthodontic tooth movements determining the size of the surgical jaw correction, which then produces the soft tissue aesthetic changes.
- There are four key areas in dento-skeletal planning:
  - Upper incisor and maxillary position.
  - Occlusion and mandibular position.
  - Maxillo-mandibular complex rotation.
  - Chin position.
- Incisor decompensation should be planned to produce a target overjet that allows the desired size of antero-posterior jaw correction.
- The surgical plan can only be provisional at the initial planning stage because it is difficult to predict how accurately the orthodontist will be able to achieve the planned tooth positions.
- Final surgical planning can only be carried out once the pre-surgical orthodontics is complete and the final tooth positions are known.

3.6 Recommended further reading

Proffit W.R., White R.P. and Sarver D.M. (2002) *Contemporary Treatment of Dentofacial Deformity*. St. Louis, Mosby.

4 The role of orthodontics

Chapter overview

Intended learning outcomes

By the end of this chapter the reader should:
- Be aware of the indications for pre-surgical orthodontics in orthognathic patients.
- Understand the objectives of pre-surgical orthodontics.
- Be aware of the scope and limitations of pre-surgical orthodontics.
- Understand the role of orthodontic appliances in the peri-operative period.
- Be aware of the scope and limitations of orthodontics in the immediate post-operative healing phase.
- Understand the objectives of post-surgical orthodontics.
- Be aware of the advantages and disadvantages of carrying out surgery before orthodontics.
- Be aware of the possible indications for carrying out surgery without adjunctive orthodontics.
- Be aware of the common complications associated with orthodontic treatment in orthognathic patients.

4.1 Introduction

Orthodontic treatment is usually an integral part of contemporary orthognathic treatment. In most cases, the attainment of a satisfactory post-surgical occlusion will require the use of fixed appliances to achieve optimal arch coordination and inter-digitation. As explained in Chapter 3, the magnitude of surgical jaw correction that can be achieved is, to a large extent,

Handbook of Orthognathic Treatment: A team approach, First Edition. Ashraf Ayoub, Balvinder Khambay, Philip Benington, Lyndia Green, Khursheed Moos, and Fraser Walker.

dictated by the size of the overjet (positive or negative), which often needs to be adjusted through carefully planned incisor decompensation. It also stands to reason that the stability of the surgical jaw correction should be assisted by a well inter-digitated occlusion.

Whilst many patients seeking orthognathic surgery report concerns regarding their facial aesthetics, a large proportion are also unhappy with the appearance of their teeth. The ideal alignment that modern fixed appliance treatment can achieve helps to deliver optimal dental aesthetics as part of the overall treatment outcome.

It is logical to consider the role of orthodontics in three stages: before surgery (pre-surgical); just before and during surgery (peri-operative); and after surgery (post-surgical).

4.2 Pre-surgical orthodontics

The tooth movements required to prepare a patient for surgery should be carefully planned in all three planes of space, with reference to the patient in the clinic as well as appropriate diagnostic records. It is essential to carefully document the orthodontic plan in a way that can be readily referred to as treatment progresses.

4.2.1 Factors affecting incisor decompensation

Most orthognathic patients will have developed a degree of incisor compensation as a result of their disproportionate jaw growth (see Chapter 2). One of the main aims of pre-surgical orthodontics is to reverse these compensations. The tooth movements required vary with the type of malocclusion. In class II, division 1 cases the lower incisors typically need to be retracted from a proclined position, whilst in class III cases they need to be proclined. In the upper arch, the opposite movements will generally be needed. The notable exceptions to this are class II, division 2 malocclusions, where the upper incisors require proclination from their retroclined pre-treatment positions.

Complete decompensation of the incisors involves correction of their inclinations to their respective cephalometric norms, which is often appropriate. However, as stated in Chapter 3, there are also situations where partial decompensation is desirable and this must be agreed at the planning stage so that the orthodontist has clear goals. The main factors that influence incisor decompensation are as follows:

- Crowding and spacing of the teeth.
- Previous extractions.
- Soft tissue resistance.
- Magnitude of surgical jaw movements.
- Mandibular plane angle.
- Type of maxillary surgery.
- Quality of the planned occlusion.
- Limiting factors.

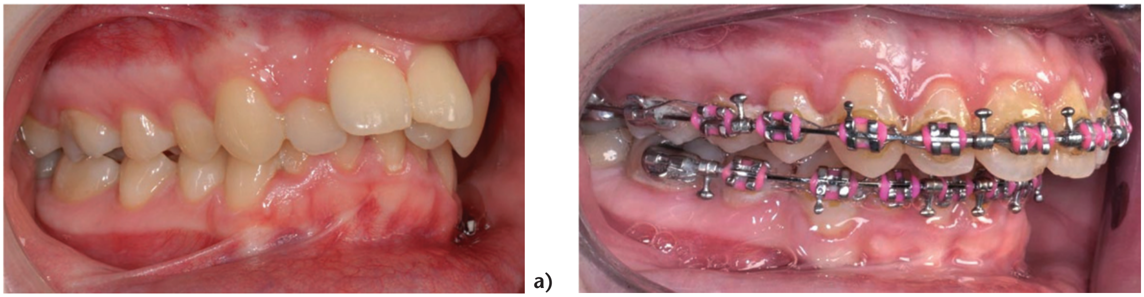
Crowding and spacing of the teeth

Space is required for incisor retraction and crowding assists proclination. Figure 4.1 illustrates how decompensation is largely facilitated by the presence of crowding, in a class III case where the lower incisors are retroclined. Conversely, in a class II case where the lower incisors are proclined and there is no spacing, extractions will be necessary to allow decompensation (Figure 4.2). For these reasons, the ideal amount of decompensation may not always be easy to achieve.


a)

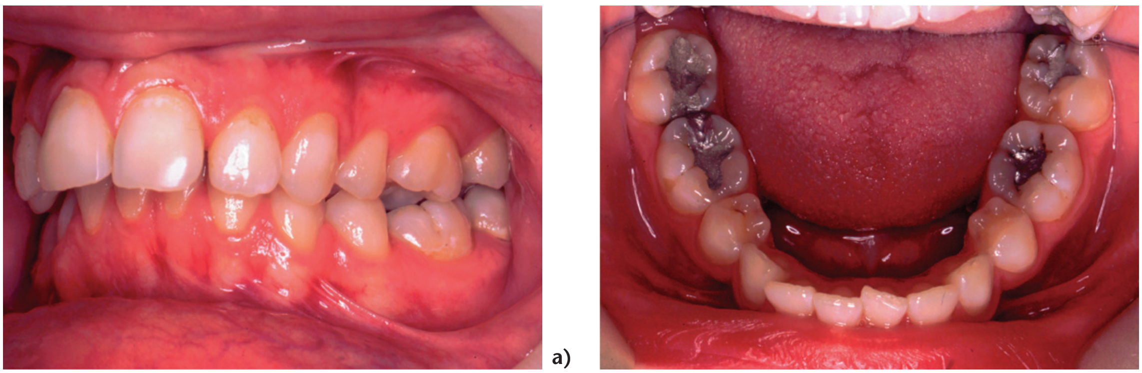

b)

Figure 4.1 Class III orthognathic typodont model showing: **(a)** Compensated and crowded lower incisors, and **(b)** the proclining (decompensating) effect of incisor alignment.



a) b)

Figure 4.2 Class II, division 1 patient. **(a)** The lower incisors are proclined and mildy crowded, with no space for retraction. **(b)** Pre-molar extractions have allowed lower incisor decompensation.



a) b)

Figure 4.3 Class II occlusion **(a)** with lower incisor compensation and previous loss of both lower first premolars and complete space closure **(b)**.

In class III cases the amount of lower incisor proclination that will be achieved as a result of crowding should be assessed. As a general rule, each millimetre of lower arch crowding will produce approximately 0.5mm of labial movement of the incisal edges, in the midline. Equally, in a class II case, where retraction of the lower incisors is required, each millimetre of space will allow 0.5mm of lingual movement.

Previous extractions

Previous extractions in either the upper or the lower dental arch can present a problem in the execution of decompensation. For example, in a class II case such as that shown in Figure 4.3, the lower incisors are proclined, but the patient has previously lost lower premolars as part of earlier fixed appliance treatment. Decompensation, through incisor retraction, will therefore be difficult, since further extractions are not an ideal option. Conversely, in the severe class III malocclusion shown in Figure 4.4, there has been previous loss of both lower first premolars and subsequent extreme retroclination of the lower labial segment. The spacing in the lower dental arch will make proclination of the incisors difficult without re-opening space for prosthetic tooth replacement.

Figure 4.4 Class III patient with severe lower incisor compensation and previous loss of both lower first premolars leaving residual spaces.

Soft tissue resistance

Teeth have to be moved within their soft tissue envelope and the lower lip and tongue may offer resistance to the proclination and retraction of incisors. This problem is likely to increase with the severity of the jaw discrepancy and, in class III cases, will also depend on the muscular tone of the lower lip. There are also the constraints of the alveolar bone which, in non-growing patients, is of limited adaptability. Careful anchorage management is required to ensure that the crowding or spacing in the lower arch translates into the planned amount of incisor movement.

Magnitude of surgical jaw movements

As explained in Chapter 3, one of the main functions of pre-surgical orthodontics is to create an overjet (class II patients), or reverse overjet (class III patients), that will allow the desired amount of surgical jaw correction. If it is not possible to adequately decompensate the incisors then the patient will be left with a residual jaw discrepancy after surgery. Equally, excessive decompensation will result in surgical overcorrection. Setting a 'target (reverse) overjet' is therefore helpful for the orthodontist and, if this is proving difficult to achieve, it is advisable to take the patient back to the planning clinic for a review of the treatment objectives.

Mandibular plane angle

In patients where the mandibular plane angle (to Frankfort Plane or horizontal reference plane) is predicted to be outside its normal range following surgery, consideration should be given to adjusting the lower incisor inclination, such that it will add with the mandibular plane angle to approximately 120° after surgery (see also Chapters 2 and 3 and Figure 3.5).

Type of maxillary surgery

Where the provisional surgical plan is to differentially impact or down graft the maxilla, there will be a corresponding change in the inclination of the upper incisors. For example, where posterior impaction is planned, the incisors will retrocline relative to the Frankfort Plane (or horizontal reference line). This should be compensated for by modifying the extraction pattern, or adding torque to the archwire (see also Chapter 3).

Quality of the planned occlusion

Incisor inclination directly affects the quality of the buccal segment occlusion that can be achieved in orthognathic patients, because proclined incisors occupy more space in the dental arch than upright or retroclined incisors. In class II cases, incomplete decompensation will tend to result in a class II molar relationship when the check models are hand occluded with the incisors in class I (Figure 4.5). In class III cases the opposite will tend to be true, although mild compensation of the incisors generally produces quite a pleasing occlusion.

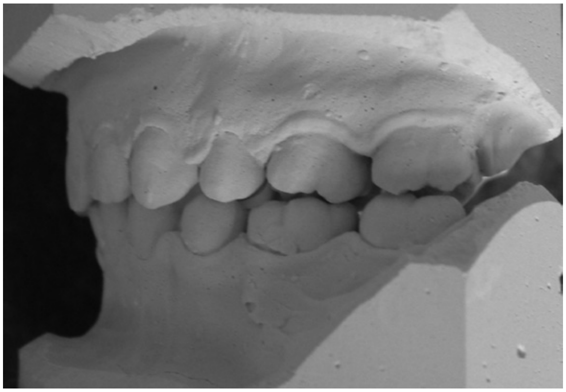


Figure 4.5 Class II case following mandibular advancement surgery, where the buccal segment occlusion is still class II, due to under-torquing of the upper incisors.

Whilst the correct torque and tip of the incisors are important in achieving an ideal occlusion, the orthodontist must also be aware of tooth-size discrepancies. Most commonly, disproportionately small upper lateral incisors can result in class II buccal segment relationships and a decision has to be made to either accept this compromised occlusion or leave space around the lateral incisor for build-up to the correct size.

Limiting factors

It is important to recognise the scope and limitations of incisor decompensation for each patient and these should inform the orthodontic planning process, as outlined in Chapter 3. Decompensation should not be planned simply to attain cephalometrically 'normal' incisor inclinations, which may not necessarily be appropriate, or achievable, for an individual patient.

4.2.2 Control of incisor decompensation

The inclination of the upper and lower incisors can be controlled orthodontically to help achieve the planned degree of decompensation, using the following methods:

- Extraction pattern.
- Bracket prescriptions.
- Mechanics.

Extraction pattern

Where compensation has resulted in significant incisor proclination, extractions will usually be required to retract them to the desired position. Typically, this will apply to lower incisors in class II cases and upper incisors in class III cases. As a general rule, the further forward the extractions are in the dental arch, the more incisor retraction will result. For example, extraction of first premolars will generally allow more decompensation than extraction of second premolars.

Bracket prescriptions

Pre-adjusted edgewise fixed appliances have first-order (in-out), second-order (tip) and third-order (torque) adjustments built into the individual brackets. The amount of 'torque' in the incisor brackets controls their inclination and therefore contributes to the delivery of decompensation during pre-surgical orthodontics. Different appliance prescriptions have different torque values for the upper and lower incisors and so may be more or less suitable as aids to decompensation.

The MBT™ prescription. One of the most common currently used prescriptions, MBT™, has negative torque in the lower incisor brackets and increased torque in the upper incisor brackets, which is aimed primarily at conserving anchorage in the orthodontic camouflage treatment of class II malocclusions. This prescription is advantageous in the pre-surgical preparation of class II cases, where retraction of lower incisors and the maintenance of a large overjet are required. However, in class III cases it will tend to be disadvantageous, limiting lower incisor proclination and maintaining upper incisor proclination.

Individual adaptations. Whilst some clinicians may opt for customised prescriptions to ensure that the brackets are working in sympathy with their treatment goals in all cases, it is possible to make certain adaptations that can help to overcome some of these problems. For example, the torque values of the lower incisor brackets can be changed from – 6° to + 6° by inverting them, which will help to procline the lower incisors in a class III case with minimal crowding (Figure 4.6). In addition, incisor inclinations can be adjusted by introducing third order bends into stainless steel rectangular archwires.

Mechanics

In addition to the effects of the extraction pattern and the appliance prescription, there are also a number of intra- and inter-arch mechanical techniques available to the orthodontist to control the incisor positions:

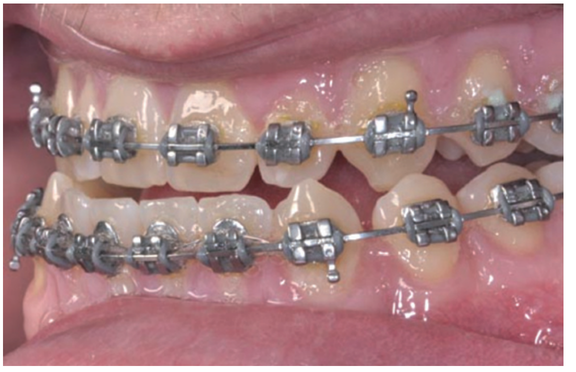


Figure 4.6 In this class III case with an absence of lower incisor crowding, the lower MBT™ incisor brackets have been inverted to convert 6° of lingual crown torque to 6° of labial crown torque to encourage incisor proclination.

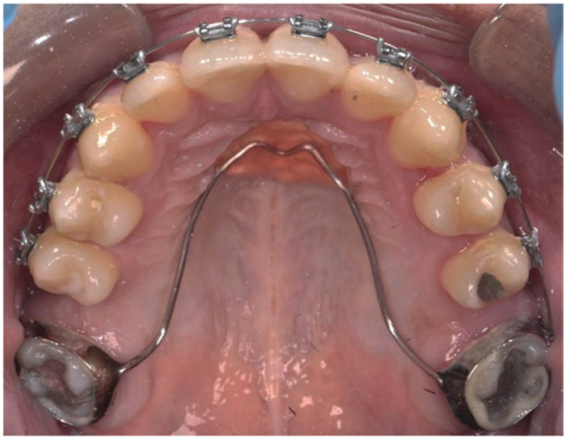


Figure 4.7 Example of a Nance palatal arch in a class III orthognathic patient requiring upper incisor retraction along with first molar extractions. Anchorage reinforcement of the second molars is acheived by a combination of maintaining inter-molar width and resisting tipping by engaging the anterior palatal vault with the acrylic button.

Intra-arch mechanics. Resistance of unwanted mesial movement of upper posterior teeth can be increased by using anchorage reinforcement devices, such as trans-palatal arches. They exert their effect by maintaining the inter-molar width and, in the case of the Nance arch, also engaging the mucosal surface of the anterior palatal vault (Figure 4.7).

Temporary Anchorage Devices (TADs) are mini screws that are placed in the alveolar bone to offer points of absolute anchorage from which to apply traction. They can provide direct or indirect anchorage for mesio-distal and vertical tooth movements, either by being placed buccally between the roots of the upper first molar and second premolar, or palatally to reinforce a trans-palatal arch (Figure 4.8).

Inter-arch mechanics. Inter-maxillary elastics can be used to apply traction between upper and lower fixed appliances. Wearing these requires good patient compliance but they allow at least small adjustments to the overjet, or reverse overjet, when the intra-arch methods of anchorage control have been exhausted. Figure 4.9 shows a class II case in which the occlusion on the first set of check models during pre-surgical orthodontics was not ideal, due to inadequate decompensation. The incisor inclinations were then adjusted, using class III elastics, producing an improved inter-digitation of the buccal segments.

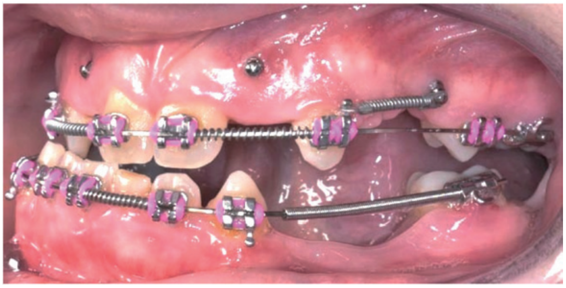
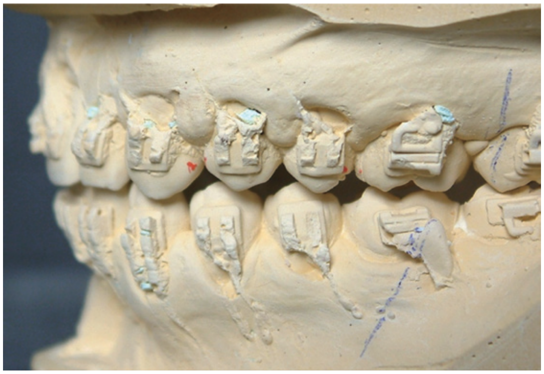


Figure 4.8 This orthognathic patient, who also has hypodontia, has a number of mini bone screws or Temporary Anchorage Devices (TADs) inserted in strategic positions to provide absolute anchorage for tooth movements that might otherwise be difficult to acheive. (Courtesy of Dr Lucy Chung.)

4.2.3 Vertical tooth movements

Patients with extreme vertical jaw disproportions will usually have developed accentuated curves of Spee. In anterior open bite cases this will tend to affect the upper arch, whilst in deep bite cases it tends to affect the lower arch (see Chapter 2). One of the treatment objectives for orthognathic patients should be to level the dental arches for an optimal occlusion. In planning pre-surgical orthodontics, the following factors must be taken into account:



a)

b)

c)

Figure 4.9 **(a)** These check models, taken for a class II patient during pre-surgical orthodontics, revealed that the buccal segment occlusion would be class II, due to incomplete incisor decompensation. **(b)** Inter-maxillary traction with class III elastics, aimed at retroclining the lower incisors and proclining the uppers enabled class I buccal segments to be achieved in the final result **(c)**.

Limitations of orthodontic mechanics

There is a limit to the amount of levelling that orthodontic appliances can achieve through tooth movement alone, particularly in a non-growing patient, and attempting orthodontic levelling of extreme curves is unlikely to be successful. In the lower arch this may be partly due to the fact that deep overbite cases tend to be accompanied by heavy bite forces, which resist the molar extrusion that normally contributes to overbite reduction.

Where pre-surgical levelling of the lower arch is required (see also 'Lower anterior face height' below) the use of utility arch wires, which bypass the premolars to apply an intrusive force to the incisors using molar tip-back bends, may be effective during the early stages of treatment. When continuous arch mechanics are required, modern reverse-curve nickel-titanium arch wires can be useful in maintaining a prolonged levelling force along the length of the arch.

Stability

In anterior open bite cases with a significant curve in the upper arch, orthodontic levelling will involve extrusion of the incisors to some extent and there is a risk that this may relapse after surgery. In such cases, the alternatives to pre-surgical levelling are two-fold:

1. Leave the curve unchanged during the pre-surgical phase and then create posterior open bites through posterior surgical impaction of the maxilla. These open bites must then be closed post-surgically by orthodontic extrusion of the molars.
2. Align the anterior and posterior segments at different levels using sectional orthodontic mechanics, and then level the arch through segmental surgery (Figure 4.10).

Figure 4.10 This patient is planned for segmental maxillary surgery to level the severe curve of Spee. The stepped archwire is aimed at preventing orthodontic extrusion of the upper anterior teeth.

The factors involved in deciding which technique to employ include the following:

- **The curve of Spee:** If this is severe, the amount of posterior impaction of the maxilla required to close the anterior open bite may be surgically unachievable without resorting to a segmental approach, particularly in cases where no down graft of the anterior maxilla is required. Also, orthodontic closure of the large posterior open bites after surgery may be difficult.
- **The risks associated with segmental surgery:** Loss of periodontal bone support and gingival attachment adjacent to the osteotomy cuts can occur, with consequences for both dental health and aesthetics. Occasionally, bone necrosis can result from loss of the blood supply to one of the segments. Because of these risks, some surgeons may be reluctant to carry out segmental surgery and will ask their orthodontist to deal with as much of the arch levelling as possible, either before or after surgery.

Lower anterior face height

In patients with a deep overbite and accentuated curve of Spee, there are a number of ways of dealing with the lower arch, depending on the change required to the lower anterior face height and the preferred approach of the clinicians:

1. Maintaining the curve of Spee, so as to leave the vertical position of the lower incisors unchanged throughout pre-surgical orthodontic treatment. When placing stainless steel archwires it is necessary to bend the curve into the wire in order to avoid unwanted levelling. A downward movement of the lower incisal edges and a corresponding increase in lower anterior face height will then accompany surgical advancement of the mandible. The surgery will create lateral open bites with contact limited to the incisors and the terminal molars (Figure 4.11). This is commonly known as a 'three-point landing' and post-surgical orthodontics is then required to close the open bites (see below).
2. Orthodontically level the curve of Spee as fully as possible prior to surgery. Theoretically, the disadvantages of this approach are that the lower incisors will be intruded to some extent during the levelling process. This, in turn, may limit the increase in lower anterior face height that is achieved through surgery. Also, the duration of pre-surgical orthodontics may be increased because of the additional time that arch levelling requires, particularly in the presence of a deep overbite.

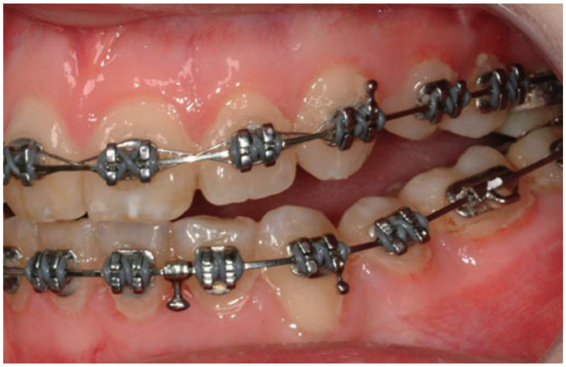


Figure 4.11 Class II case in which the lower curve of Spee has been maintained throughout pre-surgical orthodontics to produce a 'three-point landing' following surgery, with the aim of increasing the lower anterior face height.

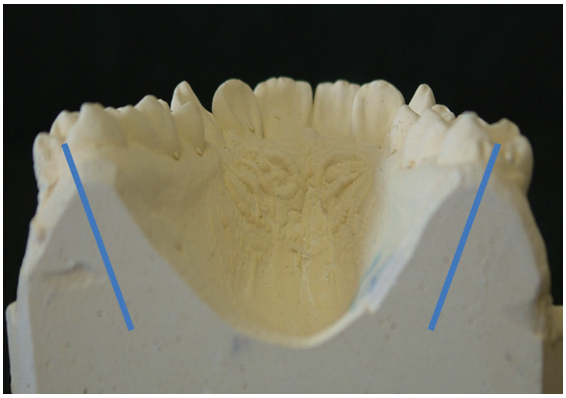


Figure 4.12 Cross-section of an upper study cast. The blue lines illustrate the long axes of the roots and the presence of buccal flaring.

3. Use sectional mechanics to level the anterior and posterior teeth separately and then surgically level the arch using a segmental approach. This will involve an anterior mandibular osteotomy to set down the lower incisors (see Chapter 7). If a sub-apical procedure is used, the mandibular advancement surgery will produce little or no increase in lower anterior face height. If a body osteotomy is planned, then this will drop the chin level at the same time as levelling the curve.

It is important to select the approach that is most likely to achieve the desired effect on lower anterior face height, whilst also keeping surgery as simple as possible and orthodontic treatment duration to a minimum.

4.2.4 Transverse tooth movements

Arch width discrepancies

Patients with antero-posterior and vertical jaw disproportions will often have developed accompanying transverse dental arch discrepancies; the most common problem being a relatively narrow upper arch. This may be a reflection of a genuinely narrow maxilla, most commonly in class III malocclusions, or may be secondary to a class II jaw discrepancy, where the wider posterior maxillary arch occludes with a narrow more anterior portion of the mandibular arch (see Chapter 2).

In planning pre-surgical orthodontics it is important to assess the extent of any transverse problem by hand-articulating the study casts in the anticipated post-surgical class I occlusion. This gives a measure of the amount of change in inter-molar width that would be required to produce ideal arch coordination. It may be that some alteration in the width of the lower arch will also be required, usually in the form of contraction in class III cases. However, in class II, division 2 cases the lower arch may be constricted and a degree of pre-surgical expansion will be indicated. The factors of relevance in the management of transverse arch discrepancies are as follows:

Occlusion. In some class III cases, where there is a well established bilateral buccal segment cross-bite, it may be very difficult to carry out significant expansion of the maxillary arch before surgery due to the locked buccal segment occlusion, even though the amount of expansion required is within the scope of orthodontic tooth movement. In such cases, it can be easier to deal with the expansion post-surgically, when the correction of the class III discrepancy will have removed the occlusal interference.

Limitations of orthodontic mechanics. Orthodontic expansion, using a quad-helix appliance (or equivalent) or stainless steel archwires, is achieved mainly by tipping the teeth within the alveolar processes and is usually limited to a few millimetres between the molar cusps. If there is a significant transverse skeletal discrepancy it is unlikely that orthodontic expansion alone will be adequate to produce satisfactory arch coordination. However, the limit of orthodontic expansion for an individual patient will depend on a number of factors, including the degree of transverse compensation present in the upper buccal segments. Where the molars are upright over basal bone, considerable expansion will be possible, but if significant compensation is present, further attempted expansion will produce excessive flaring of the molars (Figure 4.12). In such cases, the molar palatal cusps will tend to swing downwards

Figure 4.13 Capped design of RME appliance with silver alloy base, cemented onto the surface of the teeth with glass ionomer. The expansion screw has been fully opened.

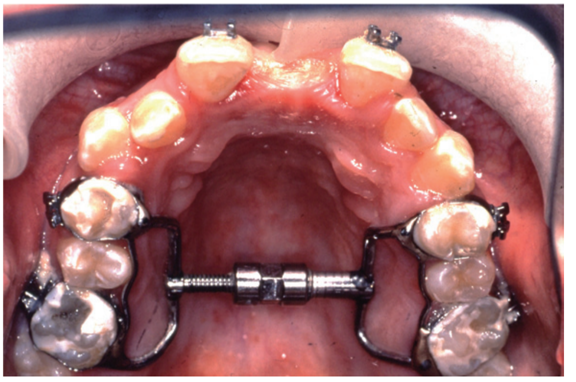


Figure 4.14 Surgically assisted RME (SARME) carried out using a banded design of appliance. Note the dramatic expansion acheived. (Courtesy of Dr David Morris.)

and cause occlusal interference, and the expansion is likely to be unstable.

Where the transverse disproportion is severe, correction will be beyond the scope of simple orthodontic tooth movement alone. An alternative method of expansion may need to be considered, or the post-surgical cross-bites accepted. If greater expansion of the maxillary arch is desirable, then the various techniques available must be carefully considered, taking into account their risks and potential benefits.

Rapid maxillary expansion (RME). Rapid Maxillary Expansion (non-surgically assisted) is delivered using a capped or banded appliance containing an expansion screw (Figure 4.13), which the patient turns each day over a period of a few weeks, with the aim of separating the mid-palatal suture. Orthognathic patients have usually completed their facial growth and are therefore at least in their mid to late teens. Conventionally, RME is recommended only in patients up until the age of approximately 16 years of age because the palatal sutures become less amenable to separation beyond this age. However, the literature does contain reports of RME in adults, albeit with a tendency to an increase in complications, such as buccal gingival recession.

Whatever the patient's age, it is essential that the key signs of successful palatal separation are observed early in the expansion process, that is, low resistance to expansion and the appearance of a midline diastema, as well as separation of the midline suture on an occlusal radiograph, if one is routinely taken. The prominence of the upper buccal segment roots in the alveolar bone and the gingival attachment levels should be closely monitored.

The possible benefits of RME are:

1. A greater amount of maxillary arch expansion in comparison to orthodontic archwires or quad-helix, due to the skeletal effect of widening the midline suture.
2. Less buccal tipping of the molars because the expansion occurs more at a skeletal level.
3. Greater stability, as a result of bony infill of the expanded mid-palatal suture.

The evidence for these benefits is equivocal and the effects of RME, at a skeletal level, have been shown to be variable and unpredictable, even in young patients. However, it remains a straightforward and relatively non-invasive technique for correcting transverse maxillary deficiencies that are slightly beyond the capability of conventional orthodontic appliances.

Surgically Assisted Rapid Maxillary Expansion (SARME). Some patients have a severe transverse deficiency of the maxilla that requires correction, but is beyond the scope of conventional RME, or the patient is not suitable for it. In such cases, there are two possible options:

1. Surgical widening of the maxilla as part of a single procedure (see Chapter 7).
2. SARME. This involves surgically dividing the mid-palatal suture and the pterygo-maxillary sutures, as well as making cuts in the lateral walls of the maxillary sinuses, to remove as much of the bony resistance to maxillary expansion as possible. A palatal expansion appliance is then used in a similar way to conventional RME (Figure 4.14). If the appliance is placed at the time of surgery, it can be a bone-borne design, engaging the palatal vault for more direct force application. The theory

is that widening of the maxilla will occur by distraction osteo-genesis, allowing greater expansion and improving stability.

There are potential advantages and disadvantages of both techniques and the evidence in support of greater stability for SARME is limited. The major drawback of SARME is undoubtedly the need for an additional surgical intervention under general anaesthetic, in advance of the main orthognathic procedure.

Surgical expansion of the maxilla. Where surgical maxillary widening is to be carried out, pre-surgical orthodontics should ideally aim to decompensate the upper buccal segments by tipping them palatally, or at least avoid any further buccal flaring of the teeth, which might lead to unfavourable dental relapse following surgery.

Dental centreline discrepancies

Any displacement of the dental centrelines should ideally be corrected orthodontically prior to surgery. However, this may be difficult in some cases where the necessary tooth movements would require extraction(s), which are otherwise unhelpful in achieving the primary treatment goal of incisor decompensation. For example, in a class III case, carrying out a unilateral lower arch extraction to correct the lower centreline may lead to excessive retraction of the incisors and a reduction in the reverse overjet. It is therefore important to ensure that any limitations of orthodontic centreline correction are accounted for in the surgical plan (see also Chapter 3).

4.2.5 Orthodontic preparation for segmental surgery

Where segmental surgery is planned, the orthodontist can play an important role in reducing the risks of iatrogenic damage in the following ways:

Mid-palatal split

Where mid-palatal widening is required it is advisable to create a small midline diastema to ease access for the surgeon's osteotome. The roots of the central incisors will also have to be adequately diverged, although this should happen as a result of the mesial crown tip built into the pre-adjusted edgewise brackets.

Two-part maxilla and sub-apical osteotomies

Surgical cuts aimed at segmentally levelling the dental arch will most commonly be sited distal to the canines. Adequate separation and divergence of the roots on either side of the cuts is important and swapping the left and right canine brackets can assist with this, converting distal to mesial root tip (see Figure 9.5.2). Extraction of a premolar can be helpful to avoid excessive proclination of the incisors and improve surgical access.

4.2.6 Progress monitoring

It is essential that progress towards achieving arch coordination is monitored throughout the course of pre-surgical orthodontic treatment. The conventional method of doing this is to take impressions for check models that can be hand-articulated. In this way, the occlusal fit can readily be assessed, including any problems with tooth positioning and occlusal interference. Check models should ideally first be taken following initial alignment, so that subsequent tooth adjustments can be planned in all three planes, and then repeated again in rectangular wires until it is felt that the aims of treatment have been accomplished. An up-to-date set of models should be available to take to the final planning appointment. In addition to the occlusal goals, the inter-molar and inter-canine width in the lower arch should be monitored to ensure that the planned arch dimensions are being achieved.

In cases where sectional orthodontic alignment is being carried out prior to segmental surgery, the check models will need to be sectioned to simulate the surgical cuts, as well as any extractions planned in theatre, to allow them to be articulated in the correct occlusion. Intra-oral radiographs are also helpful in assessing the proximity of the roots on either side of the planned cuts.

It is also essential to monitor progress towards the target overjet, or reverse overjet, which should have been set as part of the pre-surgical orthodontic plan.

4.3 Peri-operative orthodontics

4.3.1 Fixed appliance preparation for surgery

Once the aims of pre-surgical orthodontics have been achieved and upper and lower rectangular stainless steel archwires are in place (typically 0.019′ × 0.025′), it is important to ensure that the teeth are prevented from moving between final planning and surgery. This is particularly important for the technologist, who relies on the teeth being in a static position for the accuracy of the model surgery and the fit of the occlusal wafer(s). It is advisable to under-tie the brackets in both arches to prevent any spaces from re-opening, and ensure that the archwires are passive for at least six weeks, prior to the final planning appointment.

Before the patient undergoes surgery, their appliances should be checked for breakages and repaired as required. It is also important to ensure that the distal most attachments are secured to the archwire to avoid the risk of them being lost into the surgical sites. The routine use of bands, rather than bonds, on terminal molars is advisable in this regard. If bonded tubes are used, the archwire should be cinched back behind them or they should be secured in some way to the rest of the brackets.

4.3.2 Inter-maxillary fixation

For most patients, fixed orthodontic appliances provide the means of applying inter-maxillary fixation (IMF) in theatre. This is required once for single jaw osteotomy and twice for bi-maxillary osteotomy, when an intermediate wafer is used to locate the maxilla into its new position relative to the mandible. There are two common methods of attaching the elastics or wires to the fixed appliances in theatre:

1. Orthodontic brackets with integral traction hooks.
2. Hooks attached to the archwire, either by crimping or soldering.

Brackets with integral hooks avoid the need to place any attachments on the archwire prior to surgery, saving chair-side time. However, such brackets may impair oral hygiene during orthodontic treatment and some clinicians argue that they risk overloading the periodontal ligaments by delivering the potentially heavy forces of the IMF directly to the teeth, rather than to the more flexible archwire that runs between them. The authors' routine practice is to place crimpable hooks on the archwires.

In patients who go to theatre without orthodontic appliances in place, some other form of attachment is needed on the teeth to facilitate IMF. Conventional arch bars, ideally made in the laboratory, can be attached using inter-dental ligature wires and are very secure (Figure 4.15), but they have a number of associated problems:

1. They must be applied in theatre because of the need for ligature wires.
2. Ligature wires carry a risk of sharps injury.
3. Post-operative removal can be uncomfortable for the patient.
4. They can cause trauma to the periodontal tissues.

An alternative solution is to use bondable arch bars (Figure 4.21c), which largely eliminate these problems, provided that there are teeth of sufficient number and quality to support them. The authors have used Bauermash® bondable arch bars for several years and have found them to be an effective substitute for conventional arch bars in selected cases. Whilst bond failures in theatre sometimes occur, the surgeon still has the option of using ligature wires if necessary. If the patient has multiple porcelain restorations that make bonding difficult, it is often advisable to use conventional arch bars.

Figure 4.15 An example of conventional, pre-fabricated arch bars, placed using trans-dental wire ligatures in theatre.

4.3.3 The occlusal wafer

Delivering the planned occlusion

At the time of surgery, the new occlusion is dictated by the final occlusal wafer and should exactly reflect the occlusion agreed upon from the final check models. In cases where good arch co-ordination and inter-digitation have been achieved, the desired occlusion should be obvious to the technologist. However, in cases where it is less obvious, simply leaving the technologist to select the 'best fit' of the teeth might result in an erroneous wafer. It is therefore essential that the surgeon, orthodontist and technologist agree together on the occlusion they want, prior to the fabrication of the wafer. It is personal preference how this is done, but the final check models must be transferred to the laboratory either clearly marked, or located with some sort of bite register, in the correct occlusion (see Chapter 5).

Having prescribed the correct occlusion to the technologist, it is then essential that the clinical team check that this has been accurately reproduced by the model surgery on the articulator. If this protocol is not diligently adhered to for every patient, it is inevitable that some wafers will have to be remade, wasting time and resources, and causing needless stress for all concerned.

Patient and clinician acceptability

Surgical occlusal wafers are usually necessary in theatre to ensure that the correct surgical and occlusal goals are achieved, but there is divided opinion regarding the need for the final wafer to be left in situ post-operatively. It is the preference of the authors to routinely leave the wafer in place for the first week after surgery, but the choice of each team comes down to personal preference. The following factors are involved in the decision:

- It can be argued that once the final wafer has served to correctly locate the mandible relative to the maxilla in theatre, it is no longer required and can be discarded. However, some clinicians may find it reassuring to retain the wafer until at least the first post-operative review on the combined clinic so that they can see that the teeth are biting into the planned occlusion.
- Patients commonly report that they find their wafer uncomfortable and inconvenient post-operatively. Oral hygiene is certainly impaired and they are bulky to tolerate whilst recovering from jaw surgery, when eating and drinking are already challenging enough.
- Where surgical widening of the maxilla has been carried out, this will have to be retained during the immediate post-operative period. Leaving the wafer in situ is one way of achieving this.

Where the preference is to retain the wafer post-operatively, the patient must be informed that the device will be in place when they wake up and they should be given careful oral hygiene instruction.

Final wafers are conventionally retained in the mouth using wire ligatures, which pass through holes in the acrylic and around the orthodontic appliance. The disadvantages of this design for the patient are that the wafer is difficult and uncomfortable to remove at the post-surgical review appointment. A removable wafer that eliminates the use of wires is therefore advantageous and a design routinely used by the authors is shown in Figure 4.16. This saves time in theatre, reduces the risk of sharps injury peri- and post-operatively and allows easy removal and re-insertion as required.

Figure 4.16 A removable design of final surgical wafer, which is retained using elastomeric chain between the hooks on the archwire and three ball-ended clasps embedded in the acrylic.

Figure 4.17 An e-arch in place following surgery to retain expansion of the maxillary arch. The arch is made in 1mm hard stainless steel wire and is inserted into the head gear tubes on the first molars bands.

4.3.4 Orthodontic procedures in theatre

Whilst the orthodontist is seldom required in theatre, there are certain situations in which an appliance will have to be adjusted or fitted during surgery. For example, in patients undergoing certain segmental procedures, it may be possible to replace the sectional archwires, which have been in place throughout pre-surgical orthodontics, with a continuous archwire. The benefit of this is that the patient wakes up with a full thickness rectangular archwire in place, which eliminates the need to carry out post-operative realignment across the osteotomy sites. However, even in the absence of a continuous archwire, the final wafer can adequately locate the segments and bracket alignment across the surgical sites may not always be good enough to accept a continuous archwire. The approach adopted is largely down to the personal preferences of the clinicians involved.

Where surgical widening of the maxilla has been carried out, it may be beneficial for the orthodontist to fit an ‘e-arch’ in theatre to assist retention (Figure 4.17). This reduces reliance on the wafer as an expansion-retaining device and may allow it to be discarded earlier after surgery.

4.4 Post-surgical orthodontics

The role of orthodontics following jaw surgery is to achieve the final pre-planned occlusal and dental aesthetic result for the patient. Providing the surgical plan has been followed, this stage should be relatively short compared to the pre-treatment phase and is carried out in three distinct phases:
- Post-surgical healing phase.
- Post-surgical tooth movement.
- Retention.

4.4.1 Post-surgical healing phase

In the immediate post-operative period, patients are in a certain amount of discomfort and intra-oral access will be limited for at least a few weeks, particularly for those having undergone mandibular osteotomy. Post-surgical reviews should take place on the combined clinic so that any complications, such as trismus or early post-operative wound infection, can be dealt with by the surgeon. During this time, oral hygiene measures are particularly important and the services of a hygienist are invaluable.

Following surgery, the bony segments will hopefully be located in their planned positions and large occlusal discrepancies should be uncommon. However, in rare cases, where there is significant error in the jaw position(s), the patient may have to be taken back to theatre within the first week or two, for a revision of the osteotomy.

Checking the occlusion

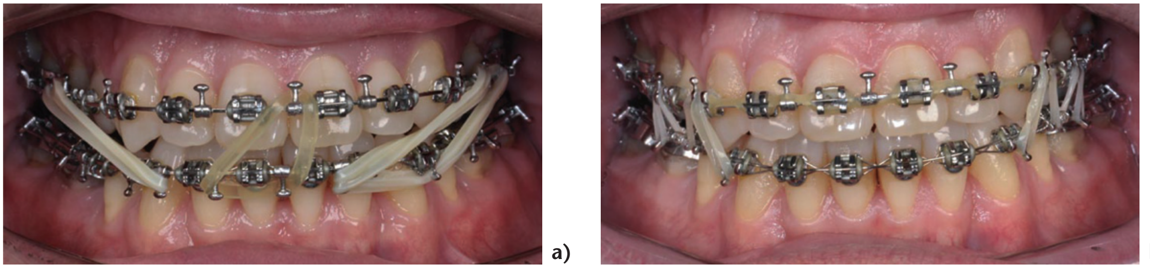
When the patient is reviewed one week post-surgery, heavy inter-maxillary guiding elastics will typically be in place, aimed at holding the teeth in the planned occlusion. At this visit, the elastics should be removed and the quality of the occlusion checked. If the wafer is still in place then the lower teeth should be biting fully into it without any sign of mandibular displacement. If a removable wafer has been used then the occlusion should be checked with it out of the mouth. Where the occlusion appears to be accurate, no active adjustment of the jaw position(s) is required but it is usually advisable to place medium weight inter-maxillary elastics that support the jaw correction (i.e. class II elastics for mandibular advancement) until initial healing is complete.

Semi-rigid fixation

The screws or plates used in contemporary orthognathic surgery provide only semi-rigid fixation and there is a degree of malleability in the surgical sites during the first six weeks or so post-operatively. This has two implications. Firstly, the surgical movements may be prone to early relapse under the influence of the altered soft tissue environment. Secondly, it is usually possible to manipulate the jaw positions to a certain extent by applying traction to the orthodontic appliances. Minor occlusal discrepancies are relatively common and the immediate post-operative period is a critical time during which close follow-up on the combined clinic is essential in order to achieve an optimal result.

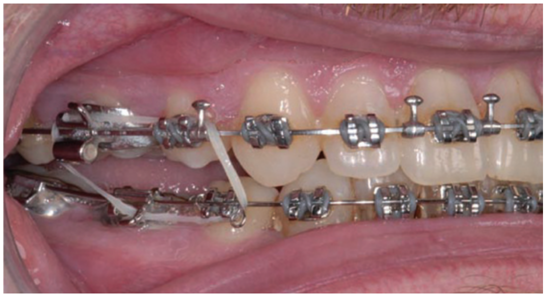
Applying traction

In these cases it is important to start appropriately directed and weighted elastic traction as early as possible to try to recover the planned occlusion (Figure 4.18). Protraction head-gear can also be useful in helping to recover the maxillary position following large advancements in severe class III cases. If early adjustment of the jaw position(s) is required then the patient may need several review appointments until the planned occlusion is achieved and appears to be stable. Heavy elastics will be required during the first few weeks to achieve the desired adjustments, with the weight reducing once the correct occlusion has been achieved. If, after approximately six weeks, the occlusion is still not correct it is unlikely that it can be improved further at a skeletal level using elastic traction.



a) b)

Figure 4.18 **(a)** Example of asymmetric inter-maxillary elastics aimed at correcting a centreline discrepancy in the immediate post-operative period. **(b)** The corrected occlusion three weeks later.



a)

b)

Figure 4.19 **(a)** Lateral open bites in a class II 'three-point landing' case, post-surgery. **(b)** The lateral open bites have been closed through combination vertical elastic traction and repositioning of attachments.

4.4.2 Post-surgical tooth movement

By the time the initial healing stage is over, it should be possible to gain sufficient intra-oral access to carry out any necessary post-surgical orthodontic tooth movement. In the majority of cases, where there are already fixed appliances in place, the surgical archwires should be removed and any breakages repaired. In cases where post-surgical orthodontics only is planned, the appliances should be placed at this stage. It is convenient to consider the post-surgical tooth movements required in all three planes of space.

Antero-posterior

Although the planned amount of incisor decompensation is usually achieved before surgery, there are cases where this can be hampered by the unfavourable pre-surgical soft tissue environment, particularly in very severe malocclusions. After surgery, this should be greatly improved and it may be possible to achieve further tooth movement in the desired direction.

Any residual space closure within the dental arches is also carried out at this time, but care must be taken to manage the anchorage balance such that the incisors and molars finish up in the correct occlusion. This may, once again, require the use of inter-maxillary elastics, but with lighter forces aimed at assisting tooth movement rather than producing skeletal change.

Vertical

As mentioned previously, where a curve of Spee is maintained throughout pre-surgical orthodontics, there will be a need to level this after surgery. Where an anterior open bite has been closed by posterior maxillary impaction, there will be bilateral posterior open bites resulting from the upper arch curve and extrusion of the upper posterior teeth will be required. In the case of a three-point landing, the lower arch curve will have resulted in lateral open bites and extrusion of the posterior teeth will be required to close these (Figure 4.19). Whilst these tooth movements are usually achievable, they can sometimes be difficult, particularly in the more severe cases and a high level of patient compliance is often required with the wear of elastics.

Transverse

Active expansion of the maxillary or mandibular dental arch may be required after surgery, where it has not been possible to achieve this beforehand due to occlusal locking. The tooth movements required will usually be only a few millimetres and should be achievable using archwires. Once good arch coordination has been established, stability should be promoted by the inter-cuspation of the teeth as well as the improved soft tissue environment, brought about by the surgical jaw correction.

4.4.3 Retention

All orthognathic patients that have had adjunctive orthodontic treatment require their dental alignment and arch dimensions to be retained following appliance removal. Whilst the surgical jaw correction may have brought about the most significant change, many patients are nevertheless still focused on the appearance of their teeth and may be disappointed if dental relapse occurs. Simple pressure-formed retainers are usually adequate, but where surgical maxillary expansion has been carried out a more rigid design may be required. As with all orthodontic patients, the length of time for which retainers will need to worn is difficult to predict and contemporary thinking is to encourage wear for as long as ideal alignment is desired. Where appropriate, bonded retainer wires allow reduced reliance on removable retainers to maintain incisor alignment. However, it must be remembered that they do not maintain transverse arch dimensions particularly well and patients that have had significant maxillary expansion carried out should be aware that they may always have to wear some form of upper arch retainer.

4.5 Surgery before orthodontics

Although a large proportion of orthognathic patients will undergo both pre- and post-surgical orthodontics, there are some patients for whom carrying out the surgery first and the orthodontics afterwards is an option. It is important that a reasonable occlusion can be achieved through surgery alone but, assuming this is the case, there are a number of advantages and disadvantages to be considered.

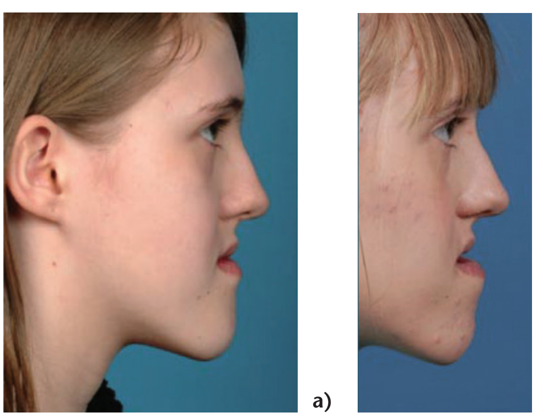
4.5.1 Advantages

Facial aesthetics

In many cases, pre-surgical orthodontics has the significant drawback that it makes the patient look worse than before they started treatment. This is particularly true for class III patients, where decompensating the incisors accentuates the jaw discrepancy (Figure 4.20). Whilst some patients may be more concerned by this than others, carrying out the surgical jaw correction first has the advantage of eliminating this phase and instead delivering the major improvement in facial appearance at the start of treatment.

Resistance to tooth movement

As previously mentioned, decompensating incisors prior to surgery often involves moving them against the resistance of the lips and tongue. Correcting the jaw discrepancy prior to decompensation reduces this resistance by normalising the soft tissue environment of the teeth.



a) b)

Figure 4.20 A class III patient **(a)** before and **(b)** after pre-surgical orthodontics, showing the detrimental effect on the profile of lower incisor decompensation.

Treatment duration

By limiting orthodontic treatment to the post-surgical phase, the overall length of treatment should be reduced, although of course patients suitable for this approach are likely to be those requiring fairly straightforward orthodontic alignment. This is clearly more convenient for the patient and reduces the risks of appliance-induced iatrogenic damage. For the patient illustrated in Figure 4.21, fixed appliances were in place for only 10 months, as opposed to possibly 18–20 months, had she been treated conventionally.

4.5.2 Disadvantages

Planning the occlusion

A key disadvantage of leaving orthodontic treatment until after surgery is that the occlusion produced must allow for any desired post-surgical adjustment of the incisor inclinations. The final wafer position must therefore be carefully judged to allow the post-surgical orthodontics to achieve as close to an ideal occlusal result as possible. This is not always straightforward since the precise way in which the incisors and molars will move within the dental arches after surgery can be difficult to predict and the orthodontist will often have to rely on good patient compliance with inter-maxillary elastics to control anchorage.

Patient commitment

One of the benefits of pre-surgical orthodontics is that the patient has several months over which to think about the prospect of jaw surgery and in some cases they may change their mind and opt for a compromised result involving orthodontics alone. Where this phase is eliminated the patient may not always have an adequate chance to adjust to the idea of surgery and have second thoughts much closer to the operation date, causing stress and inconvenience for all concerned.

This, of course, also applies to patients who have surgery alone without any orthodontics. The informed consent process is therefore particularly important for patients going straight to surgery and a ‘cooling off’ period is to be encouraged, where the patient is given some additional time to digest the information given to them and ask further questions. Having the input of a psychologist at key stages

Figure 4.21 **(a, b)** Class III patient with mid-face deficiency and mandibular prognathism. **(c)** Bi-maxillary osteotomy (maxillary advancement, malar augmentation and mandibular setback) was carried out first. Because no fixed appliances were in place during surgery, Bauermash® bondable arch bars were used for IMF and for running guiding elastics in the immediate post-surgical period. **(d)** Following initial healing, upper and lower fixed appliances were placed, with the aid of class III elastics to control the incisor relationship. **(e, f)** Satisfactory occlusion and facial aesthetics were achieved.

throughout the patient journey is invaluable in this regard.

Similarly, patients who are primarily focused on the change in facial appearance that surgery will deliver for them may agree to post-surgical orthodontics at the planning stage, but once they have seen the outcome of surgery they may decline to go through with it. Whilst in most cases this will not be disastrous, it may mean that the patient ends up with a sub-optimal occlusion and less than ideal dental aesthetics. Care should be taken, therefore, to ensure that the patient understands that orthodontics will be an integral part of the overall treatment plan during the consent process.

4.6 Surgery without orthodontics

Whilst the majority of patients planned for orthognathic surgery will benefit from orthodontic treatment as part of their management, it is not always necessary and its risks and benefits must be carefully assessed in each individual case. Reasons why a patient may undergo surgery without any adjunctive orthodontic treatment include the following:

- The predicted post-surgical occlusion and arch coordination are satisfactory, to the point where orthodontics will not significantly improve the situation.
- The antero-posterior position of the incisors is such that the desired magnitude of surgical

correction can be achieved without the need for decompensation.
- The patient's dentition is incomplete such that they are not suitable for fixed appliances, but a reasonable, functional occlusion can still be achieved.

4.7 Complications of orthodontic treatment

Fixed orthodontic appliances carry a number of risks, which the patient must be made aware of as part of the consent process. These fall into the following categories:

4.7.1 Iatrogenic tooth damage

Decalcification

The risk of enamel decalcification associated with fixed appliances should not generally be high for orthognathic patients because they are mainly adults. However, it can still occur (Figure 4.22), particularly where treatment is protracted and there are problems with oral hygiene or diet and a high previous caries experience. Frequent hygienist support is invaluable in minimising this risk.

Root resorption

A small amount of root resorption is inevitable as a result of moving teeth in most patients but it is usually clinically insignificant. Occasionally, one or more roots may shorten to a much greater extent than usual and leave the tooth slightly mobile at the end of treatment. Whilst this is unpredictable, it is most common in upper incisors and more likely to occur with large tipping or torquing movements, especially where the apices are brought into contact with the bony cortical plates. Short, blunt roots prior to treatment are a further risk factor.

4.7.2 Loss of periodontal support

Orthognathic patients frequently require dental arch expansion, both in the antero-posterior and transverse directions. In non-growing patients, moving teeth into their cortical plates carries a risk of dehiscence and this can result in gingival recession. This is probably most commonly associated with lower incisors following proclination in class III cases (Figure 4.23), but proclining upper incisor in class II, division 2 cases can cause similar problems. It can also occur as a result of transverse maxillary arch expansion, particularly where there is pre-existing recession.

In patients who have a history of periodontal disease and have lost horizontal bone support, there will be a risk of this progressing as a result of orthodontic tooth movement. It is therefore important to ensure that active disease is controlled prior to the start of treatment and assessment by a periodontologist may be required.

4.8 Summary

- Most orthognathic patients have developed incisor compensation as a result of their disproportionate jaw growth and pre-surgical orthodontics aims to reverse this in preparation for surgery through the process of decompensation.

Figure 4.22 Patient with severe enamel decalcification marks following completion of combined surgical orthodontic treatment. The overall duration of treatment was protracted due to several failed appointments and the patient struggled with oral hygiene and diet control.

Figure 4.23 Labial gingival recession affecting a lower central incisor as a result of pre-surgical decompensation in a class III patient.

- The amount of incisor decompensation carried out dictates the size of the surgical jaw movements and may influence whether surgery will involve one or both jaws.
- Decompensation may be limited by the degree of crowding or spacing in the dental arches, the quality of the periodontal tissues and the resistance of the soft tissues.
- Incisor decompensation can be controlled using the appliance prescription, the extraction pattern and torque adjustments to the archwires.
- Anchorage can be managed using inter-maxillary elastics, trans-palatal arches and mini bone screws.
- Patients with anterior open bites often have accentuated upper curves of Spee. If levelling is beyond the scope of orthodontics then segmental surgery, with sectional orthodontic mechanics, may be required.
- Class II patients with deep bites tend to have accentuated lower curves of Spee. Where a mandibular advancement is planned it will often be desirable to maintain this curve during pre-surgical orthodontics, with the aim of increasing the lower anterior face height. This is termed a 'three-point landing'.
- Narrowness of the maxillary arch can be corrected using different expansion techniques, depending on its severity. These include tipping of the teeth orthodontically, RME, SARME and surgical widening.
- In some cases, where adequate maxillary expansion will be difficult to achieve, a bilateral buccal segment cross-bite may have to be accepted.
- Where necessary, it is usually possible to manipulate the surgical segments using inter-maxillary elastics for a period of approximately six weeks post-operatively in order to correct occlusal discrepancies.
- The clinician must be aware of the potential for iatrogenic damage with fixed appliances and good oral health should be a pre-requisite to combined surgical orthodontic treatment.

4.9 Recommended further reading

Proffit W.R., Fields H.W., Sarver D.M. (2013) *Contemporary Orthodontics, Section IV*, 5th Edition, Elsevier.

5 Orthognathic technical procedures

Chapter overview

Intended learning outcomes

By the end of this chapter the reader should:
- Have a working understanding of face bow recordings and their anatomical importance, the use of articulated dental casts for surgical prediction including measurement of movements, construction of occlusal re-positioning wafers and the use of 3D models in surgery planning.

5.1 Introduction

The role of the maxillofacial technologist as a member of the team treating patients presenting at a dento-facial deformity clinic can be easily defined. The technologist will use clinical measurements of the hard and soft tissues to reproduce the planned prescribed surgery on anatomically positioned dental casts in three dimensions. This procedure will allow the surgical team the opportunity to examine the predicted surgical outcome and allow re evaluation of the plan should this be required. Perhaps the most important aspect of the model surgery is the construction of intra operative occlusal wafers in final and intermediate positions used to reposition the upper and lower jaws at the time of surgery.

The opportunity to see the patient by the technologist responsible for the model surgery is essential and invaluable. The technologist can visualise the degree of correction required to treat the patient, this can include the amount of maxillary tooth show, whether there is an occlusal cant present or indeed any facial asymmetry which needs to be considered when formulating the treatment plan.

Handbook of Orthognathic Treatment: A team approach, First Edition. Ashraf Ayoub, Balvinder Khambay, Philip Benington, Lyndia Green, Khursheed Moos, and Fraser Walker.

Once the plan has been formulated and agreed with the patient it will be necessary to formalise the model surgery with some anatomically accurate models and clinical measurements of the patient.

5.2 Clinical assessment

At the surgery planning appointment the following must be obtained in order for an anatomical model surgery plan to be carried out.

1. Planning sheet (Figure 5.1).
2. Master impressions.
3. Occlusal registration.
4. Face bow recording (if required).
5. Proposed surgical plan.

5.2.1 Patient planning sheet

The first stage in this process is to record the patient's soft tissue and dental measurements on a treatment planning sheet. This will ensure the patient's individual details are accurately recorded to allow model surgery to be carried out. Details in addition to those previously mentioned include the dental centre lines, chin point, freeway space, overjet and overbite and are amongst the relevant items of information to be recorded; a clinic during which several new patients have been seen may be vivid in one's memory on the day, however, this will be less so a few days later and the planning sheet should avoid confusion in this regard. Additional information should include patient contact details in case it is necessary to recall them for further clinical assessment.

5.2.2 Master impressions

The technologist must be given the opportunity to examine the final impressions for quality control and must ensure the impressions are not loose in the tray. All present teeth must be included, often wisdom teeth can be missed or be only partially present in the impression. These teeth may be in occlusion and their omission may well cause problems when re-positioning the jaws during surgery therefore care at the impression stage is essential. The selection of impression material is a question of operator choice but it must provide accurate models. If circumstances are such that the impressions cannot be cast quickly a dimensionally stable material such as a rubber based product must be used. The choice of impression tray is also critical and this must be capable of withstanding the difficulties associated with the removal of the impression when orthodontic attachments are present on the teeth. The orthodontic attachments often tear the impression material or separate it from the impression tray rendering it useless, under these circumstances the impression must be repeated until a suitable one is taken. The best types of impression tray are the fine perforated metal trays or the disposable orthodontic trays specifically designed for orthodontic impressions. The impression can be checked by turning it over to the tray side to ensure it is firmly attached, if not it must be rejected. The technologist will invest two or three working days on the pre-op master models obtained from the impressions so must be satisfied they are fit for purpose.

TIP: ***Commonly the impressions will be laid on a bench prior to casting. If the impressions are allowed to rest on the heel this can cause dislodging and distortion from the tray. A simple solution is to rest the impressions on a piece of wood or spatula handle which will avoid this problem*** (Figure 5.2)**.**

5.2.3 Occlusal registration

A registration of the patient's occlusion should be taken at the clinical appointment and similarly should be carefully checked for accuracy. Once again the selection of registration material is operator choice. In addition to wax there is a large selection of silicone based materials formulated for bite registration purposes available. It is worth noting the reason for most discrepancies occurring between the prediction planning and the model surgery, these tend to be as a result of inaccurate occlusal registrations so it is always worth taking the time to double check the accuracy of the bite record.

5.2.4 Face bow recording

Finally a face bow registration should be taken if required. This must be taken by an experienced member of the team used to the procedures of face bow recordings. The face bow is the foundation of model surgery and inaccuracy at this stage may be transferred to the patient's intra-operative positioning wafer and subsequently it will have a detrimental effect on the patient's post-operative outcome. The face bow recording procedure is described later in this chapter.

5.3 Articulator and face bow selection

Orthognathic model surgery plays an important part in the diagnosis and treatment of the dento-facial

NAME .... NUMBER .... CONSULTANT ....

Tel: .... Age ....

Orthodontics Yes/No

Resting lip line to upper incisal edge (tooth visible) .... mms

Smiling lip line to upper incisal edge .... mms

Tooth - upper midline normal Yes/No Left .... mms .... Right .... mms

Tooth - lower midline normal Yes/No Left .... mms .... Right .... mms

Chin point central Yes/No Left .... mms .... Right .... mms

Overbite.......... mms/overjet .... mms AOB .... mms (incisor-incisor)

Freeway space .... mms

Occlusal cant Yes/No Specify ....

Photo Prediction Plan:

Maxilla Yes/No

Level of Procedure Le Fort I. II. III Segmental Yes/No

....

....

....

Mandible Yes/No Specify type of procedure:

....

....

....

Chin .... Genioplasty Malar Right .... Left ....

Models Yes/No Facebow Yes/No

Model Surgery Yes/No Date Required ....

Mandibular Model Yes/No

Model Surgery Indicates *Please fill in mark on models*

Maxilla Anterior 1/1 ....

Molar 6/6 ....

Mandible ....

....

Date of Pre-operative visit ....

Date of Operation .... Signed ....

Date ....

Figure 5.1 Patient planning sheet.

deformity patient. There are many differing techniques and methods of model surgery used by the maxillofacial technologist within the laboratory environment, many of which are employed as a result of a particular departmental or operator preference or are simply historically employed techniques handed down from technologist to technologist. In today's practice evidence based techniques are required to comply with health care policies. The inherent problems with face bow registrations and

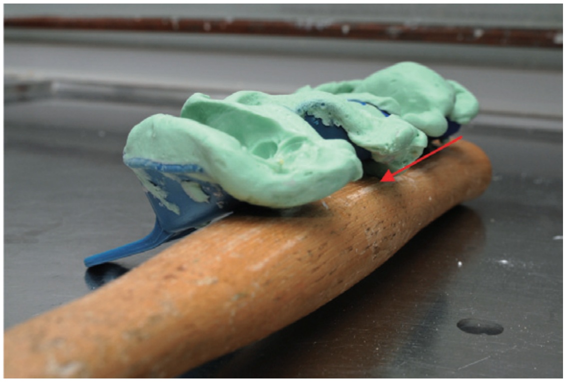


Figure 5.2 Impressions resting on a support.

Figure 5.3 Range of popular semi-adjustable articulators: left to right – Denar, KaVo, SAM, Hanau, Dentatus.

articulator selection have been well documented in the literature. Before considering the selection of the appropriate articulator for a given procedure it should be noted from the outset that the instruments in use today are dental in origin and were not designed for orthognathic model surgery, thus criticism of their inadequacy is inappropriate and the technologist must be prepared to modify techniques to compensate for their inaccuracy.

5.3.1 Plain line articulator (simple hinge)

The simple hinge articulator or plain line articulator as it is more commonly known is the most basic dental articulator capable of only opening and closing from a fixed hinged axis point. Dental casts are mounted between the top and bottom arm in an arbitrary position. There is no anatomical orientation to the skull with the exception of the occlusal relationship of the upper and lower teeth.

This can be used successfully for some single jaw osteotomies and segmental procedures typical applications would include:

1. Le Fort I Maxillary osteotomies without height changes (impaction or down grafting).
2. Mandibular advancements.
3. Mandibular setbacks.
4. Sub apical segmental osteotomies.

5.3.2 Semi-adjustable articulators and face bow recordings

For patients requiring surgery on both the upper and lower jaws (bi-maxillary procedures) to correct a facial deformity or for maxillary surgery requiring height changes, the use of a semi-adjustable articulator is essential (Figure 5.3). This principle applies to all bi-maxillary procedures with no exceptions. The semi-adjustable articulator is used in conjunction with a face bow recording. This recording is used to orientate the dental casts of the patient on the dental articulator allowing pre surgical diagnostic assessments to be made.

The principles of usage of a face bow recording and a semi adjustable articulator must be considered. The prosthetic application for which these instruments were designed must be re-evaluated as the anatomical points of interest for the correction of a dento-facial deformity differ significantly from those required for prosthetic dental restorations. The face bow recording must accurately position the maxillae in relation to the base of the skull. In addition the maxillary occlusal plane angle must be recorded precisely. Failure to record either of these with optimal precision will render model surgery inaccurate. It is important to remember that any inaccuracies incorporated into the model surgery will be transferred to the intra-operative repositioning splints and subsequently to the patient at the time of surgery producing a compromised surgical outcome.

5.4 Face bow recordings

Face bows commonly used for orthognathic model surgery will record the A.P. dimension of the patient with acceptable accuracy, however, most tend to overestimate the maxillary occlusal plane angle with dire consequences. These consequences will be discussed later in this chapter.

Firstly the available face bows should be considered to allow appropriate selection. The face bow is developed for individual articulators and as a rule should not be interchanged. Therefore it would not be wise to use for example a Dentatus face bow with a Hanau

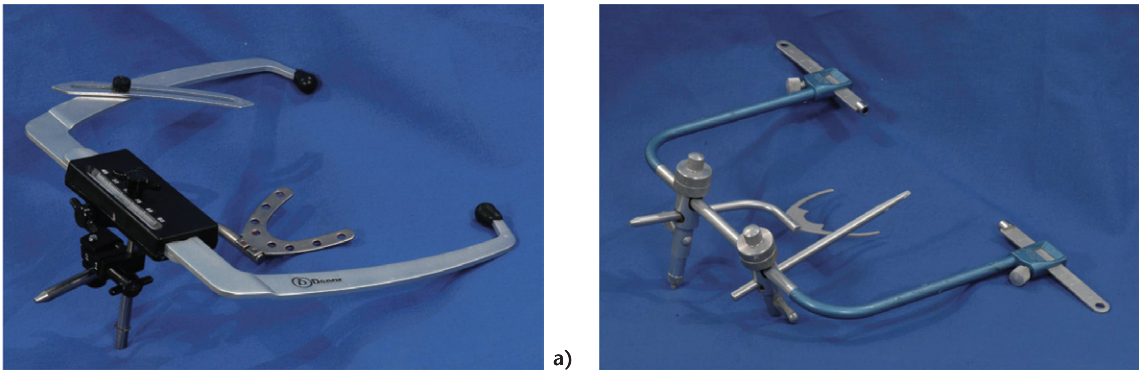


Figure 5.4 Two main types of face bow: **(a)** Denar slidematic and **(b)** Dentatus.

articulator regardless of the fact that Dentatus face bows fit the Hanau articulator and vice versa. Anatomical reference points differ depending on the manufacturer, but for the face bow to be of use for orthognathic model surgery it must record three points or planes of reference.

5.5 Face bow points and planes of reference

1. Maxillary occlusal plane.
2. External auditory meati or the condylar heads.
3. Orbitale, Campers plane or Nasion.

There are two commonly used types of face bow available for mounting casts on the semi-adjustable articulator. These are the auricular average value face bow and the condylar average value face bow.

5.5.1 Auricular average value face bow

The auricular face bow uses the external auditory meati as the posterior location. The maxillary dentition recorded on the bite fork which is attached to the face bow frame is the second recorded anatomical plane (Figure 5.4a). The third point of reference will vary depending on the manufacturer's preference. This may be any of the points listed previously as face bow points of reference item 3. The auricular face bow finds favour as it is considered to give reproducible results due to the ease of locating the external auditory meati. It is, however, hard to see the relevance of the auditory meati in relation to mandibular deformity correction or maxillary cast positioning on the articulator. This type of face bow makes the assumption that the head of the condyle will be found in the arbitrary position of 13 millimetres anterior to the external auditory meatus. This assumption may be reasonable for patients with a symmetrical deformity. However, it is not appropriate for patients with craniofacial deformities such as hemifacial microsomia where the position of the condylar head will not be in a predictable position. A further disadvantage incorporated into some auricular face bows is the design of the bite registration fork. This fork is part of a removable jig which is detached from the face bow after bite registration has been completed. This allows the operator to have one face bow with several registration jigs providing a cost efficient system in comparison to the condylar type of face bow which does not have removable components. The literature has many evaluations which show this to be the least accurate method of maxillary cast orientation due mainly to the separation of the bite registration fork from the face bow, its instability and its subsequent transfer to the articulator for maxillary cast mounting.

5.5.2 Condylar face bow

The condylar face bow (Figure 5.4b) requires the operator to identify the centre of the condylar head. This operation is carried out by palpating the soft tissue covering the condylar head and marking the centre point on the patient's skin with a pen.

With the condylar heads identified the face bow is offered up to the patient and the condylar rods are independently adjusted (Figure 5.5) and the face bow is positioned with the condylar rods recording the same measurement on each side of the patient: (1) The bite fork is tightened on the face bow, (2) lastly the orbital pointer is placed over orbitale and (3) is similarly tightened.

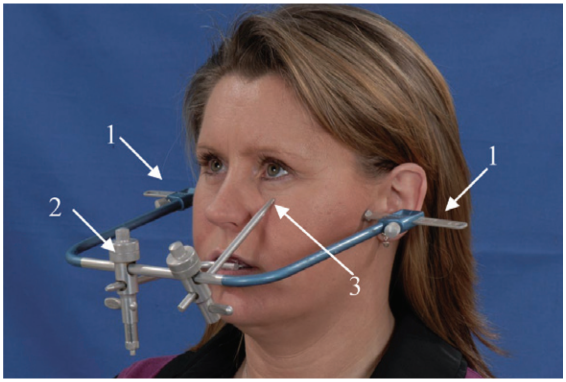


Figure 5.5 Patient with face bow recording.

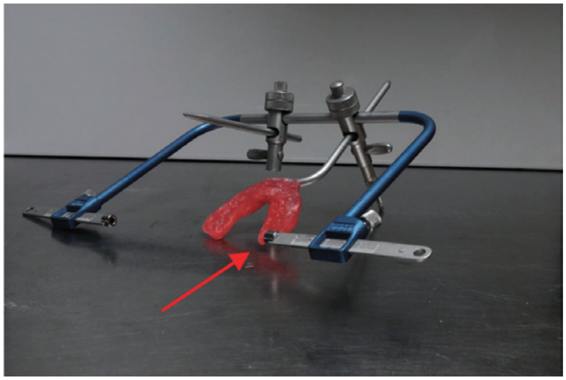


Figure 5.6 Arrow showing bite fork resting on the bench.

All the joints on the face bow are tightened to prevent movement when using the face bow to mount the maxillary dental cast on the articulator. This type of face bow with modifications would be the author's choice as it records anatomical points of interest which would be relevant for the process of jaw deformity correction.

TIP: ***The face bow registration should always be hung on a hook*** (Figure 5.7) ***or similar method of storage. If left lying around or resting on anatomical pointers or the wax bite fork*** (Figure 5.6) ***the face bow could be rendered inaccurate and this would not be readily visible at the time of mounting the model.***

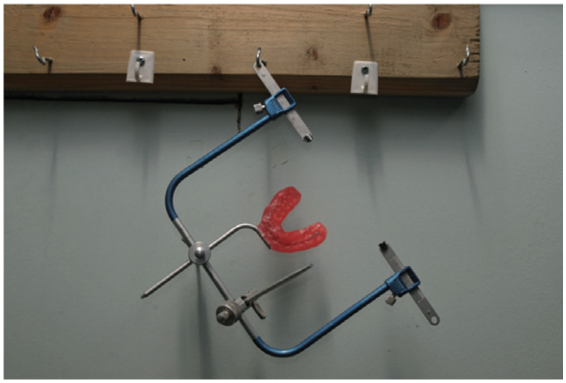


Figure 5.7 Face bow hung on a hook to prevent damage.

5.6 Errors in face bow registrations used for orthognathic model surgery

The previously described methods of face bow recording are recommended by the instrument manufacturers and are commonly used for mounting casts for model surgery. However, they have inherent anatomical design faults which will hinder accurate model surgery prediction. These errors have been well documented in the literature over many years and many suggestions for modifying the cast mounting technique have been made. The anatomical errors become more serious when the upper and lower casts are separated from the mounting plaster on the articulator and are subsequently repositioned to simulate the new position of the jaws. Once again it must be remembered this instrument is being adapted for a purpose for which it was not designed or intended.

The face bow systems used for mounting the maxillary cast on to semi adjustable articulators tend to over-estimate the maxillary occlusal plane angle which will produce unseen and unwanted movements from the model surgery prediction. This finding shows the errors which would be incorporated in the model surgery should the maxillary occlusal plane angle not be recorded accurately.

Figure 5.8 shows a lateral cephalogram placed in the correct anatomical position of the maxilla in relation to the articulator. The vertical line is a datum line with no anatomical significance other than being positioned in relation to the anterior position of the upper central teeth.

Figure 5.9 shows the maxillary cast mounted to the articulator using the face bow according to the manufacturer's instructions. At this stage the increase of the maxillary occlusal plane angle is obvious. For the purpose of this illustration we have assumed the maxilla has been impacted by 6mm with no advancement.

Figure 5.10 shows the maxillary cast with 6mm impaction but with the maxillary cast positioned

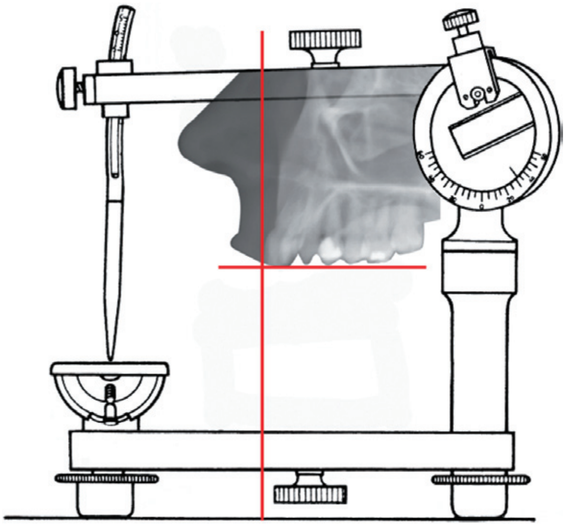


Figure 5.8 Patient's ceph anatomically positioned on the articulator.

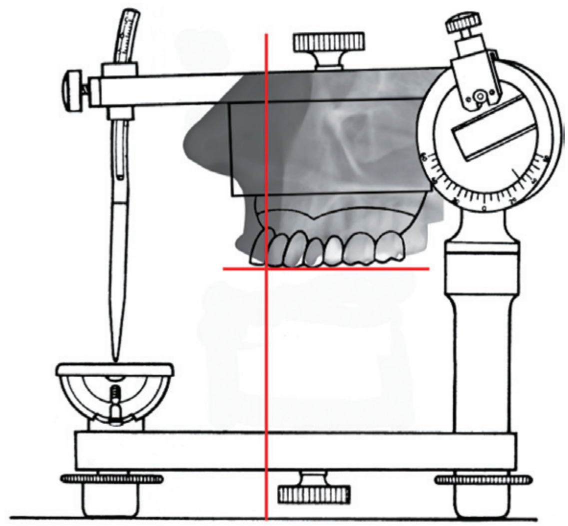


Figure 5.10 Maxillary cast showing unwanted advancement.

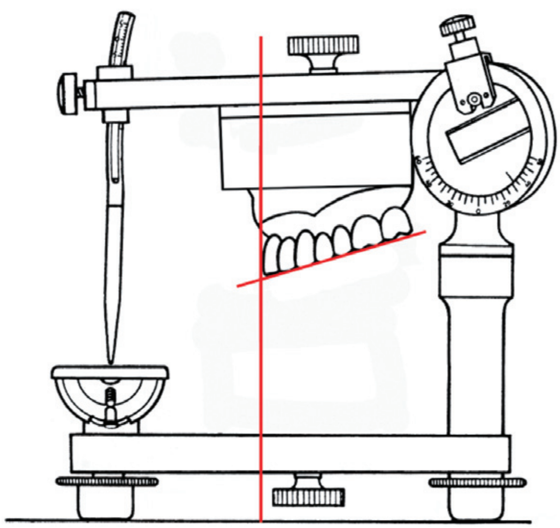


Figure 5.9 Patient's maxillary cast mounted according to manufacturer's instructions.

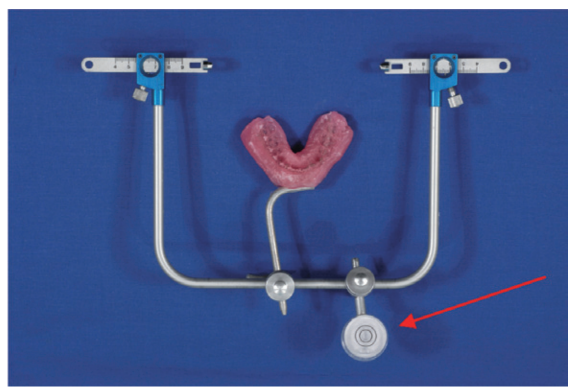


Figure 5.11 Face bow with orbital pin replaced with a bulls eye spirit level.

over the superimposed lateral cephalogram which represents the patient's true maxillary occlusal plane angle. This reproduces the actual anatomically correct position of the patient's maxilla. The illustration shows the amount of maxillary advancement anterior of the vertical red line (arrowed) which is unseen on the model surgery. This error is entirely as a result of mounting the maxillary cast on the articulator with an increased occlusal plane angle. As previously mentioned, these illustrated errors would be transferred to the intra-operative wafers and subsequently to the patient.

Operational errors can be greatly reduced by abandoning anatomical landmark indicators such as orbital pointers and nasion rests which are commonly found on commercial instruments and substituting these for a bull's eye spirit level (Figure 5.11). By securing a spirit level to the face bow it is then possible to record the patient's natural head position and thus transfer the casts to the articulator with greatly increased accuracy.

5.7 Face bow with orbital pin replaced with a bull's eye spirit level

The procedure for face bow registration using the spirit level is straightforward and does not take appreciably more time than adopting the manufacturer's method. The recording process is identical to that previously described but without the necessity to record orbitale with the orbital pointer when a bull's eye spirit level is used. To do this the patient is sat on a stool with no back support, positioned two metres from a full length mirror and is asked to stare directly back into their own eyes, the spirit level is adjusted until it is accurately centred. This records the patient's natural head position which in turn records the maxillary occlusal plane angle with a significant improvement in accuracy.

Figure 5.12 shows the maxillary cast mounted to the articulator using the face bow in accordance with the manufacturer's instructions. Figure 5.13 shows the same case mounted using a face bow with the orbital pointer replaced with an adapted bull's eye spirit level. Finally Figure 5.14 shows the patient's lateral cephalogram, providing the gold standard. This method of orientation has been the subject of several studies including scientific and clinical evaluation and has proved to be significantly anatomically more accurate.

5.8 Orthognathic articulator and face bow

As a direct result of the systematic errors found in face bow registration and cast mounting on the articulator studies were conducted to find an improved method for these procedures. It became apparent the solution would lie in a purpose designed face bow and articulator for orthognathic model surgery.

5.8.1 Face bow

The new face bow is adjustable for width and has independently adjustable condylar rods in both A/P and vertical planes. There is an adjustable bull's eye spirit level attached to the anterior rod which also

Figure 5.13 Spirit level mounted cast.

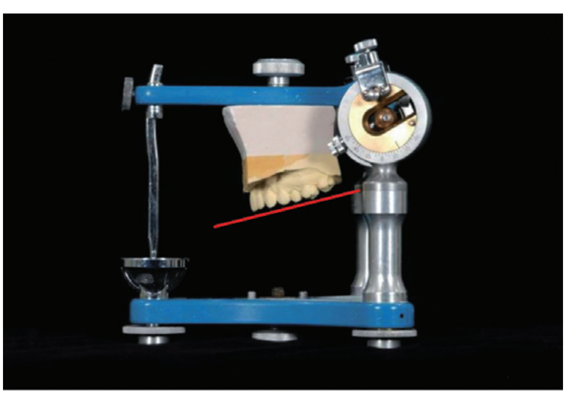


Figure 5.12 Face bow mounted cast.

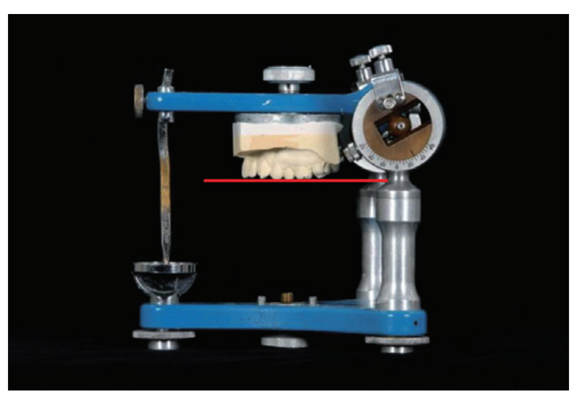


Figure 5.14 Patient's ceph.

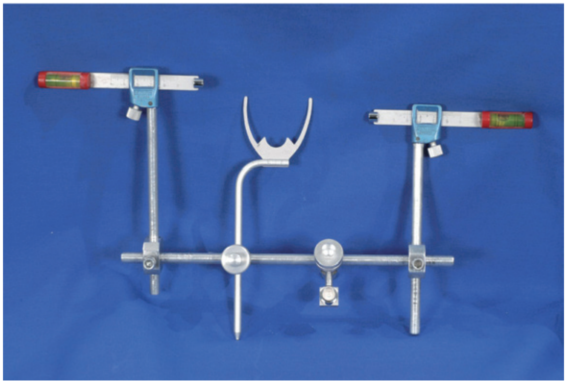


Figure 5.15 New orthognathic face bow.

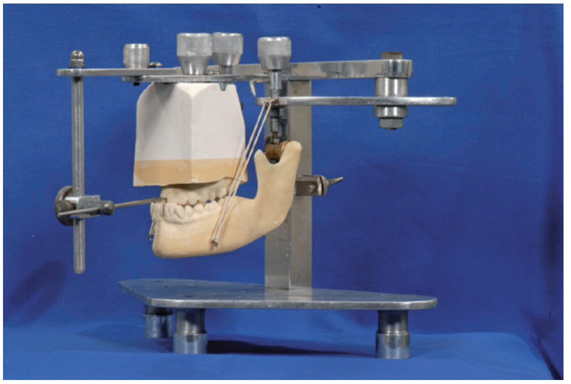


Figure 5.16 New orthognathic articulator.

has the bite registration fork attached (Figure 5.15). The face bow registration is taken in the same way as previously described. The main operational difference of this face bow is it is not adjusted to fit the articulator as the previous adapted Dentatus unit is, rather the articulator is adjusted to the face bow registration. The benefits of this are the registration of differing heights of condyle, such as may be found in cases of hemifacial microsomia, more accurate setting of the condylar width and an improved accuracy in the representation of any existing occlusal canting. All of these features are not available using a semi-adjustable dental articulator, and all are helpful for orthognathic model surgery planning.

5.8.2 Articulator

The face bow is attached to the condyles on the articulator. The condylar components on the articulator are adjustable for both width and height. These allow A/P and height adjustment independently of each other and are capable of the accurate representation of asymmetric condylar relationships. There is sufficient space between the upper cross member and the base of the articulator to ensure ease of mounting of the casts. This is a shortcoming of most semi-adjustable articulators. The mandible has been designed to be the hinged component as this replicates the human anatomy more accurately (Figure 5.16). Using the face bow and articulator allows improved accuracy in recording the patient's relevant anatomical structures and landmarks required for orthognathic model surgery. This combination of improved face bow and articulator have proved useful tools in the diagnosis and treatment of patients with both symmetric and asymmetric deformities. A full report of the clinical application and significance of this methodology is listed in Further Reading at the end of this chapter.

5.9 Preparing the casts for articulation

The dental impressions should be cast in class IV dental stone. This provides a very hard and accurate cast and withstands the stresses of re-positioning when assessing a new final occlusion. The manufacturer's instructions should be followed closely when mixing these types of stone as failure to do so will lead to a weak and inaccurate cast.

As an alternative to gypsum based products there are several dual component model resins which provide an accurate and very hard model of the dentition which will also resist the previously mentioned stresses and would be the best choice if multiple occlusal repositioning wafers are to be constructed. This material will resist breakage of the teeth which commonly occurs during occlusal repositioning wafer construction.

The master impressions should be duplicated and trimmed to provide a set of study models. A good set of study models will provide a record of the relationship of upper and lower dental centre lines, degree of over jet, degree of overbite and will allow the assessment of the patient's occlusion. Additionally, in some cases a rough measurement of potential changes to the facial height can be assessed.

The master casts can be trimmed in several ways. It is common for a conventional semi circular trimmed cast to be used for model surgery. This shape of cast particularly in the case of the maxilla will prevent detrimental rotations about the centre of the palate being easily detected. Such rotations could lead to surgically impossible positions being predicted due to interference with the pterygoid plates as a result of unseen and unwanted posterior movements being incorporated in the model surgery. The

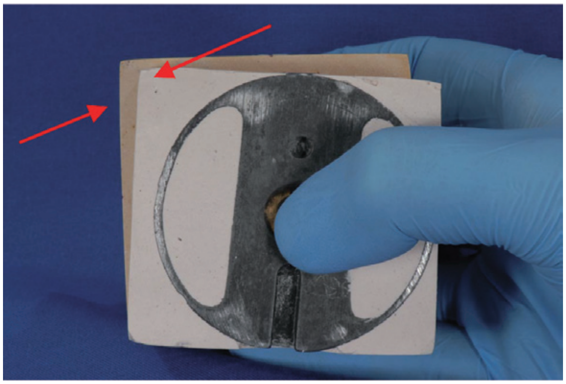


Figure 5.17 Arrows showing the movement of the repositioned cast.

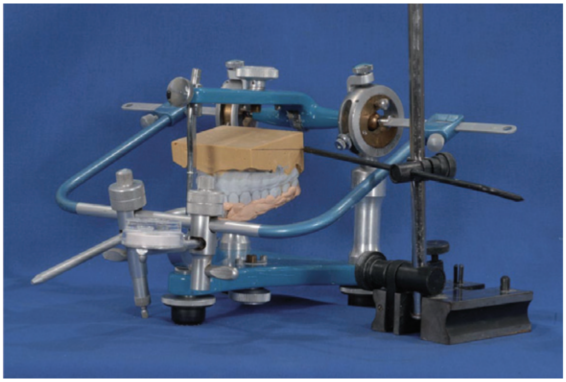


Figure 5.18 Engineering surface gauge marking out maxillary cast.

use of master casts with square bases will allow more accurate visual assessment of the movements predicted by the model surgery, clearly showing any movements as deviations from the square bases (Figure 5.17).

5.9.1 Articulating the casts

Depending on the operator's choice of system the first step in the model mounting procedure is to attach the face bow or bite jig to the articulator according to the manufacturer's instructions. The maxillary cast is placed in the face bow's bite registration fork and is checked for stability. It is not uncommon for the master cast to be unstable in the bite registration due to interference between the orthodontic brackets (if present) and the bite registration. The simple solution is to trim areas of contact between the bite and the cast until stability is obtained, carefully ensuring that there is no movement of the face bow components or damage to the teeth or occlusion.

The maxillary cast is trimmed until the base is parallel to the horizontal. This can easily be done by marking a line on the base of the cast using an engineering surface gauge. With a line scribed on the base of the cast it can be trimmed using a plaster model trimmer (Figure 5.18).

The maxillary cast is attached to the upper arm of the articulator using anti expansion plaster. On completion of this procedure the face bow is detached from the articulator. The mandibular cast is now occluded with the mounted maxillary cast using the wax jaw registration and is attached to the lower arm of the articulator using anti expansion plaster. The casts are now ready for model surgery to commence.

5.9.2 Marking out the casts

With the casts mounted on the articulator the model surgery can commence. The system described has evolved over a long period of time and has been effectively used by the author. Many units will have their own preferences and methods of orthognathic model surgery, however, when studied the various systems are all similar. One of the advantages of the described system is the ability to return the casts to the start position without the need to repeat the face bow and cast mounting procedure should modifications to the final treatment plan be made.

The first stage when marking the casts for model surgery is to mark datum lines on the upper and lower casts in order to measure the movements of the casts as directed by the prescription on the planning sheet. The casts may also be marked using a system which will allow the casts to be returned to the start position. A colour key system is applied to the markings. The start position of the model surgery is denoted by red lines; the intermediate position is denoted by green lines. This system is in use within our laboratory, however, can be adapted to suit individual operators. The use and evaluation of markings and measurements will be explained as the procedure is described.

Orthognathic model surgery will require the dental casts and articulating plaster to have a series of scribed vertical and horizontal lines. These lines will be used to measure the prescribed movements on the repositioned articulated casts. At this stage it is worth mentioning that the master cast is not trimmed (unless a segmental procedure is prescribed) this allows accurate repositioning of the separated casts to the original articulated position, which allows for a change of plan without the need for a further face

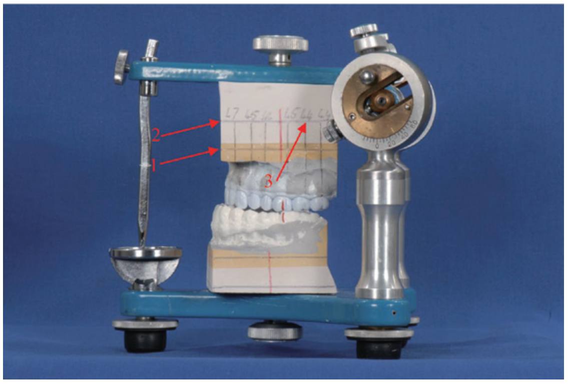


Figure 5.19 Mounted casts showing datum lines for model surgery.

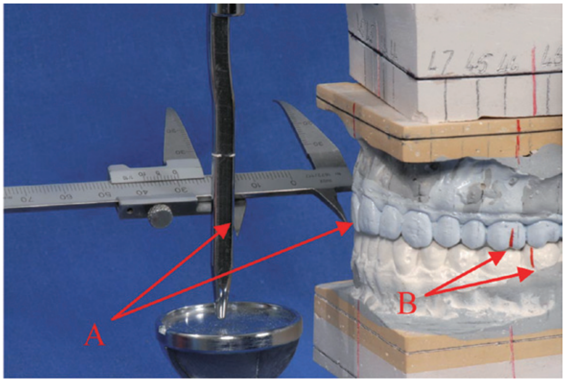


Figure 5.20 Markings for A/P movements.

bow recording or new master casts as previously mentioned. All lines and markings will be scribed into the plaster as this assures longevity unlike ink which will fade over time (Figure 5.19). The expected storage time of the final plan casts is a minimum of five years. This is the time from initial surgery to discharge from hospital care. The markings on the casts and mounting plaster must be legible at the final appointment to allow for a clear record of the prescribed surgical movements and to allow the assessment of the surgical outcome.

5.9.3 Marking and measuring the casts for vertical movements

The first line scribed on the maxillary cast (1) is a horizontal line at a distance of 5mm from the base. A second line is scribed on the mounting plaster (2) at a distance of 10mm this allows a total of 15mm between lines (1+2). Trimming to reposition casts should be limited to the mounting plaster. The distance of 10mm has been found sufficient to accommodate most prescribed movements, however, there is no requirement to adhere to this measurement and the individual operator may prefer different dimensions of mounting plaster. It is important to scribe the distance between the horizontal lines on the mounting plaster if this differs from job to job this measurement then allows for calculation of the original movements.

Each tooth should be measured from the tip of a chosen cusp or incisal edge to the uppermost horizontal line on the mounting plaster (3). This measurement is scribed on the mounting plaster. This will allow for a double check of the prescribed vertical movement.

5.9.4 Marking and measuring the casts for antero-posterior movements

A line is scribed on the buccal cusp of the upper and lower first molars (B).

Using a set of Vernier callipers a second measurement is taken from the incisal edge from each of the upper and lower centrals to the incisal pin on the articulator (A) (Figure 5.20). This measurement is scribed on the back of the cast for future reference. Using these measurements advancement of the maxilla and advancement and set back of the mandible can be evaluated.

5.9.5 Repositioning the casts

There are several considerations when marking and measuring the casts.

1. Measurements at tooth level will be more accurate than those taken from the bases of the casts. The teeth are the only anatomically accurate structures on the casts. The chosen model surgery method should always allow the operator to return to the starting position should the surgery plan change.
2. Avoid measuring in an arc (Figure 5.22). This situation can occur when the maxillary cast has been advanced a significant amount and the protruding cast tempts the operator to arc dividers or callipers to make a measurement. This will give a false measurement of movement (Figure 5.21).
3. Measure the advancement from a fixed point and at tooth level. Vernier callipers are ideal for this procedure. Maxillary and mandibular advancement should be measured by taking a point between the upper and lower central incisors and the articulator pin prior to the commencement of the model surgery. This can be compared to the

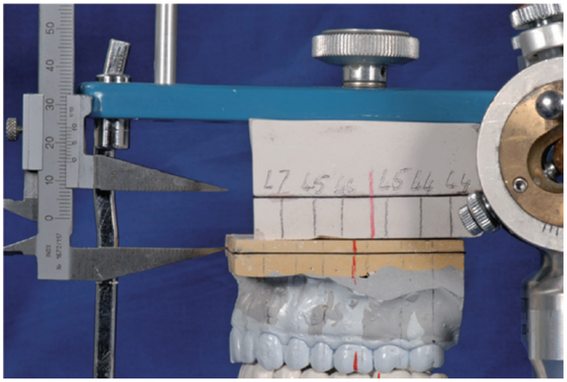


Figure 5.21 Parallel measurement.

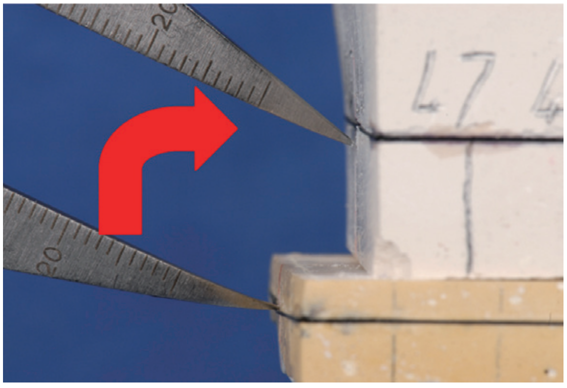


Figure 5.22 Measurement in an arc.

same measurement points post-model surgery and simple subtraction will provide the amount of advancement at tooth level.

4. Geometrical movements may occur showing anomalies in the markings. Two examples of this would be in the case of a differential impaction, that is, Posterior maxillary impaction of 6mm and anterior maxillary impaction of 2mm. The markings on the sides of the models will show gaps between the lines and this can be mistaken for advancement which is not the case. Secondly, a medio lateral correction of an occlusal cant will show a similar separation of the datum lines. This is not rotation of the centrelines, but simply a differential movement of the cast to correct the canting.

5.9.6 Occlusal re-positioning wafer

Once the model surgery has been completed to prescription an occlusal re-positioning wafer will be

Figure 5.23 Occlusal re-positioning wafer.

made. This wafer is used intra-operatively to re-position the surgically separated jaw by relating the relationship of the upper and lower teeth to each other. In the case of single jaw surgery one wafer will be required to record the final occlusal position. Bi-maxillary osteotomies will require two wafers, the first to re-position the maxilla and the second to relate the mandible to the surgically corrected maxilla which will be the final occlusion. The usual sequence of bi-maxillary surgery would be to re-position the maxilla to the prescribed position and relate the mandible to the maxilla. There are some exceptional situations in bi-maxillary surgery where the mandibular surgery would be carried out first. Severe mandibular asymmetry would be one such situation. In this case the mandible would be corrected and the maxilla related to the new mandibular position. There are further exceptional circumstances where sub-apical segmental osteotomies might be required. In such cases there may be more than the two occlusal wafers. As a rule each stage of surgery will require one wafer, so an example might be, first wafer maxillary surgery, second wafer mandibular sub-apical osteotomy from canine to canine, third and final wafer mandibular advancement. It is worth considering a system of colour coding the intra-operative wafers to avoid confusion in theatre during surgery. Our chosen system always colour codes the intermediate wafer in ivory and the final occlusal wafer clear.

There are several materials and designs for wafer construction and they are once again operator preference. The wafer can be made using self cure acrylic, heat cure acrylic, light curing materials and silicone. They can have attachments for securing the wafer during use such as power chain, holes can be drilled for wires or cleats can be added. Figure 5.23 shows the author's preferred design of final occlusal wafer, this is constructed using self cure acrylic and incorporates three cleats which are used to attach the wafer to the patient's orthodontic attachments with power chain. This design allows the patient to remove the wafer for cleaning which improves oral hygiene.

5.10 Recent advances in model surgery

With the introduction of CT and MRI volumetric scanning it has become possible not only to view digital images of patient data on the computer screen, but also to create physical skull models from this data through improved developments in rapid prototyping. One of the limitations of this technology is the inaccurate reproduction of the teeth where streak artefacts are created due to metallic dental restorations and orthodontic brackets being present. In addition to this the teeth themselves do not replicate accurately due to their complex structure and resultant beam hardening. A technique has been created for exchanging the inaccurate dentition of a three dimensional physical skull model with plaster dental cast taken from a direct impression of the patient.

At present most surgeons use lateral cephalographs and dental casts for planning orthognathic surgery. This provides little information about any associated deformities of the jaw bones, including condylar abnormalities, mediolateral facial asymmetries, dysmophology of the chin, or abnormalities of the inferior border and ramus of the mandible. The inclusion of selected portions of the skull and jawbones will improve the accuracy of surgical planning and would also negate the difficulties associated with the use of the face bow. This new method has the potential to be more applicable to patients with complex craniofacial problems and pronounced asymmetry. To obtain an accurate replica of the patient's skull and dentition would be beneficial in explaining the procedure and would be of educational value. It should be pointed out that three dimensional skull models are expensive compared to techniques currently available and rely on experienced personnel to operate the necessary equipment for their production. The cost of the technology is, however, becoming more affordable, which makes it more attractive for larger specialist units. Smaller units could liaise with larger units to make full use of this technology and make it more cost effective.

With the aid of a denture reline jig (Figure 5.24) the sectioned three-dimensional maxillary dental alveolar process of the physical skull model was placed into the lower section of the jig. Before the top section of the jig was closed a dental impression material was added to allow an impression to be taken of the maxillary dentition of the skull. Once the material was set, the jig was opened and the three-dimensional dentition of the physical skull was removed. A polyvinyl splint which had been fabricated on the plaster model of the patient was placed into the indentations of the teeth within the impression on the top section of the jig. Plaster was poured into the fitting surface of the splint to reproduce the accurate dentition. Cold cure acrylic resin was placed

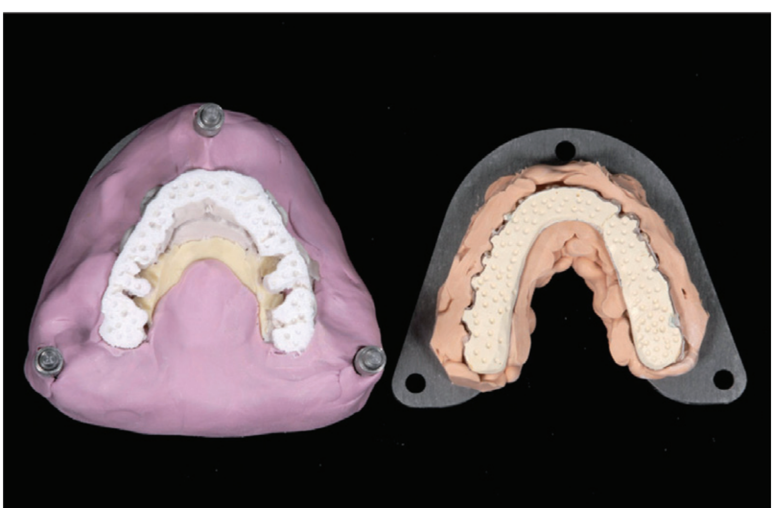


Figure 5.24 Maxilla and impressions in jig.

Figure 5.25 Patients 3D model with dentition replaced.

between the plaster base and the maxilla to hold them together. The jig was reassembled and bolted down to ensure that the dentition was orientated in an accurate position and to maintain the vertical dimension. The jig was opened and the splint removed, leaving the accurate plaster dentition attached to the dental alveolar process of the three-dimensional printed skull model. The dental alveolar process of the skull bearing the plaster teeth was removed from the transfer jig and returned to the three-dimensional physical skull using locating plates and screws (Figure 5.25). This technique allows the skull with the mandible to have the surgical procedures carried out and the bones re-positioned to simulate the proposed surgery with an anatomical accuracy not available using conventional dental articulators and face bows. This method of model surgery eliminates many of the errors inherent in the presently used systems because of the improved anatomical accuracy and represents a significant step forward in model surgery techniques.

The model surgery techniques presented in this short chapter do not represent a definitive guide to this highly complex procedure. More detailed explanation of many of the techniques described is available in the papers listed under further reading. The overview presented has been formulated with the input from many colleagues over a number of years, all of whom contributed in some way to the techniques presented. It is hoped this brief insight might enthuse the reader to seek further information on this highly rewarding aspect of maxillofacial surgery.

We must acknowledge the input and assistance of three of our valued colleagues for their assistance in the preparation of this chapter: Mr Michael O'Neil, Principal Maxillofacial Prosthetist, Regional Maxillofacial Surgery Unit, Southern General Hospital, Glasgow, for his expertise in the use of three dimensional software and associated models, Ms Barbara Thomson, Maxillofacial Prosthetist, Regional Maxillofacial Surgery Unit, Southern General Hospital, Glasgow, for numerous face bow recordings, and James Eyland, our medical photographer, for his patience in preparing the images used to illustrate this work.

5.11 Suggested further reading

Barbenel, J.C., Paul, P.E., Khambay, B.S., Walker, F.S., Moos, K.F. and Ayoub, A.F. (2010) Errors in orthognathic surgery planning: the effect of inaccurate study model orientation. *International Journal of Oral and Maxillofacial Surgery*, **39**, 1103–1108.

Paul, P.E., Barbenel, J.C., Walker, F.S., Khambay, B.S., Moos, K.F. and Ayoub, A.F. (2012) Evaluation of an improved orthognathic articulator system: 1. Accuracy of cast orientation. *International Journal of Oral and Maxillofacial Surgery*, **41**(2), 150–154.

Paul, P.E., Barbenel, J.C., Walker, F.S., Khambay, B.S., Moos, K.F. and Ayoub, A.F. (2012) Evaluation of an improved orthognathic articulator system: 2. Accuracy of occlusal wafers. *International Journal of Oral and Maxillofacial Surgery*, **41**(2), 155–159.

O'Neil, M., Khambay, B., Moos, K.F., Barbenel, J., Walker, F. and Ayoub, A. (2012) Validation of a new method for building a three-dimensional physical model of the skull and dentition. *British Journal of Oral and Maxillofacial Surgery*, **50**(1), 49–54.

Walker, F., Ayoub, A., Moos, K.F. and Barbenel, J. (2008) Face bow and articulator for planning orthognathic surgery: 1 face bow. *British Journal of Oral and Maxillofacial Surgery*, **46**, 567–572.

Walker, F., Ayoub, A., Moos, K.F. and Barbenel, J. (2008) Face bow and articulator for planning orthognathic surgery: 2 articulator. *British Journal of Oral and Maxillofacial Surgery*, **46**, 573–578.

6 Prediction planning

Chapter overview

Intended learning outcomes

By the end of this chapter the reader should:

- Be aware of the current methods of prediction planning.
- Understand and be able to apply the two-dimensional planning process in routine clinical practice.
- Be aware of the advantages and disadvantages of two-dimensional planning.
- Understand the steps in producing a three-dimensional 'virtual patient'.
- Have knowledge of navigation surgery and its potential future role in orthognathic surgery.

6.1 Introduction

The aim of this chapter is to introduce the different methods of orthognathic prediction planning, highlighting current practice to state of the art three-dimensional planning. The strength and short comings of each method of planning will be discussed. This chapter will describe in detail the methods of planning that are currently used by the Team; both two dimensional prediction software (CASSOS – Computer Assisted Surgical Simulation for Orthognathic Planning) and three dimensional prediction software (Maxilim)*. The majority of computer planning programs apply a similar methodology

*The Authors have no financial interest in these companies.

Handbook of Orthognathic Treatment: A team approach, First Edition. Ashraf Ayoub, Balvinder Khambay, Philip Benington, Lyndia Green, Khursheed Moos, and Fraser Walker.

which will help the reader transfer knowledge and techniques learned in this chapter into their own clinical practice.

6.2 Prediction planning for orthognathic surgery

The successful outcome of orthognathic surgery requires precise surgical technique and comprehensive orthodontic treatment. More importantly the final outcome must provide an aesthetic improvement that meets the patient's expectations and an occlusion that is functional. Involving the patient in the decision making process is an important part of pre-surgical planning and as such providing patients with a 'realistic' simulation of the post-surgical result is becoming a necessity. The current method of planning uses profile views of the patient in the form of lateral cephalograms and profile photographs. The challenge of planning is to position the teeth in an ideal class I incisor relationship whilst at the same time producing the correct final soft tissue appearance bearing in mind that the skeletal hard tissue lays in between (Figure 6.1).

Orthognathic surgical planning should achieve the following objectives:

1. Determine the final post-surgical dental occlusion – termed 'model planning'.
2. Illustrate to the patient and Team the potential post-surgical soft tissue profile facial appearance – termed 'soft tissue profile prediction planning'.
3. Determine the magnitude of skeletal hard tissue movement necessary at the time of surgery.

6.3 Methods of prediction planning

6.3.1 Model planning

Model surgery prediction is based on surgical procedures performed on study models, which are sectioned to achieve normal occlusal relationships. This gives an indication of the surgical skeletal movements required to correct the malocclusion but provides no information about the soft tissue change. It was soon realised that this approach may be detrimental to the facial profile and that an approximately ideal occlusion may not be accompanied with the best facial aesthetic results. However, model planning is still essential to predict the final dental occlusion and to construct the intermediate and final orthognathic wafers to guide the surgical procedure. This is dealt with in greater detail in Chapter 5 Orthognathic technical procedures.

6.3.2 Soft tissue profile prediction planning

Combined cephalometric tracings and photographs

Henderson (1974) introduced a technique that combined cephalometric radiographic tracings with photographs. A lateral transparent positive 1:1 photograph was superimposed on the patient's lateral cephalometric radiograph. A tracing was made of the relevant hard tissue structures from the cephalometric radiograph onto the photograph. The photograph was then sectioned along the planned osteotomy sites and moved according to the desired surgical movements. The soft tissues were then moved according to

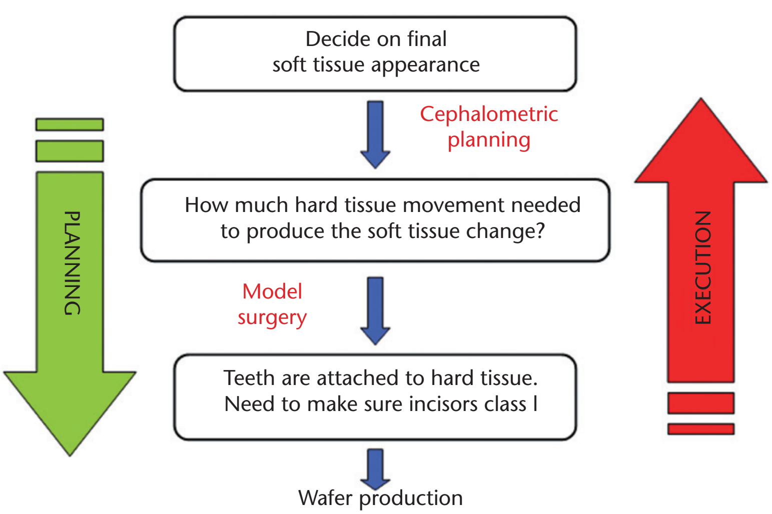


Figure 6.1 Shows the interaction between soft tissue, hard tissue and teeth during the planning and execution phases of orthognathic surgery. Source: Ayoub, A.F. and Khambay, B. (2012) A paradigm shift in the diagnosis and management of dentofacial deformities. *The Saudi Dental Journal*, **24**, 121–125. Reproduced with permission of Elsevier.

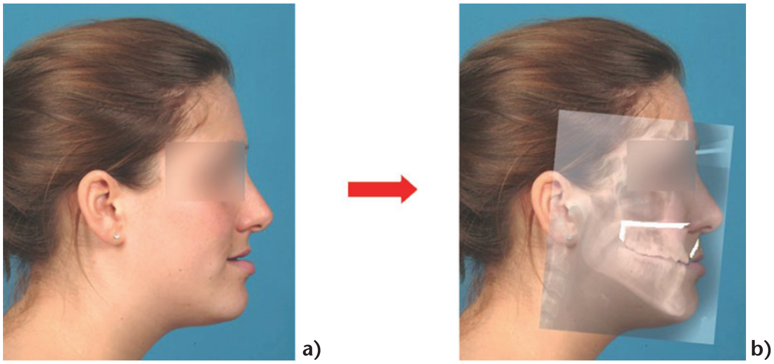


Figure 6.2 1:1 prediction planning. Pre-operative profile **(a)**. Superimposed lateral cephalogram radiograph showing predicted hard and soft tissue movements following a maxillary advancement **(b)**.

the known ratios of hard to soft tissue movements, as in Figure 6.2.

These photocephalometric planning techniques have proved useful in orthognathic planning and have been used in many centres, and are still being used in many units, to plan the outcomes of orthognathic surgery. These techniques, however, have a number of limitations:

1. The method of planning is complex and time-consuming.
2. The ratios of hard tissue to soft tissue movement have become increasingly complex and the surgeon or orthodontist must be very experienced to be able to predict the response of the soft tissues to bony movements. A degree of artistic skill is required when using such planning techniques.
3. The methods are not consistent and reproducible and are open to human error.
4. Differential movement of the soft tissues can be complex. It requires multiple cuts and small numerous segments to reproduce the soft tissue profile. This results in a number of step defects in the profile outline which does not provide a realistic prediction of facial appearance to patients.
5. The final plans are easily distorted and with time the adhesive degrades with parts of the plan moving or even being lost. This makes audit and research from these records difficult.
6. An experienced surgeon or orthodontist is able to visualise the results of prediction planning, but for the patient the sectioned photographs are difficult to interpret.

6.3.3 Computerised prediction

In an attempt to overcome the limitations of the manual techniques, a number of computer-based packages have been developed. The early computer packages were able to generate simple line drawings of profile prediction. Following the evolution and development of computer hardware and software, prediction imaging packages are able to incorporate lateral profile photographs of the patient, which could then be morphed to produce photo realistic predictions.

All of the modern commercially available packages are in essence computerisations of the manual planning technique. Firstly, specific landmarks are digitised on both the lateral cephalometric radiograph and the profile photograph; the number of landmarks vary for each program. The prediction software then automatically superimposes the radiograph and photograph. Obviously the soft tissue on both the cephalogram and the profile photograph needs to be identical for the best superimposition. The method of superimposition is often not known to the operator and the factors which may effect the accuracy are therefore unknown. The orthodontist or surgeon is then able to analyse dental, skeletal and soft tissue variables against standardised sets of linear and angular measurements and plan the surgery on-screen. The software is programmed using mathematical algorithms to allow the simulation of hard and soft tissue movements. The final profile prediction is a 'morphed and smoothed' photo realistic prediction of the proposed surgical outcome. Some packages allow the clinician to "tidy-up" the lips if they appear incorrect; this however introduces a subjective element to the prediction which may introduce even larger inaccuracies.

Advantages of computerised prediction

1. Computerised planning has greatly simplified the prediction process and reduced operator time. For most packages digitisation of the landmarks on the radiograph and profile photograph is time consuming but the real advantage comes from

being able to rapidly and accurately analyse and predict surgical results. The operator can easily explore a number of orthodontic and surgical options.

2. The software may be programmed with a number of complex non-linear mathematically derived algorithms to predict the soft tissue response to the surgical movements. The software can easily be updated and the software algorithms adjusted, based on any new data that becomes available.
3. The computer software package is able to morph and smooth the image meaning less artistic skill is required. Some packages do have the option of using touch-up tools to enhance the final prediction.
4. The use of computer packages has improved the reproducibility of orthognathic surgical planning. The process of planning is standardised from digitising landmarks and superimposition through to morphing and smoothing of the final prediction. Orthodontists and surgeons are able to produce similar predictions and in the same format.
5. Computerised predictions are easily stored and retrievable at a later date. This method lends itself to audit and research more so than the manual prediction technique. It is relatively easy to back up patient data and plans and electronically transfer information between various hospital sites.
6. The greatest advantage of software prediction packages is the ability to produce photorealistic post-surgical predictions. This greatly improves patient participation in the planning process and communication between orthodontist, surgeon and patient. This has a clear positive impact on patient satisfaction following surgery.
7. As a result of the ability of computer packages to calculate calibrated distances and angles it is more accurate to calculate the desired surgical movements.

Disadvantages of computerised prediction

1. Initial set up cost of the hardware and software.
2. As with any new technique there is a learning process.
3. The patient may perceive the photo realistic images to imply a guarantee of treatment result. In reality the actual surgical outcome is usually more aesthetically pleasing than the prediction. To prevent patients believing that the prediction will be a guarantee of the actual surgical outcome some authors have advocated adding the phrase ‘Treatment Simulation Only’ to all predictions. It has also been suggested that the patient should sign a waiver stating that the prediction is only an approximation of the actual surgical outcome. The Team has however determined the validity of CASSOS scientifically (Jones et al., 2007).
4. The increased accuracy of prediction planning must be matched by surgical accuracy.
5. The majority of computer programs cannot deal with ‘incompetent lips’ and as a result the final prediction around the lips is often poor. Some manufacturers have added ‘tools’ which allow for correction but this can undermine the process and once again introduces subjectivity.

6.3.4 Factors affecting the accuracy of prediction planning

The accuracy and reliability of prediction planning is dependant on a number of factors. These include:

1. Cephalometry. Lateral cephalograms are subject to errors of projection during capture as well as landmark identification and measurement errors.
2. Photography. Photographs are two-dimensional representations of three-dimensional objects and are therefore subject to the same errors as lateral cephalometric radiographs.
3. Superimposition of radiographic and photographic images. Manual methods of superimposition have been shown to be inaccurate. The errors are the result of three factors: differential magnification and distortion of the cephalometric radiograph and photograph, errors of landmark identification on both the photograph and radiograph are combined during superimposition increasing potential errors.
4. Soft tissue response to the underlying hard tissue movements. The ratios of hard to soft tissue movement currently used in prediction planning are average responses. Ratios will only describe a relationship between two specific points and it is unlikely that a series of ratios will be able to predict the response of the entire soft tissue drape. Unfortunately there is considerable individual variation and this can lead to inaccurate predictions of the outcome of orthognathic surgery.

6.3.5 Hard tissue and soft tissue ratios

Regardless of the method of prediction planning the hard and soft tissues are broadly the same and based on historical data, Figure 6.3. Orthognathic surgical simulation programs are based on algorithms that relate soft tissue response to the underlying skeletal change. The soft tissues are stretched, or become thinner as the maxilla is advanced in surgery and interpreting this interaction is important in predicting

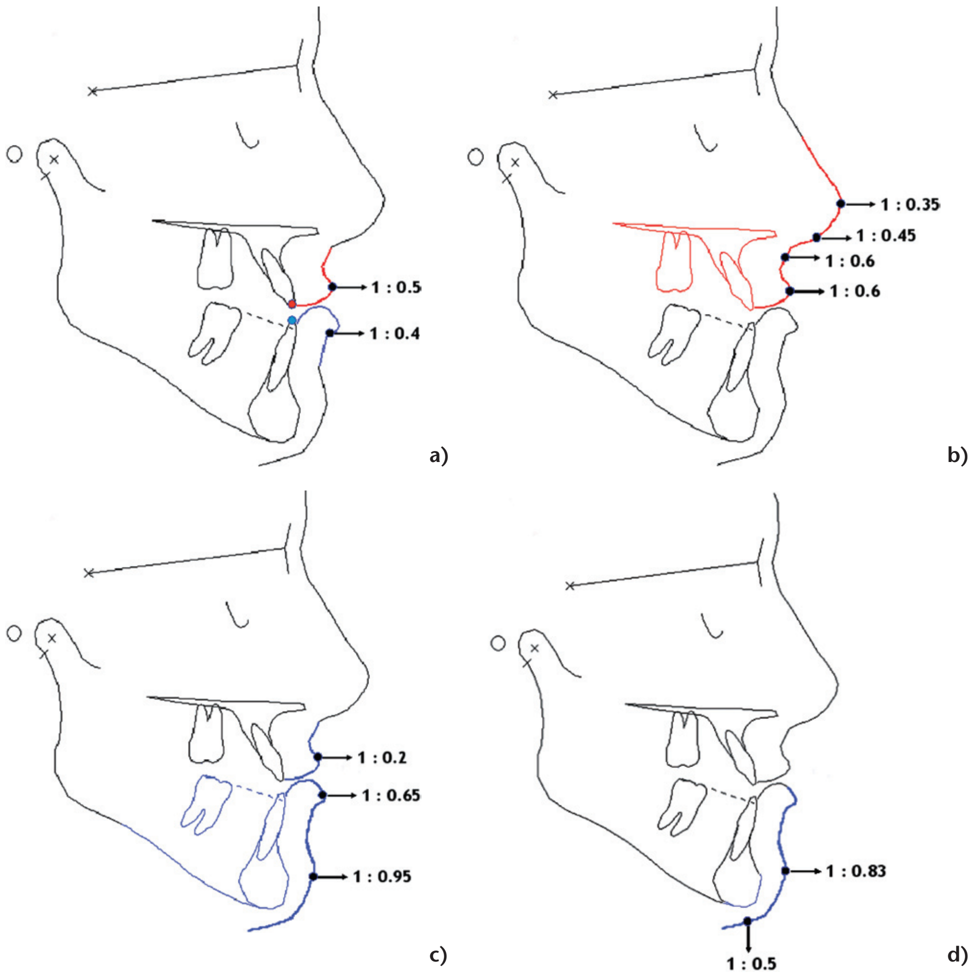


Figure 6.3 Diagrams showing approximate hard to soft tissue ratio for **(a)** incisor movement (orthodontics), **(b)** maxillary surgery, **(c)** mandibular surgery, and **(d)** genioplasty.

the outcome. The relative changes are expressed as mean ratios of soft tissue movements versus those of the hard tissues, and the software packages are based on these values. Therefore, though clinically useful, computerised predictions of soft tissue profile changes after orthognathic surgery are imprecise. This is because the treatment simulation is only as accurate as the data used. Historically, reporting of soft tissue changes following orthognathic surgery concentrated more on profile changes associated with mandibular procedures in the early 1970s. Maxillary procedures were reported, but to a lesser extent, only increasing later in the decade as they became more popular. A review of the literature concerning the soft tissue reaction of the nose tip, nasal base, upper lip and the naso-labial angle to surgical advancement of the maxilla reveals a wide variation of results. Table 6.1 lists a number of studies and their findings, adapted from McCollum et al., 2009.

The use of linear ratios for prediction planning has its limitations. For example, with maxillary advancement, initially there will be no change in soft tissues due to the labial sulcus space between the upper lip and incisors. As the maxilla is advanced, contact will be made with the lip and the magnitude of soft tissue movement will increase. Further advancement of the maxilla results in stretching and resistance of the upper lip. The lip becomes thinner and the ratio of soft tissue change to the underlying bone movement decreases.

Table 6.1 Soft tissue to hard tissue ratios for various soft tissue points (adapted from McCollum et al., 2009).

Soft tissue point	Author	Ratio	Comments
Nasal tip			
	Louis et al., 2001	0.16:1	
	Mansour et al., 1983	0.17:1	
	Teuscher and Sailer, 1982	0.22:1	
	Freihofer, 1977	0.25:1	
	Altug-Atac et al., 2008	0.25:1	
	Soncul and Bamber, 2004	0.30:1	
	Carlotti et al., 1986	0.34:1	
	Rosen, 1988; Chew, 2005	0.35:1	
	Proffit and White, 1991		The nose tip elevates slightly
Nasolabial angle			
	Louis et al., 2001		The nasolabial angle became more acute, decrease of 5°, unrelated to the amount of maxillary advancement
	Conley and Boyd, 2007		The nasolabial angle decreased by 3.9°
Subnasal			
	Proffit and White, 1991	0.20:1	
	Mansour et al., 1983	0.24:1	
	Lines and Steinhauser, 1974	0.39:1	
	Freihofer, 1977	0.50:1	Anterior nasal spine removed
		0.67:1	Anterior nasal spine left intact
	Rosen, 1988	0.51:1	
	Chew, 2005	0.60:1	Chinese adults
	Carlotti et al., 1986	0.67:1	V-Y lip closure and an alar base cinch
Superior labial sulcus			
	Carlotti et al., 1986	0.78:1	
	Lin and Kerr, 1988	0.81:1	A strong correlation with A point
	Chew, 2005	0.73:1	
	Conley and Boyd, 2007	0.96:1	With additional surgical procedure
Labrale superius			
	Altag-Atac et al., 2008	0.40:1	
	Proffit and White, 1991	0.60:1	
	Teuscher and Sailer, 1982	0.63:1	
	Rosenberg et al., 2002	0.64:1	Without an alar base cinch and an intact anterior nasal spine (ANS)
	Chew, 2005	0.73:1	No additional surgery
	Louis et al., 2001	0.80:1	V-Y closure only
	Lin and Kerr, 1998	0.81:1	Found a moderate correlation to A point
	Rosen, 1988	0.82:1	
	Hack et al., 1993	0.82:1	After 1 year
		0.91:1	After 5years
	Carlotti et al., 1986	0.90:1	Alar base cinch. Suture and V-Y lip closure
	Conley and Boyd, 2007	0.96:1	Piriform fossa recontouring, ANS removed
	Peled et al., 2004	0.89:1	Simple continuous suturing
		0.90:1	V-Y lip closure technique

6.3.6 Summary

A shortcoming of two-dimensional prediction planning is that the prediction is only as accurate as the ratios used for soft tissue movements in response to hard tissue changes, which are based on historical, varied and questionable evidence. Moreover, based on profile prediction only anterior-posterior and vertical changes can be determined. The technique does not investigate, and therefore cannot report on, the transverse dimension.

6.4 The two-dimensional planning process

The planning process requires a method of producing a two-dimensional 'virtual' patient by simultaneously capturing the profile facial hard and soft tissues. The lateral cephalogram achieves this but without the colour soft tissue texture. The addition of a profile photograph overcomes this deficiency.

6.4.1 Acquisition of lateral cephalogram

The procedure of lateral cephalogram acquisition should be a relatively simple procedure for orthodontic patients but poses some difficulties for the orthognathic patient. The two main controversies are head position and occlusion.

Head position

At present two methods are used to position the patient's head during exposure; Frankfort Plane (FP) parallel to the floor or in natural head position (NHP). For routine orthodontic patients the use of FP is often satisfactory, but for patients with facial dysmorphology NHP may be more representative taking into account aberrant facial and cranial base positions. Planning should therefore be based on NHP as this is the position the patient's head would adopt during 'normal' function. As indicated in Chapter 2 the position of the patient's head can have a marked effect on the perceived skeletal jaw relationship of the patient.

Occlusion

The routine for orthodontic patients is to take the lateral cephalogram with the teeth in occlusion and the soft tissues at rest and recorded lips at repose. Again, for the majority of orthognathic patients, this may be satisfactory but may not be appropriate for others. Patients who are skeletal class II have a tendency to posture their mandibles forward (perhaps subconsciously) masking the severity of their malocclusion. To overcome this, patients must be imaged in a retruded contact position. High angle class II and class III patients with incompetent lips, often approximate their lips together during imaging to obtain an oral seal. This will distort the labial soft tissues and produce an erroneous profile prediction. The last group of patients are those with vertical maxillary deficiency and they tend to 'over close' due to the excessive freeway space. This is a source of error, as the mandible 'over rotates' into occlusion, the upper lip is distorted by the lower lip; again producing an incorrect initial soft tissue pattern from which to begin prediction planning, as in Figure 6.4. One solution is to construct a wax wafer, with the mandible in the rest position, to provide a stable 'stop' for the patient to bite against during lateral cephalogram and profile imaging.

Procedure for wax wafer construction

1. Position patient in NHP.
2. Place mark on nose and chin.
3. Ask patient to say 'Mississippi' and 'N', lick lips gently and put lips together.
4. Measure distance between marks using calipers.
5. Repeat stages 3 & 4 and record the average value.
6. Place softened wax (several sheets if necessary) into hot water and construct a wax wafer.
7. Place wax wafer in between patient's teeth and ask them to gently close, simultaneously measuring the distance between the marks. Once the measured distance in stage 5 is reached stop, remove wafer and chill in cold water.
8. Trim excess wax buccally with a sharp scalpel to prevent any soft tissue distortion.
9. Re-insert wafer into patient's mouth and re-measure the distance between the dots ensuring there is no soft tissue distortion.
10. Keep this wax wafer safe since it will be used again for photocephalometric planning, three-dimensional stereophotogrammetry image, CBCT and model surgery.

For the application of any computer software package the cephalogram has to be in a digital format. Conventional hard copy cephalograms are scanned as black and white images with a back lit high quality scanner at the desired resolution; size and saved in the appropriate format, that is, normally JPEG, but this is software dependant. This file is then imported into the software prediction package (CASSOS).

6.4.2 Acquisition of the lateral profile photograph

In order to produce the best possible profile prediction, given the limitations of the method, each stage must be executed with the minimum amount of error. The process relies on superimposing the hard and soft tissues of the cephalogram on the soft tissue profile of the lateral profile photograph. Therefore the morphology of the two soft tissue profiles should be identical. The gold standard method, therefore, is to capture the cephalogram and profile photograph simultaneously, whilst the patient is still in the cephalostat. This may not be logistically practical, in which case the photograph needs to be taken after the cephalogram. This should be carried out as soon

Patient in occlusion – note distorted upper lip

Patient at rest with wax wafer in situ

Figure 6.4 Example of a patient who requires a wax wafer to control the vertical dimension and prevent soft tissue distortion.

as possible using a digital camera, maintaining the same soft tissue position as for the cephalogram using the same wax wafer if necessary.

In order to reduce perspective error it is important to make sure that the photograph is taken perpendicular to the patient's sagittal plane with the camera focused on the external auditory meatus. To help enhance the soft tissue profile we have found it useful to place an illuminated source behind the patient. This is either secured to the wall or held by a nurse during photography. When taking the photograph it is important to make sure that the image fills the full view using the zoom function on the camera. If zooming in is required it is vital that only the optical zoom is used and not the digital zoom which may distort the final image.

6.4.3 Superimposition of lateral cephalogram and profile photograph (Matching)

This process involves identifying corresponding landmarks on the lateral cephalogram and the profile photograph. Some software packages use only the anterior soft tissue landmarks for this process whilst others add a posterior landmark forming a triangle. This triangulation process in our opinion is a more accurate technique of superimposition. The method of matching is derived by the programmers and

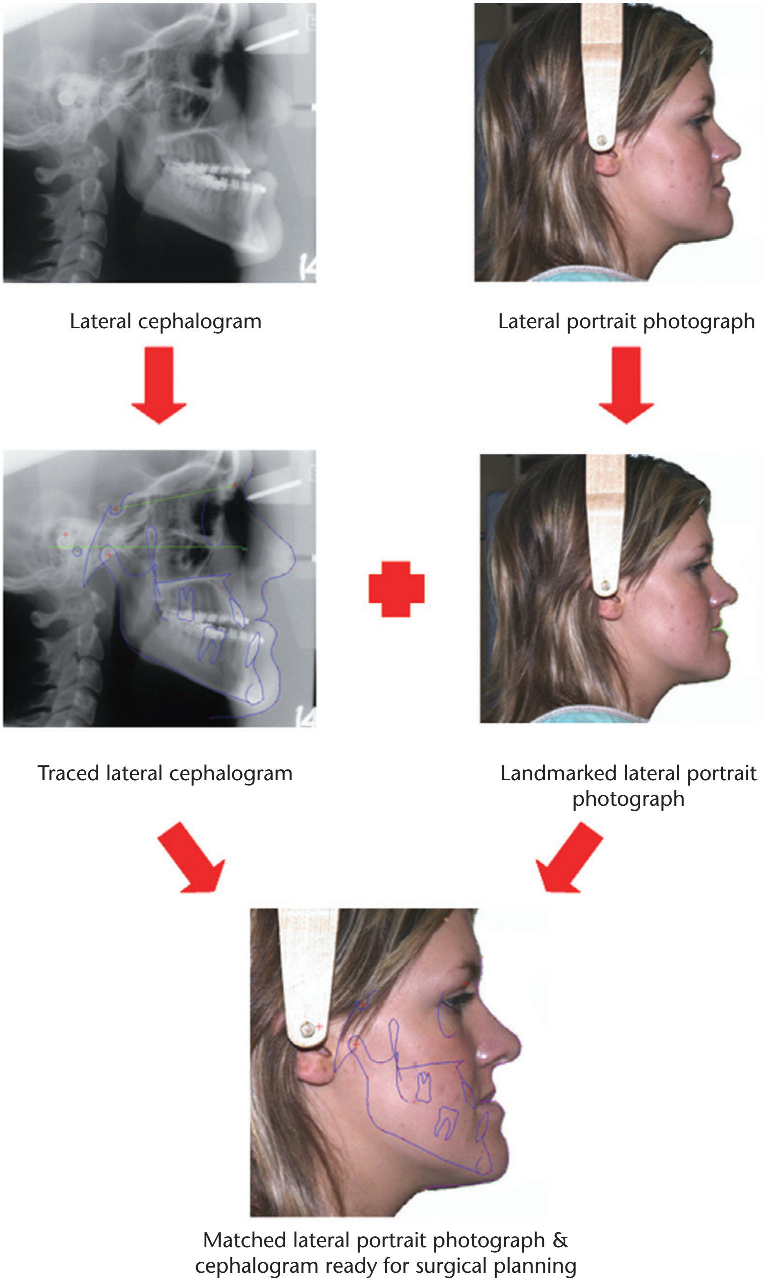


Figure 6.5 Stages of computer prediction from hard tissue acquisition, soft tissue acquisition to merging of 'matched' ready to plan surgery.

therefore the user generally has no ability to change the technique but only to follow it according to the 'matching wizard' (Figure 6.5).

6.4.4 Planning

This is carried out on the matched images which display both the hard and soft tissue profiles of the face. The types of surgical movements that can be carried out are again determined by each computer package. The basic principles should be similar across all prediction software packages in that the maxilla and/or mandible are moved in one piece or segmentally whilst the 'linked' soft tissue moves accordingly. The amount of hard and soft tissue movement will be dependant upon the ratios or algorithms used by the software programmers. Some software packages allow these values to be changed but the question is, what should they be changed to?

When planning for orthognathic surgery, treatment starts with the position of the upper incisors and maxilla, once this is corrected the mandible is then moved into the desired position and the chin position assessed, if necessary a genioplasty is considered. These stages are shown in Figure 6.6. Remember that the required surgical movements produced must produce a class I incisor relationship. It is essential to have the articulated model surgery prediction plan available to allow verification of the magnitudes of skeletal movement and the final occlusion. The surgical movements obtained during model surgery must be similar, within 1mm, to the computerised prediction plan, whilst simultaneously producing the desired profile soft tissue result.

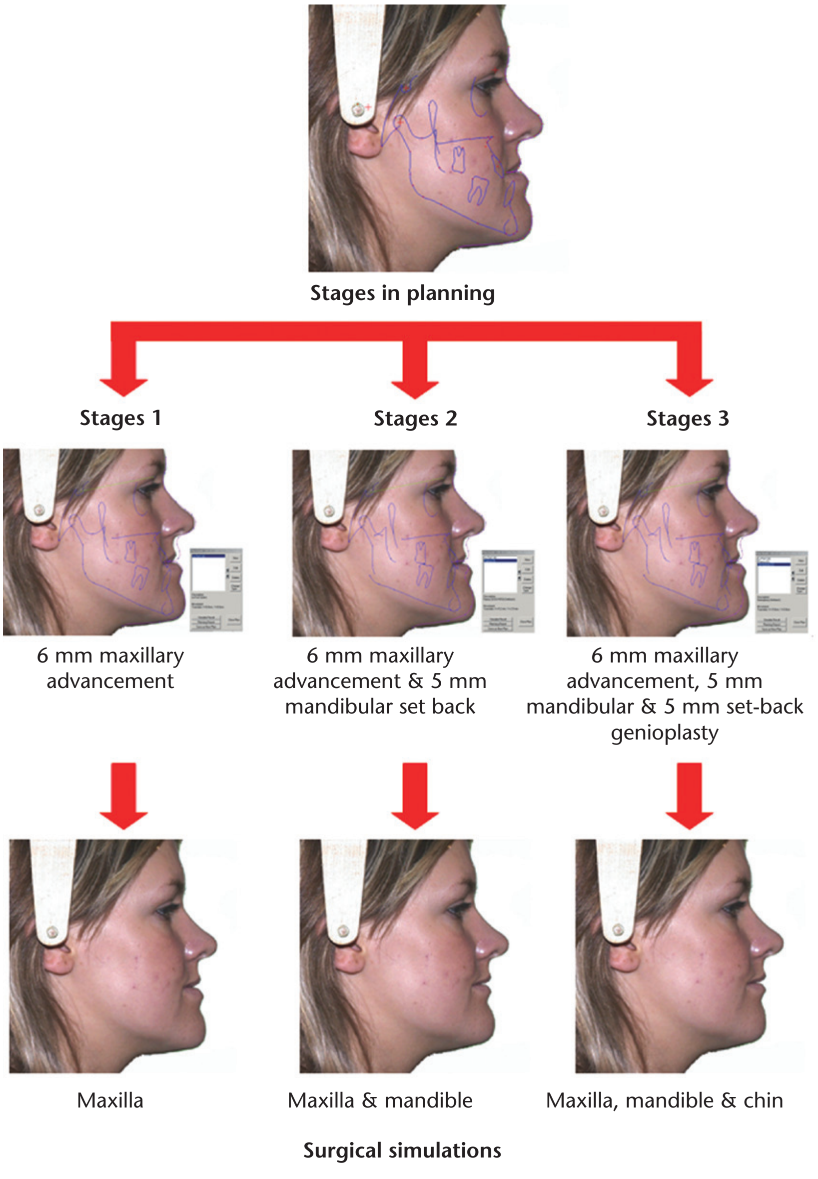


Figure 6.6 Surgical planning stages and simulations generated using CASSOS.

Figure 6.7 Surgical simulations generated using CASSOS. **(a)** transparent superpositions **(b)** before and prediction complete profiles side by side.

6.4.5 Simulation

Each specific jaw effect on the soft tissue is simulated by the computer. In CASSOS this can be displayed as a complete profile before and prediction image or a transparent superimposition of complete profiles, as in Figure 6.7. Again the final simulation image is dependant on the software used for prediction planning.

6.4.6 Surgical planning sheet

The final agreed surgical plan can then be printed out showing the direction and amount of each jaw movement that has been decided upon, as in Figure 6.8. To this any other adjunctive procedures can be added, that is, simultaneous bone graft, extraction of teeth and so on. This is then taken to theatre and used peri-operatively so that no confusion or omission occurs.

6.5 Three-dimensional prediction software

Interest in three-dimensional planning with soft tissue prediction in maxillofacial surgery started over 25 years ago. Many research groups have since continued working on the simulation of soft tissue deformation for maxillofacial surgery. There has been overlap of two and three-dimensional prediction planning as progressive evolution occurred in image acquisition modalities, surgical techniques, patient expectations and technological innovations in both computer hardware and software.

The ideal three-dimensional surgical planning computer software system should integrate all essential requirements forming a pipeline for the entirety of the patient's journey including initial diagnosis, high quality digital three-dimensional data records, virtual surgical planning, wafer construction, accurate prediction and subsequent reviews. At present such a comprehensive surgical planning system does not exist. However the combination of the latest technologies in this field of work is moving closer to the envisioned goal.

Virtual surgery is performed on a virtual patient which has been produced by the 'fusion' of three-dimensional soft, hard and dental tissue. The stages are as follows:

1. Conebeam CT acquisition of the patient. This produces simultaneously volumetric hard and soft tissue data.
2. Colour three-dimensional surface soft tissue capture. This is acquired using either stereophotogrammetry or laser scanning.
3. Superimposition of a colour soft tissue surface image over the soft tissue CBCT volumetric data. This is based on corresponding anatomical landmarks followed by a 'refined' alignment.
4. Three-dimensional dental model production. This is acquired using either laser scanning or CBCT scanning of plaster models or impressions to produce three-dimensional virtual study models.
5. Alignment of virtual dental models into the hard tissue CBCT scan and replacement of the distorted dentition. The dentition is often distorted by the CBCT scan which produces 'streak artefacts', mainly due to metal fixed appliances or metallic restorations.
6. Final image fusion of the three component images into a single 'virtual patient'.

These techniques include the use of computer tomography, three-dimensional reconstructions of models colour texture mapping, and real-time soft tissue modelling. These fused images are then used by the surgeons enabling them to undertake virtual osteotomies on a three-dimensional computer generated skull model with a soft tissue surgical prediction.

The latest versions of software are now in their infancy in predicting in three-dimensional soft tissue

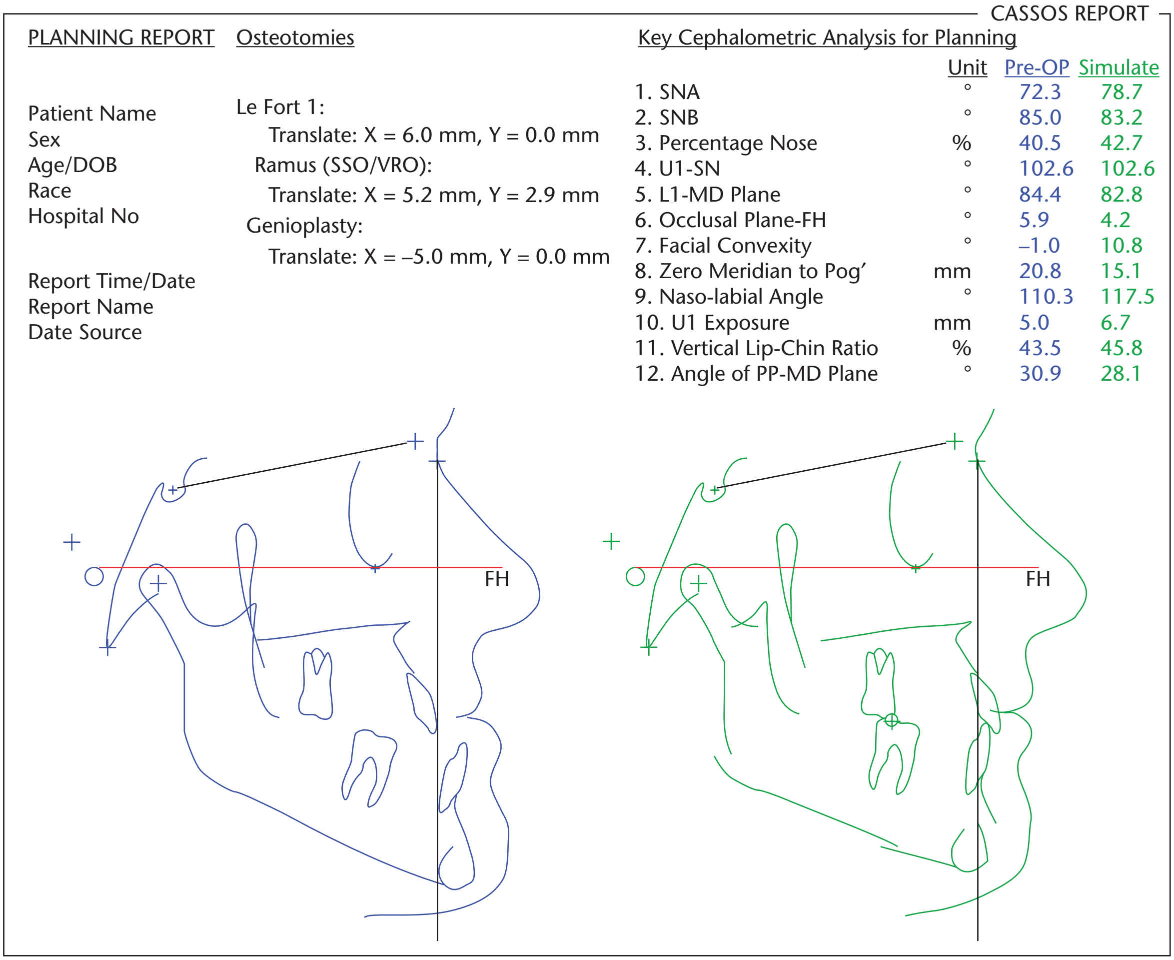


Figure 6.8 Final surgical planning sheets generated using CASSOS.

changes following orthognathic surgery, with some being used in academic research institutions and others being marketed commercially. Programs have been developed specifically for orthognathic surgery, which are being used for orthognathic surgery planning.

The commercially available packages generally attempt to create a three-dimensional environment for assessing maxillofacial anatomy, simulating surgical moves and predicting a soft tissue response. These are often modular or 'wizard' based with each performing various functions: importing DICOM (Digital Imaging and Communications in Medicine) CT image files to create a three-dimensional CT model, map texture information of two-dimensional or three-dimensional photographs to the three-dimensional CT skin surface, provide tools to perform a three-dimensional cephalometric analysis, simulate osteotomies with three-dimensional movements of bony segments and simulate accompanying soft tissue changes.

Case reports and description of the surgical planning pipeline have been published, confirming that three-dimensional soft tissue simulation still requires improvement and the clinician should be careful in communicating this information to the patient, especially for patients with long faces and facial asymmetries.

6.6 The three-dimensional planning process – acquisition of different imaging modalities

6.6.1 CBCT

Conebeam CT simultaneously provides an image of the hard and soft tissues of the maxillo-facial region (see Figure 6.9). As previously discussed, it is important that the occlusion and the position of the soft tissue are appropriate prior to CBCT capture. As with all images created using ionising radiation, the ideal image should be obtained once on the first occasion to reduce radiation exposure to the patient. It is recommended that a CBCT machine in which the patient sits upright rather than lies supine, this should prevent the unwanted effects of gravity on the soft tissues.

Image not available in this digital edition

Figure 6.9 Conebeam CT simultaneously provides an image of the hard and soft tissues of the maxillo-facial region. Source: Benington, P.C., Khambay, B.S. and Ayoub, A.F. (2010) An overview of three-dimensional imaging in dentistry. *Dental Update*, **37**, 494–6, 499–500. © George Warman Publications (UK) Ltd.

Head posture is not generally controllable during CBCT scanning. The patient needs to be placed in a specific volume of space to allow imaging of the desired region and the head needs to stabilised. Stabilising is important to prevent any motion artefacts during the CBCT scan, this is achieved normally by the use of a chin cup. Since the chin cup distorts the soft tissue around the chin region it will render it unusable for planning, it should be avoided and a high head strap used. The head strap should lie as high up towards the hair line as possible in order to prevent any forehead soft tissue distortion. Following imaging the data is stored in a DICOM format which will be later loaded into appropriate software.

6.6.2 Three dimensional stereophotogrammetry

A disadvantage of CBCT imaging is that the soft tissue/air boundary interface is a uniform non-skin coloured texture following rendering. A colour three-dimensional image of the patient can be captured using three-dimensional stereophotogrammetry or laser scanning (see Figure 6.10), which can then be superimposed over the soft tissue of the CBCT scan. As with any superimposition the two images need to be as similar as possible; again this can be achieved with simultaneous CBCT and three-dimensional stereophotogrammetry capture. These obviously can be taken at two different time points but the error of superimposition may then occur. The superimposition technique involves choosing corresponding landmarks on both the CBCT and three-dimensional photographic images. These correspondences need to be as far apart as possible and across all three planes of space to allow accurate superimposition. The computer then rigidly aligns these two images based only

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Figure 6.10 The equipment used to capture three dimensional stereophotogrammetric photograph of the patient. Source: Benington, P.C., Khambay, B.S. and Ayoub, A.F. (2010) An overview of three-dimensional imaging in dentistry. *Dental Update*, **37**, 494–6, 499–500. © George Warman Publications (UK) Ltd.

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Figure 6.11 Stages for alignment and fusion of CBCT scan soft tissue and three dimensional stereophotogrammetric photograph of the patient. Source: Benington, P.C., Khambay, B.S. and Ayoub, A.F. (2010) An overview of three-dimensional imaging in dentistry. *Dental Update*, **37**, 494–6, 499–500. © George Warman Publications (UK) Ltd.

on these corresponding points. To further refine the superimposition specific corresponding areas are chosen. These areas are made up of thousands of points and these are used to refine the alignment. Finally the two images are merged together to produce a CBCT scan with a photo-realistic texture, as in Figure 6.11.

The last structure which requires replacement is the distorted dentition. Nearly all orthognathic patients proceed with metallic fixed orthodontic appliances or may have metallic restorations. During CT scanning these produce streak artefacts which distort the teeth and the occlusion. Therefore techniques have been developed which attempt to replace the dentition, some of which include the 'triple scan' (Swennen et al., 2009).

In this procedure the patient's head is scanned at 0.4mm voxel size from the hair line above to below menton. Alginate impressions are taken of the patient's teeth using a tray which simultaneously records the upper and lower dentition. These impressions are then scanned at a higher resolution of 0.2

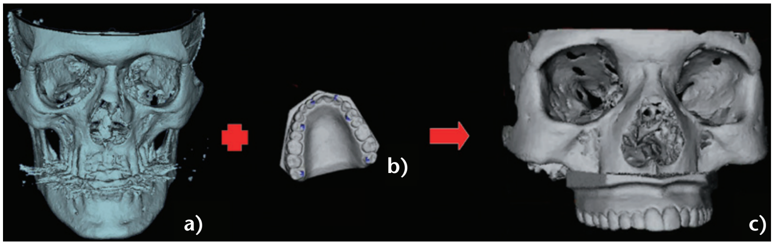

Figure 6.12 Replacement of the distorted dentition (streak artefacts) on the CBCT model **(a)**, with the laser scanned or CBCT image of the plaster teeth **(b)** to produce a 'composite image' with a workable dentition **(c)**.

voxel. Finally the tray is re-inserted into the patient's mouth and a 0.4mm voxel scan is taken of the upper and lower dentition with the tray in situ, this is the second occasion the patient receives a CBCT scan but the area of interest is smaller. Using this method the virtual dentition generated from the CBCT scan of the impression can be used to replace the dentition in the limited field of view patient scan using the tray as the common structure in each image and ignoring the soft tissue which will be distorted by the protruding tray handle. This composite image of skeletal hard tissue and teeth can be used to replace the hard tissue of the CBCT scan of the whole head leaving the undistorted soft tissue intact.

Alternative methods of replacement of the dentition have been developed utilising intra-oral registration techniques which prevent extra-oral soft tissue distortion. These methods require only one CBCT scan of the patient with the intra-oral registration device in situ. An impression of the patients' dentition is than taken with the device in place and a plaster model obtained. Following laser scanning or CBCT scanning of the plaster model, the intra-oral registration device which is common to both the CBCT skull image and the plaster model image is used to align and replace the distortion dentition on the CBCT scan using CAD/CAM software, as in Figure 6.12. (Narin et al., 2013)

6.6.3 Planning

As stressed previously each program will have its own method of planning with regard to procedure type and hard and soft tissue ratios and so on (see Figure 6.13). One of the problems of virtual planning is that the software is unable to deal with 'collision detection' satisfactorily. For example it is possible to carry out a 15mm maxillary impaction on the computer since the maxillary image can be readily displaced through the skull structure. This cannot be avoided unless the program has some form of 'collision detection' algorithm or 'haptic' technology which is used in conjunction with the software. Haptic technology is tactile feedback technology that takes advantage of a user's sense of touch by applying forces, vibrations, or motions to the user. It allows the use of 'feel' in a virtual environment.

The lack of tactile feedback (haptics) makes several aspects of orthognathic planning difficult, including the final occlusion based on intercuspation between the teeth. As clinicians we determine the final occlusion by 'best fit' or maximum contact between the teeth. This is not possible with any degree of accuracy using software which lacks haptic planning. As a result the final occlusion is difficult to find and the wafer becomes difficult to construct. It is expected that in the future this problem will be overcome. In fact it has been suggested that 'virtual' wafers are associated with poor fit because they are too accurate and can not be fully seated!

Once a virtual wafer has been produced, the image can then be exported as an STL file and used in a rapid prototyping machine to produce the physical wafer (Figure 6.14). This method of wafer production obviously negates the use of a face bow and the associated errors, but may introduce new types of inaccuracies which require fuller assessment.

6.7 Navigation surgery

One possible solution to determine the final position of the osteotomy segments during surgery and eliminate the need for occlusal wafers may be using navigational surgery.

The first bone segment navigation system for preoperative planning was the Surgical Segment Navigator (SSN), developed in 1997 at the University of Regensburg, Germany, with the support of the Carl Zeiss Company. This novel system did not require any mechanical surgical guides (such as a headframe). It was based on an infrared (IR) camera and IR transmitters attached to the skull. At least three IR transmitters were attached in the neurocranium area to compensate the movements of the patient's head. There were also three or more IR transmitters attached to the bones which required repositioning. The three-dimensional position of each transmitter was identified by the IR camera, using the same principles as

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Figure 6.13 An asymmetric case planned using Maxilim. The hard tissue images on the left show the virtual osteotomies and on the right the corresponding predicted soft tissue change is shown. Source: Benington, P.C., Khambay, B.S. and Ayoub, A.F. (2010) An overview of three-dimensional imaging in dentistry. *Dental Update*, **37**, 494–6, 499–500. © George Warman Publications (UK) Ltd.

for satellite navigation. The workstation of the Surgical Segment Navigator (SSN) was constantly visualising the actual position of the bone fragments, comparing them with the pre-planned position. Thus, fragments could be very accurately re-positioned into the target position. These surgical navigators have been used routinely in neurosurgery, but are now being used in some centres for orthognathic surgery (Marmulla and Niederdellmann, 1998).

6.7.1 Summary

The evolution of orthognathic surgical techniques and the accompanying need to correct facial and dental aesthetics have made orthognathic surgery planning more complex. The necessity to move the maxilla and mandible in three planes of space has required surgical expertise and clinical judgement, to ensure both the surgeon's and the patient's expectations are fulfilled. Therefore the long-term aim for

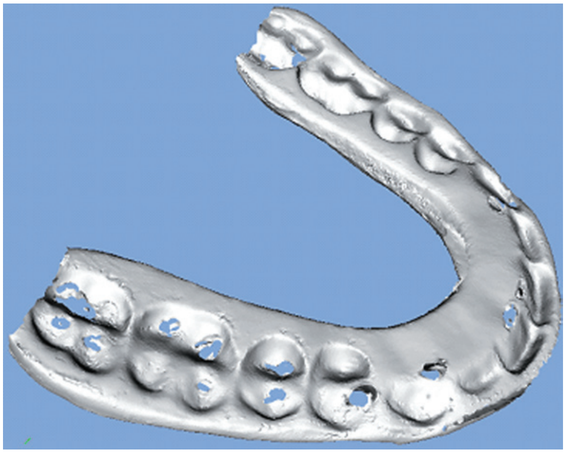

Figure 6.14 Virtual wafer ready for rapid prototyping in STL format.

orthognathic surgery planning is to produce an accurate method of three-dimensional assessment, develop a planning and prediction tool that will also allow digital construction of study models and occlusal wafers, thus eliminating some of the inherent inaccuracies in the current methods of planning.

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7 Basic orthognathic surgical procedures

Chapter overview

Intended learning outcomes

By the end of this chapter the reader should:
- Have an understanding of the indications and applications of the various orthognathic surgical procedures.
- Have an awareness of the basic orthognathic surgical techniques.
- Have an awareness of the potential surgical complications.
- Have an understanding of the general medical consideration during and following orthognathic surgery.

Handbook of Orthognathic Treatment: A team approach, First Edition. Ashraf Ayoub, Balvinder Khambay, Philip Benington, Lyndia Green, Khursheed Moos, and Fraser Walker.

7.1 Introduction

This chapter illustrates basic surgical techniques for the correction of dento-facial deformities, it also highlights the main indications and potential complications of each procedure.

7.2 Le Fort I osteotomy

This procedure is used routinely for the correction of maxillary positions and discrepancies in jaw size.

7.2.1 Indications

1. Correction of the hypoplastic and retrognathic maxilla. Due to the anatomical position of the pterygoid plates, a maxillary posterior shift is limited to 2–3 mm and removal of bone in the tuberosity area may be required. The pterygoid plates should prevent a significant posterior shift of the maxilla.
2. Correction of vertical maxillary excess and deficiency. Vertical movements of the maxilla at the Le Fort I level can be used for the correction of disparities between the upper lip length and the magnitude of teeth show at rest and with maximum smile. Surgical lengthening of the upper lip is usually limited to 2–3 mm.
3. The correction of occlusal canting by impacting the longer side or down grafting the shorter side or a combination of both.
4. Correction of an anterior open bite. This is usually achieved by impaction of the posterior part of the maxilla to allow the mandible to auto rotate and close the anterior open bite.
5. Correction of a narrow maxilla and narrow dental arch.
6. Correction of a prominent anterior maxillary segment with or without extractions.

7.2.2 Surgical technique

Preparation

Under general anaesthesia an external midline reference point is usually established at the nasion point using either a Kirschner wire or a mono-cortical screw. This is used as a reference point for measuring the vertical height, before mobilising the maxilla, in relation to the upper incisal edge or the central point between the orthodontic brackets on both the right and left maxillary central incisors (Figure 7.1a). The distance between the medial canthus and the tip of the canine can also be used to record the vertical height before surgery. The distances between internal points marked on the maxilla above the level of the Le Fort I osteotomy cut can provide reference for vertical height changes and horizontal shifts. The right and left bases of the nose (alar bases) are marked through the skin using the sharp end of a needle to measure the width of the nose before surgery (Figure 7.1b).

Figure 7.1a Recording the anterior facial height before surgery.

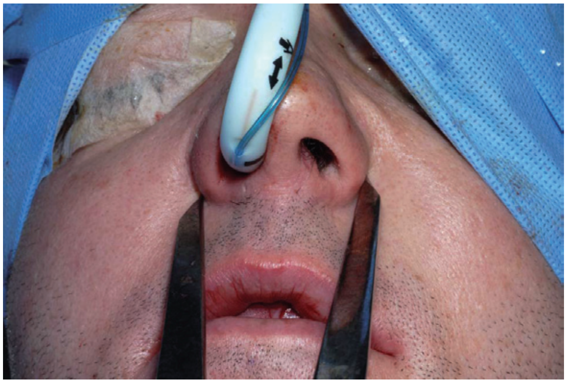

Figure 7.1b Recoding the alar base width before surgery.

Soft tissue reflection

A U-shape incision is made across the mucosa and deep to the periosteum of the buccal sulcus from the distal aspect of the first molar around to the opposite side (Figure 7.2a). A full mucoperiosteal flap is raised to expose the maxilla from the pyriform aperture anteriorly to the pterygo-maxillary suture posteriorly (Figure 7.2b). The infra orbital nerves are identified and protected. The nasal muco-periosteum is reflected from the floor of the nose starting at the lateral margin of the pyriform aperture and extended medi-

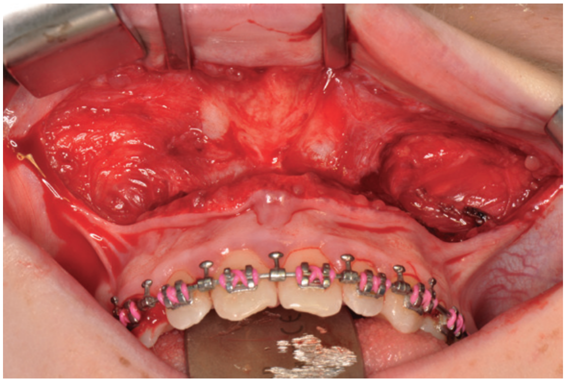

Figure 7.2a A U-shape muscosal incision on the labial sulcus across the mucosa and deep to the periosteum.

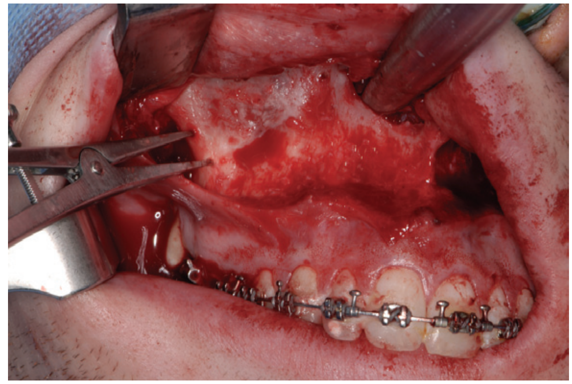

Figure 7.2c Reflection of the nasal mucosa using Hawath's periosteal elevator and recording the posterior height of the maxilla.

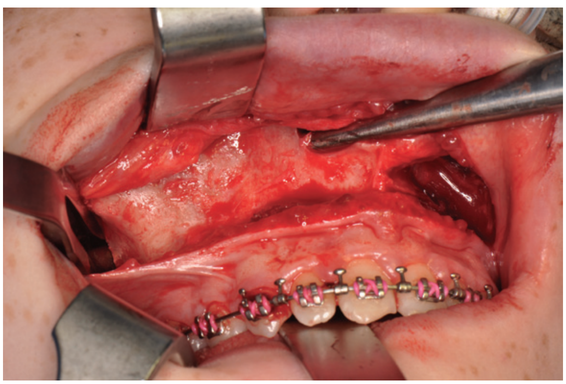

Figure 7.2b A full mucoperiosteal flap is from the pyriform aperture anteriorly to the pterygo-maxillary suture posteriorly.

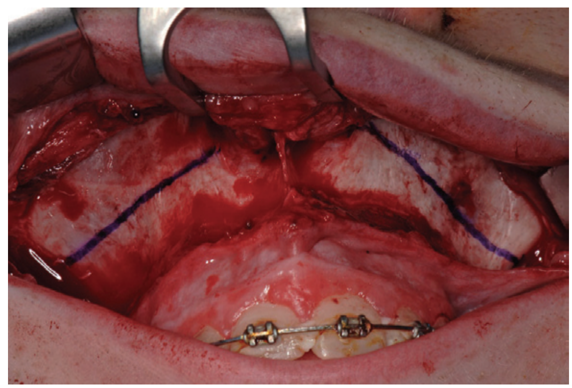

Figure 7.2d Marking the lateral surface of the maxilla to guide the level of bone cut and avoid occlusal canting.

ally up the nasal septum with a Howarth periosteal elevator. Internal reference points above the molar region can be applied to measure the posterior facial height which guides the vertical changes of the posterior part of the maxilla (Figure 7.2c). Marking the level of bone cut on the maxilla maintains the vertical symmetry of the osteotomy and prevents canting of the occlusion (Figure 7.2d).

Bone cut

The outer surface of the maxilla is marked using a marking pen (Figure 7.2d) before it is cut using a surgical bur or a saw from the buttress part of the zygoma upward and forward to the lateral corner of the pyriform aperture about 8 mm above the apices of the roots (Figures 7.3a, 7.3b). A curved saw is used to complete the cut backwards and downwards to the pterygo maxillary suture. The lateral nasal wall is cut from the palate using a lateral nasal chisel (Figure 7.3c). The maxillary septum is separated from the palate using a nasal septal chisel (Figure 7.3d).

Separation and mobilisation

The maxillary bone is gradually separated from the base of the skull using a Smith spreader on each side (Figure 7.4a). Pterygo-maxillary disarticulation is achieved using Rowe's disimpaction forceps (Figures 7.4b, 7.4c, 7.4d). Some surgeons advocate the use of a curved osteotome but the inappropriate application of this instrument for the separation of the maxillary tuberosity from the pterygoid plates can lead to excessive bleeding and fracture of the pterygoid plates. Once the maxilla is down-fractured a pair of Tessier mobilisers is inserted behind the tuberosities

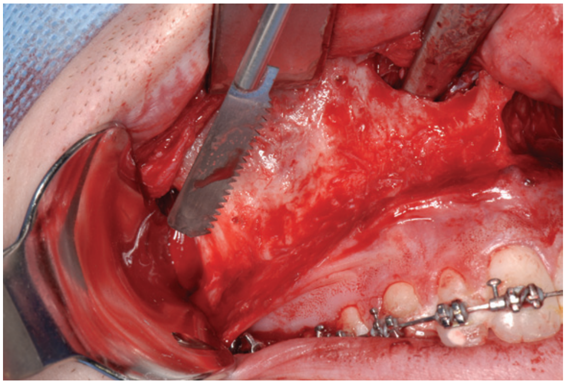

Figure 7.3a Bone cut using surgical saw about 8 mm above the apices of the teeth.

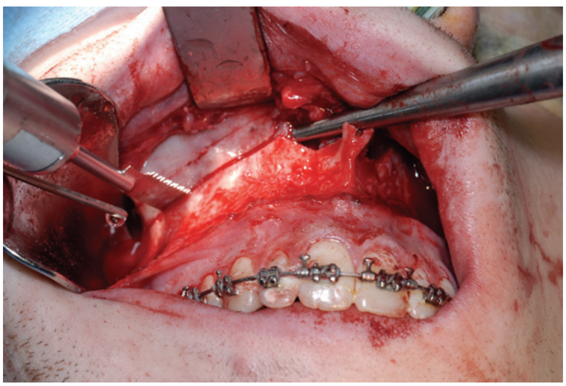

Figure 7.3b Saw from buttress part of the maxilla upward and forward to the lateral corner of the pyriform aperture.

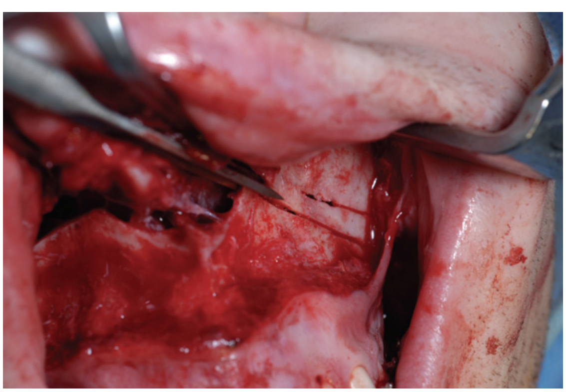

Figure 7.3c Cutting the lateral nasal wall using a lateral nasal chisel.

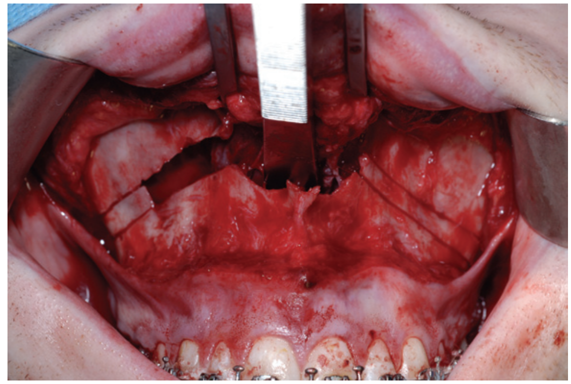

Figure 7.3d Separation of the septum from the palate using a nasal septal chisel.

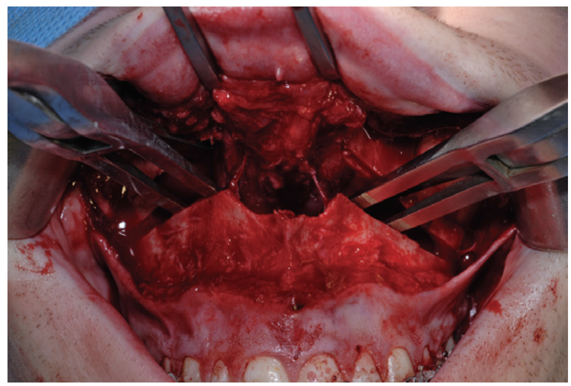

Figure 7.4a Gradual separation of the maxilla from the base of skull using a Smith spreader.

Figure 7.4b The application of Rowe's dysimpaction forceps for pterygo-maxillary disarticulation.

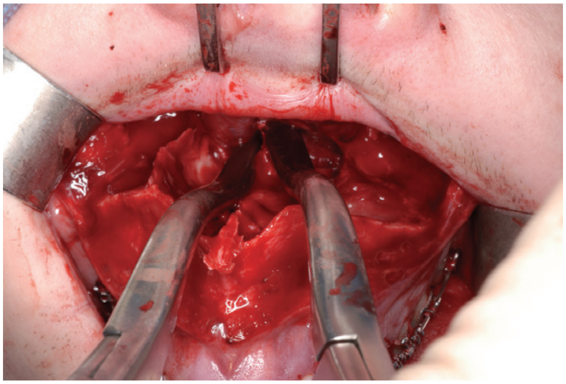

Figure 7.4c The position of the mobilisation forceps' blades on the nasal surface of the maxilla.

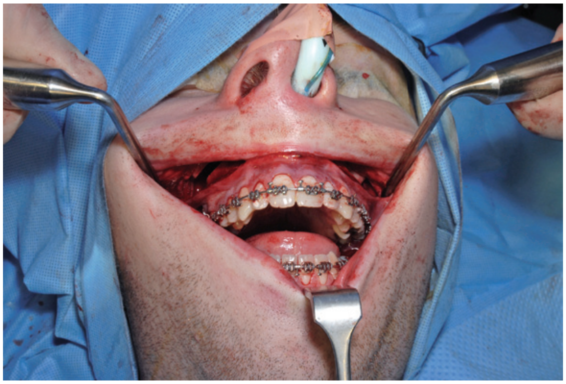

Figure 7.4e The application of Tessier mobilisers behind the tuberosities to mobilise and advance the maxilla.

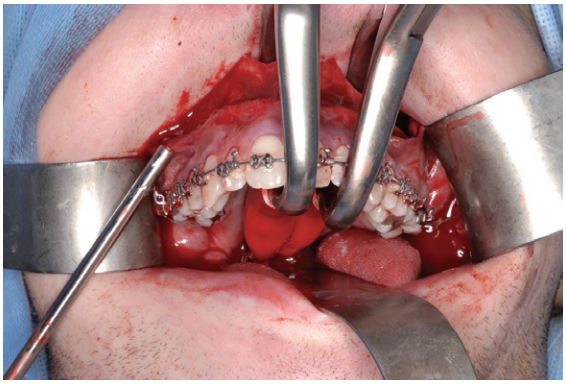

Figure 7.4d The position of the mobilisation forceps' blades on the oral surface of the maxilla.

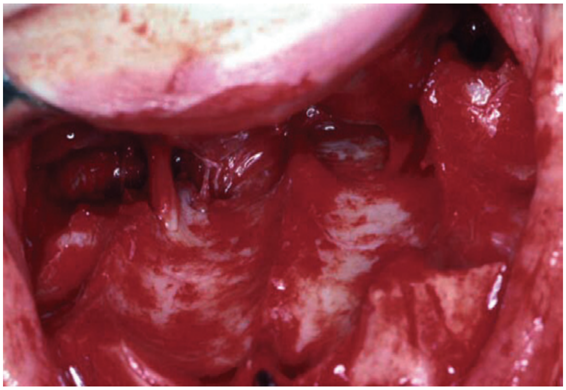

Figure 7.4f Shows the greater palatine artery at the posterior edge of the palate.

to mobilise and advance the maxilla (Figure 7.4e). This is a mandatory manoeuvre aimed at stretching the soft tissues attached to the maxilla, to minimise postoperative relapse. Damage to the greater palatine artery (Figure 7.4f) should be avoided during the manoeuvre.

Final adjustments and fixation

The prefabricated occlusal wafer is seated on the incisal edges and occlusal surfaces of mandibular teeth. The maxilla is then placed in the pre planned anteroposterior occlusal relationship and kept in place using temporary intermaxillary fixation. The vertical height is adjusted in relation to the external or internal reference points to achieve the pre planned vertical position of the maxilla. Bone removal is required for maxillary impaction. It is usually removed from the buttress area of the maxilla, and from the septum at the mid-palatal suture, the medial wall of the maxillary sinus (the lateral nasal wall) and the inferior border of the nasal septum itself which is readily accessible from the nasal surface of the palate (Figure 7.4f). Inferior turbinectomy may be required in cleft cases and where significant impaction is needed. In cases of maxillary down grafting, iliac bone graft may be inserted as interpositional material (Figure 7.5a). However, this will depend on the magnitude of the inferior maxillary shift, the associated advancement and quality of bone. The standard method of fixing the maxilla into its final position is by using four 1.7 mm bone plates. Two placed on each side, one at the pyriform aperture and the other in the buttress part of the maxilla (Figure 7.5b). Poly L-Lactide (PLLA) resorbable plates can also be used for fixation (Figures 7.5c, 7.5d). The stability of a large maxillary advancement can be improved with the insertion of cortico-cancellous bone blocks in the gap created between the maxilla and the base of the skull at the

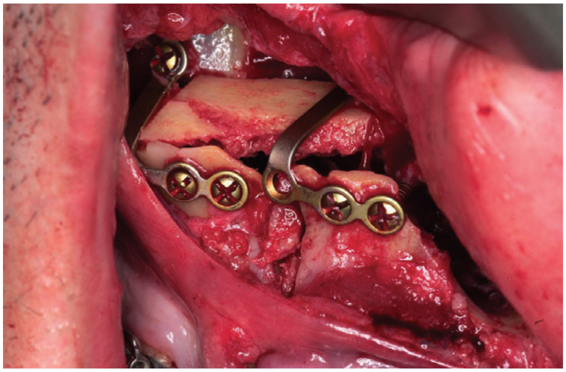

Figure 7.5a Bone graft inserted as interpositional material.

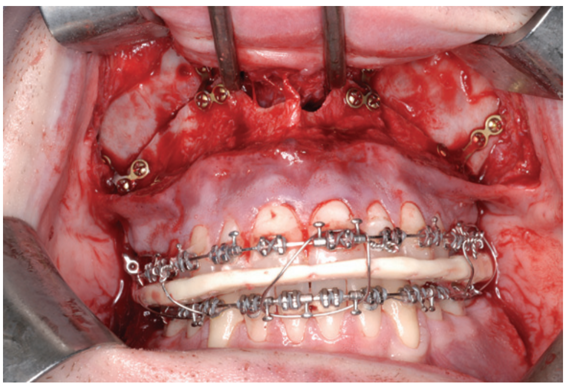

Figure 7.5b Two 1.7 mm plates placed on each side, one at the pyriform aperture and the other in the buttress part of the maxilla.

buttress area posteriorly, at the buccal surface of the maxilla and at the pyriform aperture. There is considerable debate in the literature regarding the indications of bone grafting, however, there is a general agreement that maxillary advancements more than 8 mm with or without vertical height augmentation would benefit from grafting.

Closure

A V-Y closure may be considered where lip lengthening is required. This is achieved by suturing, in the midline, the mucosal surface of the upper lip first followed by suturing the mucoperiosteal flap bucally and labially (Figure 7.6a). A cinch stitch can then be applied to maintain or achieve the desired alar base width which tends to widen in Le Fort I osteotomy cases. This is usually carried out using a 3(0) non-resorbable suture that is passed from inside the mouth underneath the reflected mucoperiosteum to the skin of the right alar base (Figure 7.6b), then

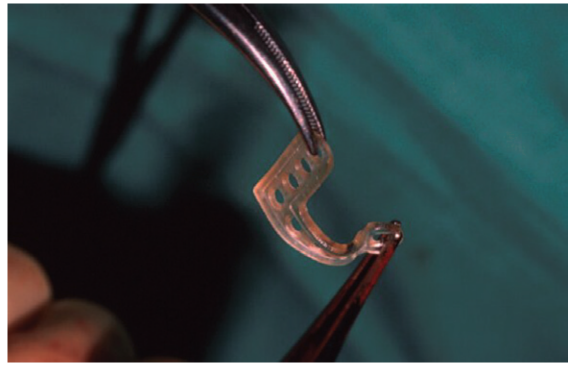

Figure 7.5c Poly L-Lactide (PLLA) resorbable plates.

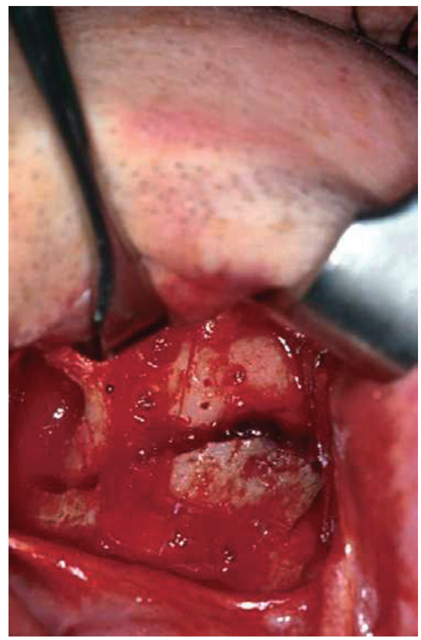

Figure 7.5d The application of PLLA plates for fixation of Le Fort I osteotomy.

through the same penetration point of the skin to inside the mouth to anchor the alar cartilage. This is repeated with the same suture for the other alar cartilage of the opposite side and the two ends of the suture are then anchored through a hole drilled in the anterior nasal spine (Figure 7.6c). A cinch stitch can be also carried out by anchoring each alar cartilage separately to a drilled hole through the anterior nasal spine.

7.2.3 Le Fort I segmental osteotomies

Mid-palatal split (Figures 7.7a, 7.7b)
Indications. The main indication of this surgical procedure is the correction of a narrow maxilla and

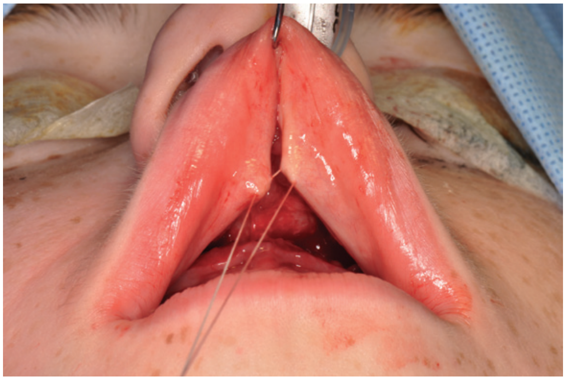

Figure 7.6a Suturing, in the midline, the mucosal surface of the upper lip first followed by suturing the mucoperiosteal flap bucally and labially to achieve a V-Y closure for lip lengthening.

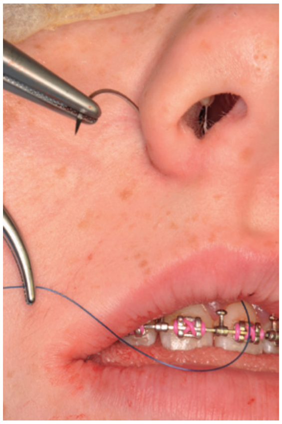

Figure 7.6b Cinch stitch passed from inside the mouth to the skin of the base of the nose to anchor the alar cartilage.

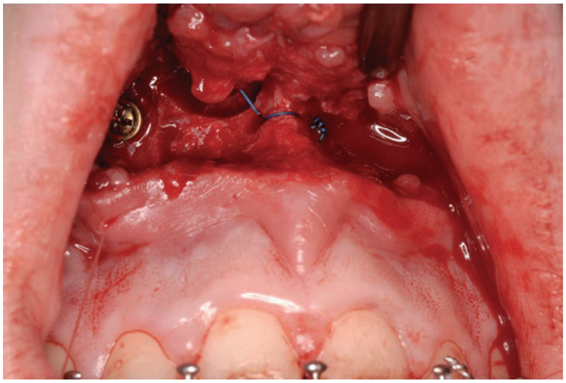

Figure 7.6c A cinch stitch carried out by anchoring alar cartilages to a drilled hole in the anterior nasal spine.

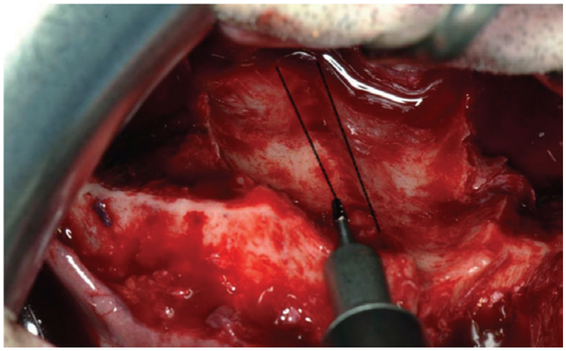

Figure 7.7a A fine fissure bur is used for the para sagittal palatal bone cut.

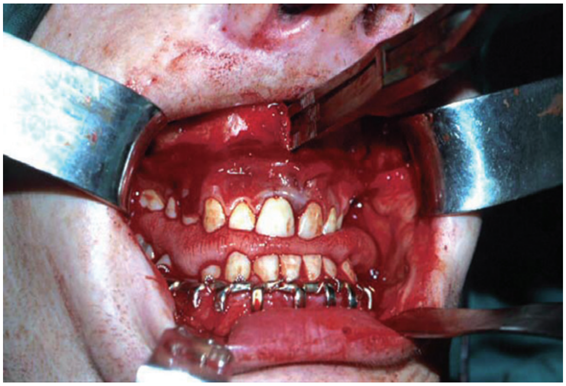

Figure 7.7b The application of Smith spreader to split the maxilla into two segments across the midline.

narrow dental arch. This technique deals with posterior cross bite where correction is indicated and is beyond the scope of orthodontic treatment. A maximum 8–10 mm increase in the posterior maxillary width can be achieved with mid-palatal osteotomy. It is an unstable procedure, therefore, adequate fixation and mid-palatal bone grafting are necessary to reduce postoperative relapse.

Technique. Right and left para-sagittal bone cuts are made through the nasal surface of the palate with a fissure bur (Figure 7.7a). A fine fissure bur and a thin spatula osteotome are used for the remaining vertical labial bone cut between the roots of the central maxillary incisors and palate. This area is exposed by tunnelling from above the labial mucoperiosteum between the central incisors. The attached gingiva should be kept intact. Following this, the maxilla can be split into two segments using a Smith spreader

(Figure 7.7b). The removed mid-palatal strip of bone can be cut into sections for grafting and wedging in the same surgical site at the mid-palatal suture following the mobilisation of the two halves of the maxilla. Mobilisation is essential, and this is usually achieved after reflection of the palatal mucoperiosteum at the para-sagittal cut from the nasal side. Maintaining the integrity of the mucoperiosteum is essential in segmental Le Fort I osteotomies and unavoidable perforations require careful suturing. Some surgeons advise additional fixation of the two maxillary segments by applying an extra plate on the labial surface of the maxilla below the pyriform aperture.

Two piece maxillary osteotomy (Figures 7.8a, 7.8b)
The main indication of this surgical procedure is the correction of an anterior open bite. This is usually achieved by impaction of the posterior part of the maxilla to allow the mandible to auto rotate and close the anterior open bite.

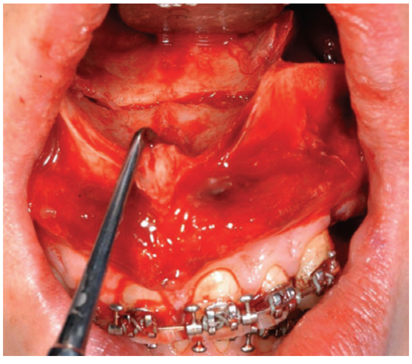

Figure 7.8a The horizontal cut across the palate to separate the anterior part of the maxilla from the posterior segment.

Surgical technique. This can be most easily achieved once the maxilla is down fractured at the Le Fort I level. Access to the buccal surface of the maxilla in the area of the first or second premolars is achieved by incising the gingival sulcus around the premolars and tunnelling the mucoperiosteum using a periostel elevator. The bone cuts are made using a tapered fissure bur from the horizontal maxillary osteotomy line to the alveolar crest on each side of the maxilla. A thin spatula osteotome can facilitate this bone cut which should extend to involve the palatal bone whilst maintaining the integrity of palatal mucoperiosteum. The ends of the two vertical osteotomy lines are connected to the horizontal bone cut across the nasal surface of the palate (Figure 7.8a). The anterior maxillary segment can then be mobilised, repositioned in to its final position guided by the acrylic occlusal wafer and fixed in position using two plates on each side (Figure 7.8b).

Three-piece maxillary osteotomy (Figure 7.8c)
Indication. The main indication of this surgical procedure is the correction of a narrow posterior maxilla and allowing differential vertical movements of the anterior and posterior segments of the maxilla. The procedure should be considered for correction of anterior open bite which is associated with a narrow maxillary dental arch posteriorly.

Technique. This surgical technique provides a combination of anterior maxillary osteotomy and posterior mid-palatal split. The sagittal palatal bone cut is achieved as explained above but would only extended to the horizontal palatal cut of the anterior part of the maxilla, that is, no vertical cut is made between the roots of the central incisors. The three bone seg-

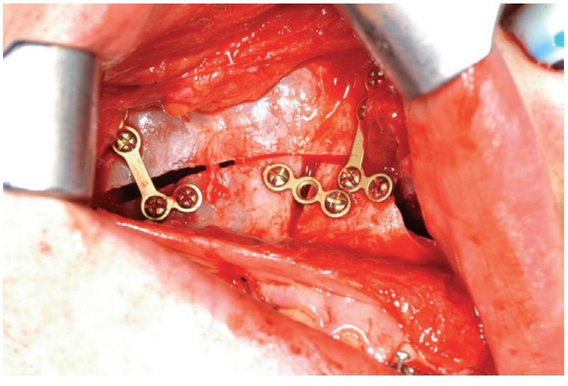

Figure 7.8b Fixation of the two-piece maxillary osteotomy using 1.7 mm titanium plates.

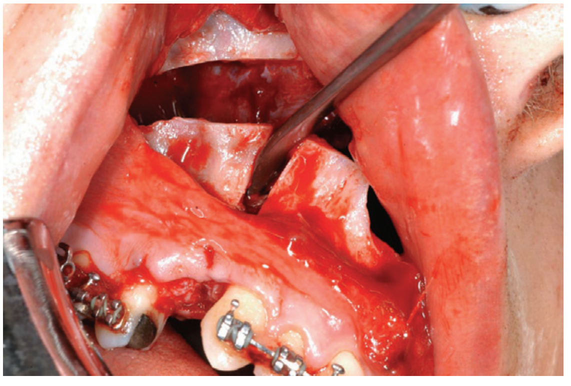

Figure 7.8c Anterior maxillary osteotomy of the three-piece maxillary osteotomy.

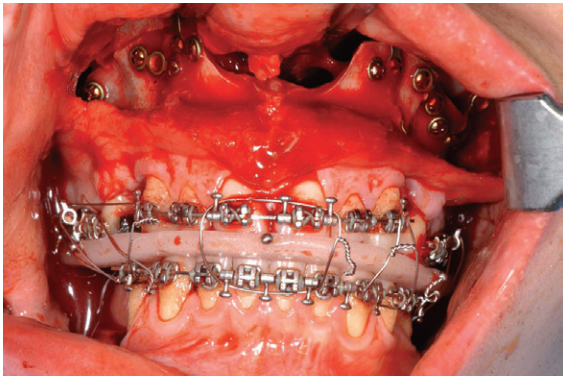

Figure 7.8d Four piece Le Fort I maxillary osteotomy.

ments (right posterior maxillary, left posterior maxillary and anterior maxillary segments) are adjusted into their pre-planned position, guided by the acrylic occlusal wafer, temporary inter maxillary wiring is applied and the segments are finally fixed in place with mini plates.

Four-piece maxilla (Figure 7.8d)
Indication. The main indication of this surgical procedure is the correction of a transverse maxillary deficiency which involves both the inter-canine and inter-molar width. It also allows differential vertical movements of the anterior and posterior segments of the maxilla. The procedure should be considered for correction of anterior open bite which is associated with a narrow maxillary dental arch at the canine and molar regions.

Technique. This provides a combination of the full antero-posterior mid-palatal split of the maxilla, including the vertical labial bone cut between the roots of central incisors, and the standard anterior maxillary osteotomy. The sagittal palatal bone cut is achieved as explained above. This is then connected with the horizontal palatal cut of the anterior maxillary osteotomy. This allows widening of the posterior part of maxilla medio-laterally as well as an increase in the inter-canine width. The maxilla is split into four segments (right posterior maxillary, left posterior, right anterior and left anterior) which are then adjusted into their pre-planned position, using the occlusal wafer, and fixed in place using mini plates.

7.2.4 Complications

The following are the most common complications associated with segments Le Fort I osteotomies:

1. Damage to the side of the roots and apices of the teeth adjacent to the osteotomy cut.

Figure 7.9 A preoperative and postoperative profile photograph shows the improvement of appearance following anterior maxillary osteotomy.

2. Gingival recession and loss of the inter-dental papillae.
3. Loss of the vitality of the teeth adjacent to the osteotomy lines.
4. Oro-antral communications due to perforation of the palatal mucoperiosteum.
5. Relapse which is the most common complication.
6. Loss of bone segments due to infection and damage to the blood supply which is rare.

7.3 Anterior maxillary osteotomies

7.3.1 Indications

The anterior segment of the maxilla can be osteotomised separately using the Wassmund or the Wunderer approach. The following are the main indications for this osteotomy:

1. Maxillary prognathism where posterior movement of the maxilla is not required.
2. Anterior vertical maxillary excess with excessive gingival show.
3. Protrusion of the anterior segment of the maxilla with proclined upper incisors but a satisfactory posterior occlusion (Figure 7.9).
4. Anterior open bite caused by anterior vertical deficiency of the maxilla with reduced tooth show.

7.3.2 Surgical technique

Wassmund approach
This approach is used for the correction of discrepancies in the antero-posterior position and axial inclination of the anterior part of the maxilla whilst producing minimal change in vertical height.

A curved or inverted L incision is performed above the apex of the first premolar. A buccal mucoperiosteal flap is reflected to expose the buccal surface of the maxilla from the alveolar crest to the pyriform aperture on each side. The nasal floor is reflected using the rounded end of the Mitchell's osteotrimmer. Through a palatal gingival sulcus releasing incision from the canine to the second premolar the palatal mucoperiosteum is tunnelled from the alveolar crest to the mid-palatine suture bilaterally.

A bone cut is performed on each side using a surgical fissure bur after the extraction of the first premolar or at an edentulous area distal to the maxillary canine. The cut extends from the pyriform fossa distally above the apices of the teeth and vertical down at the edentulous area or through the alveolar bone before or after the extraction of the first premolar (Figure 7.10a). The buccal cortical bone cut extends to the palatal cortex. The use of a spatula osteotome facilitates the bone cut at the maximum height of the palate. The tunnelled palatal mucoperiosteum (Figure 7.10b) provides the necessary access for a surgical fissure bur and osteotome to complete the bone cut. Through a vertical incision of the labial mucoperiosteum overlying the anterior nasal spine (Figure 7.10c, a) nasal septal chisel is applied to separate the nasal septum for full mobilisation of the anterior maxillary segment. The palatal mucoperiosteum provides the main blood supply to the osteotomised segment and should be kept intact.

Guided by the occlusal wafer and temporary intermaxillary fixation the segment is fixed in the preplanned position using mini plates. Bone removal is usually required between the two cut surfaces (anterior and posterior maxillary bone segments), both buccally and palatally, to allow accurate positioning of the anterior maxillary segment. Wounds are closed using 4 (0) resorbable sutures.

Wunderer approach

This approach is used mainly for correction of vertical discrepancies of the anterior part of the maxilla with minimal antero-posterior changes.

The approach to the buccal surface of the maxilla is similar to the Wassmund approach. The buccaly bone cut is usually at the first premolar region.

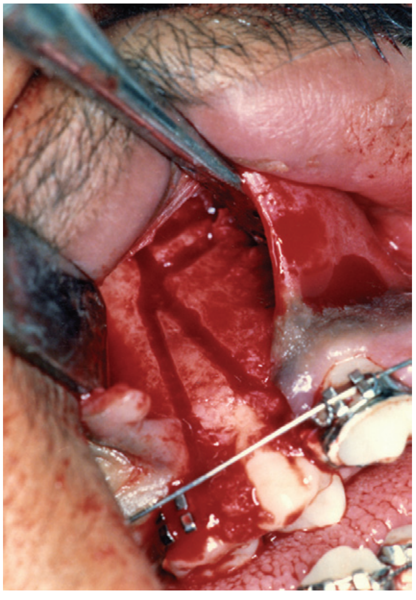

Figure 7.10a Bone cut extending from the pyriform fossa distally above the apices of the teeth and vertical down on the buccal surface of the maxilla.

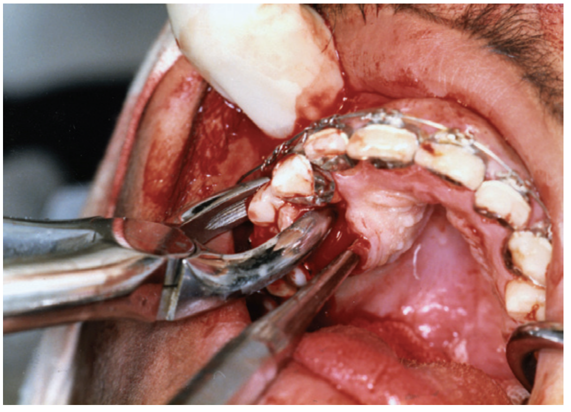

Figure 7.10b Tunnelling of the palatal mucoperiosteum to facilitate palatal bone cut.

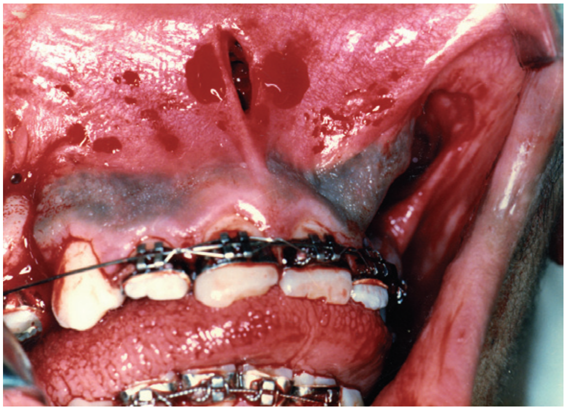

Figure 7.10c A vertical incision of the labial mucoperiosteum overlying the anterior nasal spine to facilitate cutting of the nasal septum.

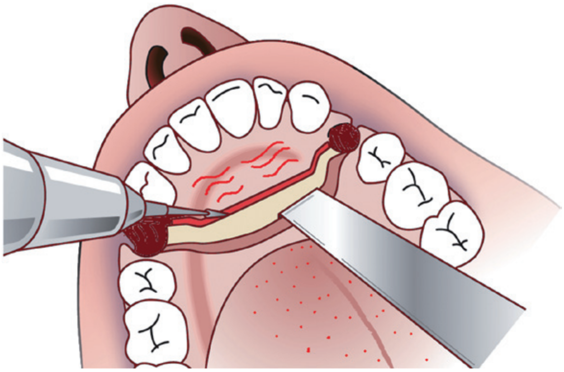

Figure 7.11a Transverse palatal incision from the first premolar of one side to the other, the palatal mucoperiosteum is reflected backward and the palatal bone is exposed. Source: Medical Illustration Department, Glasgow Royal Infirmary, Greater Glasgow & Clyde NHS Trust.

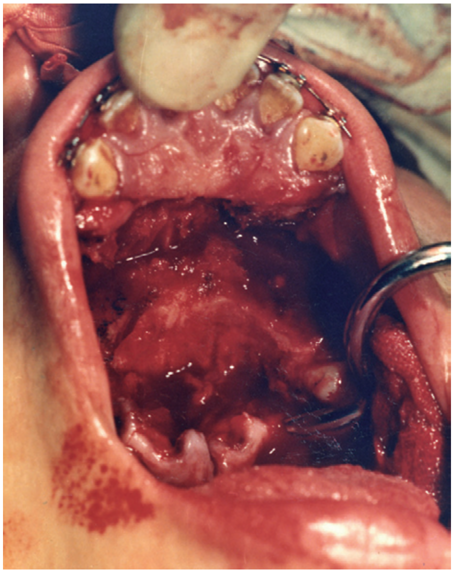

Figure 7.11b Rotating the osteotomy segment in an anti-clockwise direction so that its nasal surface becomes accessible through the palatal incision.

Through a transverse palatal incision from the first premolar of one side to the other, the palatal mucoperioteum is reflected backward and the palatal bone is exposed (Figure 7.11a). The palatal bone cut is readily performed using a surgical fissure bur. The application of a spatula osteotome through the bone cuts on the buccal and palatal surfaces facilitates the mobilisation of the anterior segment of the maxilla. The osteotomy segment is rotated in an anti-clockwise direction (Figure 7.11b) so that its nasal surface becomes accessible through the palatal incision (Figure 7.11c). Bone is removed from the latter using a surgical cylindrical bur (Figure 7.11c) or bone nibblers for upward movement of the anterior maxillary segment without interference with the nasal mucoperiosteum.

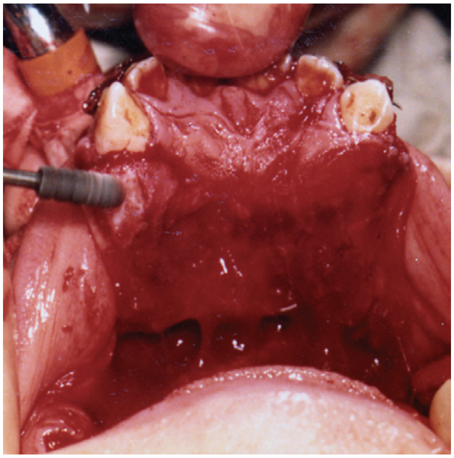

Figure 7.11c Bone removal from the posterior edge and superior surface of the anterior part of the maxilla.

Fixation of the anterior maxillary segment and closure of the surgical wounds are similar to the Wassmund approach in addition to careful suturing of the palatal flap.

7.3.3 Complications

1. Perforation of the palatal mucoperiosteum with the Wassmund approach and inadequate closure of the palatal mucoperiosteum with the Wunderer approach can lead to an oro-nasal fistula. Careful tunnelling of the palatal mucoperiosteum and double suturing of the palatal mucoperiosteum in the Wunderer approach should minimise this risk. An oro-nasal fistula requires surgical repair.
2. Gingival recession and damage to the roots of the teeth adjacent to the osteotomy cut are potential complications which are avoidable through careful planning and presurgical orthodontic adjustment of the angle of the roots of the teeth adjacent to the osteotomy cut.
3. Relapse is usually minimal with these procedures due to limited occlusal changes and minimal alterations of the oro-facial muscles.

General complications associated with maxillary osteotomies

1. Surgical complications

Excessive bleeding during surgery is unusual. The average blood loss associated with Le Fort I osteotomy is about 500 ml. Excessive blood loss during surgery can be prevented with careful handling of the soft tissues and by avoiding damage to major blood vessels close to the surgical sites. Excessive bleeding may result from damage of the descending greater palatine vessels and the pterygoid venous plexus. This can be reduced by avoiding high posterior maxillary cut, ensuring gentle pteyrgo-maxillary disarticulation and by the use of hypotensive anaesthesia.

Damage to the roots of the teeth is a potential complication. This is more likely to occur in segmental osteotomies due to the close proximity of the osteotomy cuts to the roots of the adjacent teeth. This can usually be avoided through orthodontic divergence of the adjacent roots. Damage to the roots of teeth can also occur during plate fixation due to close proximity of the root apices to the tips of the fixation screws.

Tearing of the palatal mucoperiosteum is most likely to occur with segmental osteotomies used for extensive posterior widening of the maxilla. Careful suturing of any localised tear is essential together with the maintenance of an intact nasal floor mucosa.

Difficulty in achieving the required magnitude of movement is a serious problem which may occur due to unrealistic pre-planned maxillary advancement or due to inaccuracies in face bow recording, occlusal registration and model surgery planning. These can all introduce errors into the fabrication of the occlusal wafer which determines the antero-posterior surgical movements of the maxilla.

2. Immediate postoperative complications:

a. Pain

Pain is the most common complication reported by patients who have undergone a Le Fort I maxillary osteotomy. A standard protocol of pain management should be readily available for delivery by the designated nurse or the consultant anaesthetist during the immediate postoperative period. Morphine injection should be considered provided the respiratory rate and oxygen saturation are within the normal range.

b. Swelling

Swelling may not be a major complication following surgery because of steroid injections during surgery and postoperatively in the first 24 hours. Patients should be warned that facial swelling is likely to increase after the effects of the steroid wear off and may remain for up to a few weeks after surgery.

Localised swelling, due to a surgical hematoma, should be recognised as early as possible, this may require surgical intervention with drainage or by dealing with the damaged tissues. Epistaxis is not uncommon following a Le Fort I osteotomy. Avoiding the damage to the nasal mucoperiosteum minimises the risk of this bleeding; it tends to settle within 24 hours, the application of a nasal pack may have to be considered.

c. Vomiting

Vomiting is more likely to occur within the first few hours following surgery and patients must be informed of this possibility. Intermaxillary fixation may be required to be released, if this was in place, but in most cases where guided elastics are used, the inter-occlusal space will allow vomit to escape. Routine administration of antiemetics minimise the incidence of vomiting.

d. Relapse

- Immediate

Relapse occurs within the first few days postoperatively following the release of the intermaxillary elastics, this manifests as an anterior open bite. This is usually in cases where sufficient posterior impaction of the maxilla for closure of an anterior open bite was not achieved. The result is distraction of the condyle out of the glenoid fossa per-operatively, rather than true autorotation of the mandible.

- Delayed

Relapse is the most common complication following Le Fort I osteotomy. A Le Fort I maxillary impaction is the most stable surgical movement. On the other hand, maxillary downward movement is the most unstable movement, the application of autogenous bone graft following significant maxillary downward movement tends to minimise postoperative relapse. There is sufficient evidence in the literature to support the concept that relapse is directly related to the magnitude of maxillary advancement. The most unstable surgical movement is medio-lateral posterior widening of the palate. The use of rigid fixation, the application of bone graft at the mid-palatal suture and positive intermaxillary occlusal interdigitation following surgery should minimise this complication. The use of an occlusal wafer, as an external method of fixation of the two maxillary segments minimises the magnitude of medio-lateral relapse.

3. Delayed complications:

a. Effects on the nose

Deviation of the nasal septum and widening of the alar base have been reported following Le Fort I maxillary impaction and advancement. The former can be avoided by ensuring that there has been sufficient nasal septal reduction and palatal bone removal. The application of a nasal cinch stitch to approximate the alar cartilages and the surgical widening of the pyriform should prevent flaring of the alar base. However, the long term stability of the cinch stitch is doubtful.

b. Altered sensation

Persistent alteration of sensation around the cheeks, lateral side of the nose and the upper lip can occur as a result of damage to the infra orbital nerve. This can be avoided by careful protection of the nerve and positioning of the plates during surgery. Patients may also complain of altered sensation around the gingivae due to damage to the branches of the superior alveolar nerves. In most cases the sensation gradually improves with time.

Oro-antral and oro-nasal fistulae, loss of the vitality of maxillary teeth especially with segmental osteotomies, and exposure of fixation plates are late complications that have been reported in the literature.

7.4 Sagittal split ramus osteotomy

(Figure 7.12a)

This technique is used routinely for the surgical correction of both mandibular deficiency and prognathism. The technique was developed by Trauner and Obwegeser and has undergone several modifications to improve its reliability and safety.

7.4.1 Indications

1. Surgical correction of mandibur retrognathism and antero-posterior deficiency.
2. Correction of mandibular prognathism.
3. Correction of mandibular asymmetry.
4. Correction of small anterior open bite.

7.4.2 Procedure (Figure 7.12a)

Surgery is carried out under general anaesthesia exposing subperiosteally the ramus medially and the angle and posterior part of the body of the mandible laterally. The first cut is limited to the medial cortex just above the lingula, the inferior dental nerve should be identified and protected (Figure 7.12b). The higher the cut, the less the chance of an uncomplicated split of the ramus. To avoid a potential unfavourable split this cut is kept short, just behind the lingula and does not extend to the posterior border of the mandible (Hunsuck modification) (Figure 7.12b). A routine surgical fissure bur or Lindemann bur or straight saw can be used to make this cut.

Using a standard fissure bur the sagittal bone cut is made just lingual to the external oblique ridge of the buccal cortex of the mandible connecting to the lingual cut (Figure 7.12c) and then passing down

Figure 7.12a Plastic model showing the bone cuts of the sagittal split osteotomy.

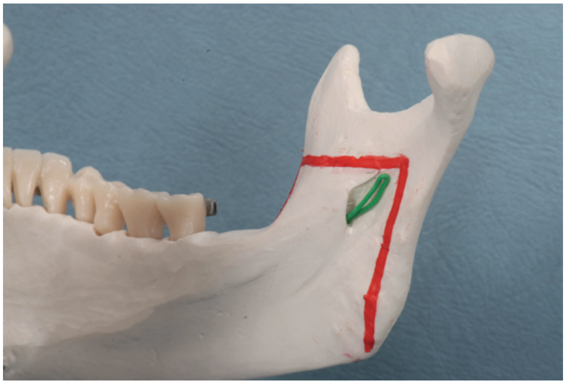

Figure 7.12b Medial cortex short horizontal bone cut just above the lingual and does not extend to the posterior border of the mandible (Hunsuck modification) the vertical line illustrates the pattern of medical cortex split from the outer cortex of the ramus of the mandible.

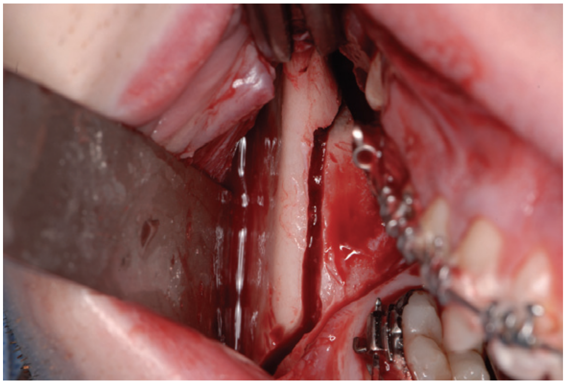

Figure 7.12c A sagittal bone cut made just lingually to the external oblique ridge of the buccal cortex of the mandible.

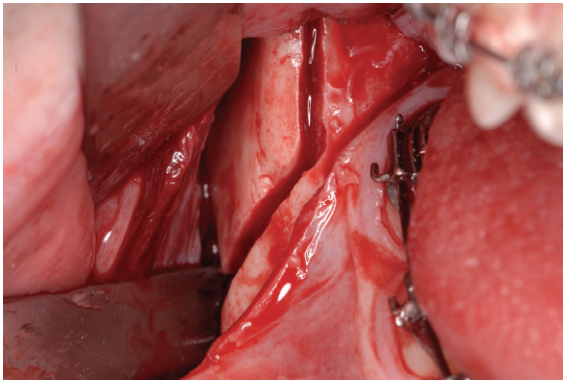

Figure 7.12d The osteotomy of the buccal surface connecting to the sagittal bone cut.

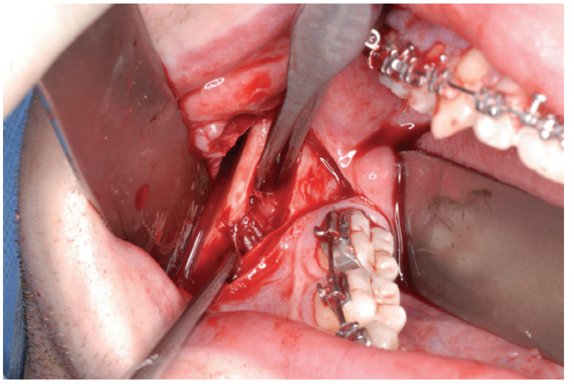

Figure 7.12f Gradual separation of the lateral surface of the ramus (proximal segment) from the rest of the mandible (distal segment) using Smith spreader.

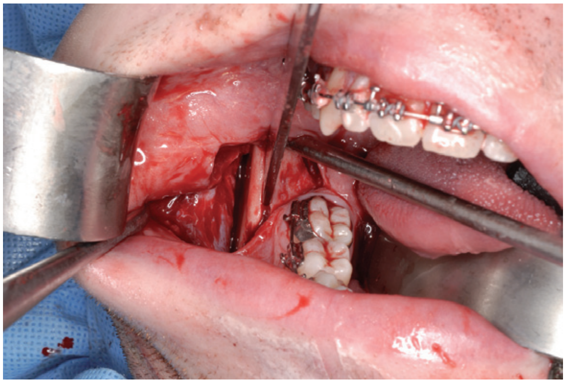

Figure 7.12e Completion of the sagittal split bone cut using an osteotome.

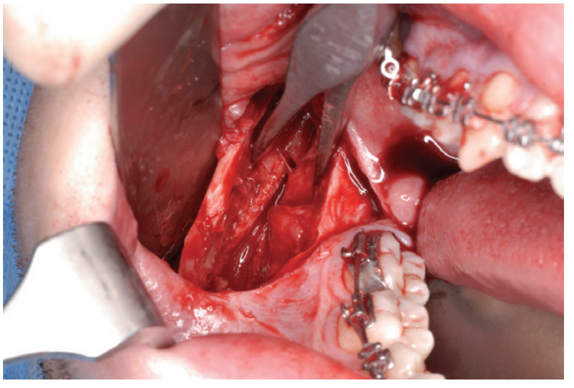

Figure 7.12g Gradual separation of the two segments to avoid fracture of the buccal or the lingual cortices.

the anterior border of the ramus connecting with a buccal surface osteotomy (Figure 7.12d). According to the Dal Pont modification the buccal bone cut is located more anteriorly away from the angle of the mandible just distal to the second molar tooth. This bone cut is limited to the buccal cortex connecting with the sagittal osteotomy, with the bone cut at the inferior border of the mandible. The latter is achieved using a surgical fissure bur after careful reflection and retraction of the mucoperiosteum at the inferior border of the mandible. That cut must be limited to the inferior cortical bone taking into consideration the position of the inferior dental nerve. Some surgeons tend to carry the sagittal osteotomy of the inferior border of the mandible posteriorly to achieve a more precise sagittal split of the ramus, however, this is not universally practised.

After completion of the bone cuts the ramus is split sagittally using a combination of osteotomes (Figure 7.12e) and Smith spreader (Figure 7.12f) which allows gradual separation of the lateral surface of the ramus (proximal segment) from the rest of the mandible (distal segment) (Figure 7.12g) and much reduces the risk of damage to the inferior dental nerve which is the main complication of this procedure. Gradual separation of the two segments allows the identification of the inferior dental bundle (Figure 7.12h). Ideally, it should be located on the distal segment; however, in some cases the nerve may be attached to the proximal segment within the bony canal of the mandible. In these cases it should be carefully dissected out using a combination of fine osteotomes and an excavator. A fissure bur can be used for bone removal and de-roofing of the mandibular canal followed by using a blunt dissection instruments to ensure the nerve bundle is freed from the proximal segment, this helps to ensure it lies lingually on the distal segment.

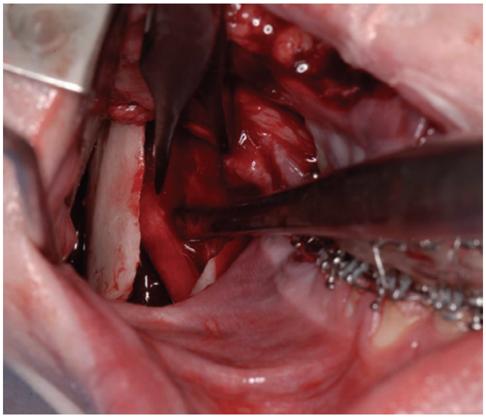

Figure 7.12h Identification of the inferior dental bundle with the gradual separation of the osteotomy segments.

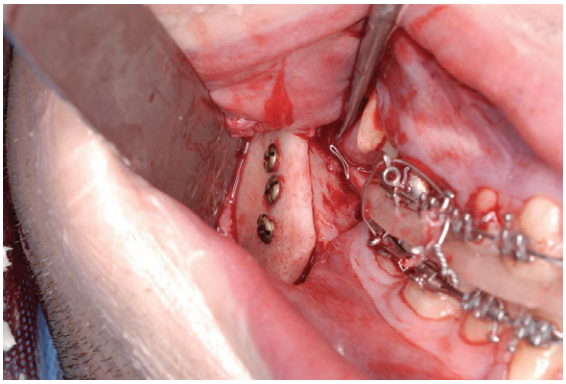

Figure 7.12j Three bi-cortical screw used for fixation of the sagittal split osteotomy.

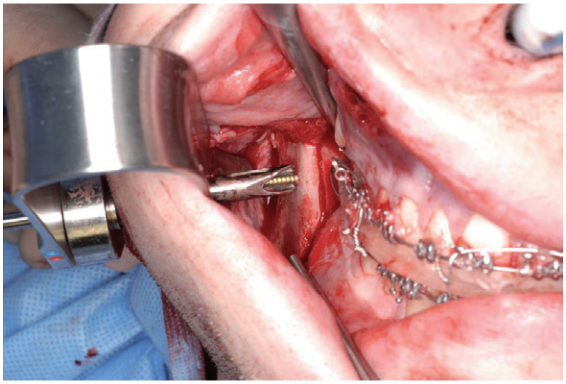

Figure 7.12i The trans-buccal approach for a direct access to the osteotomy site.

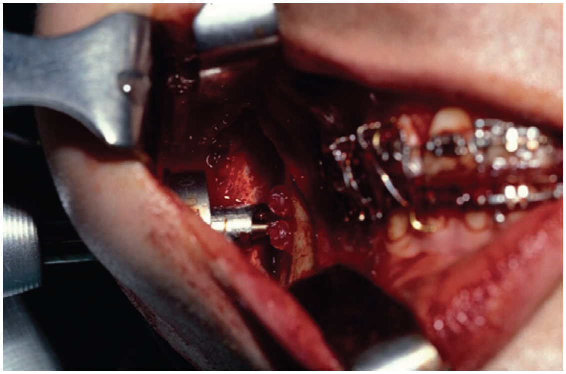

Figure 7.12k PLLA resorbable screw fixation of the sagittal split osteotomy.

The pterygo-masseteric sling should be detached from the inferior border of the distal segment to allow free mobilisation of the body of the mandible in an antero-posterior direction.

Guided by a prefabricated occlusal wafer, several methods have been used successfully for fixation of the mandible in its final position. These include three bicortical screw fixations or a 2 mm titanium plate fixation on each side of the mandible. Despite the fact that a wire fixation alternative may achieve a satisfactory fixation of the bony segments, the long term results showed suboptimal stability due to the quality of the bone formation at the osteotomy site with this type of fixation. The author uses the trans-buccal approach routinely which provided a direct access to the bone segments (Figure 7.12i) and the insertion of a three bi-cortical screws for fixation (Figure 7.12j). The trans-buccal approach may not be required if an upper border plate is used for fixation of the osteotomy segments. Despite the fact that titanium bicortical screws have routinely been used for fixation, PLLA resorbable screws have also been successfully utilised for this purpose (Figure 7.12k).

7.4.3 The condylar segments

The most important and trickiest manoeuvre during fixation of the sagittal split osteotomy is the accurate repositioning of the condyle or the proximal segment in its normal anatomical position. Various methods have been used to guide the condyle into its fossa using positioning plates and condylar devices (Figure 7.13a), however, their application is cumbersome and time consuming which limits their routine use (Figure 7.13b). Every effort should be made to maintain the condyle in its fossa, avoiding posterior displacement. Gentle extra oral vertical pressure at the angle of the mandible and light intra oral posterior force at the anterior border of the ramus would facilitate the positioning of the condylar segment in the articular fossa (Figure 7.13c).

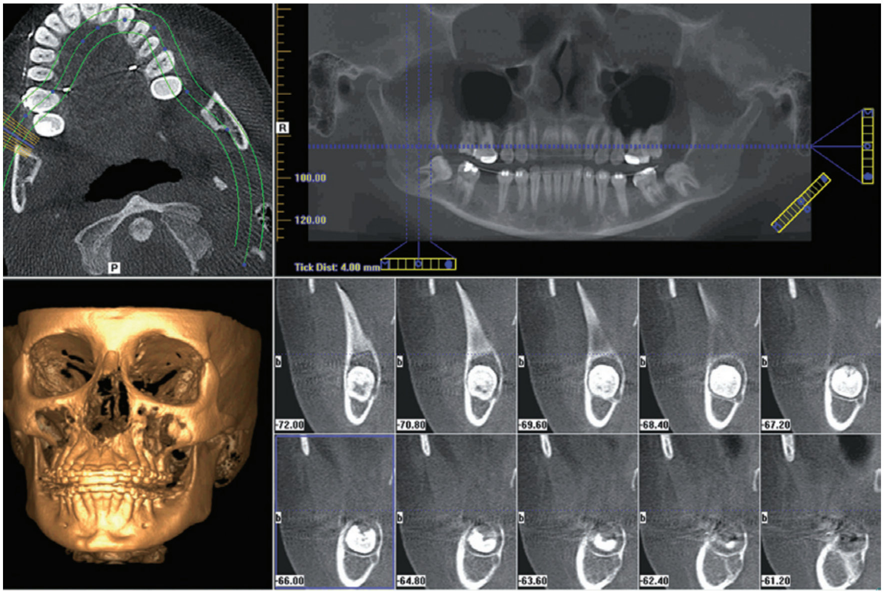

Figure 7.12l CBCT showing the medio-lateral width of the ramus, the position of the mandibular foramen, and the course of the inferior dental nerve.

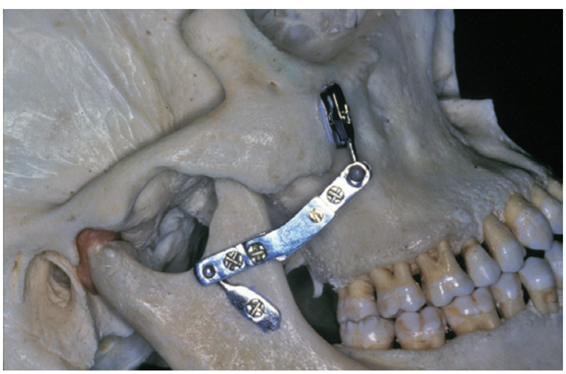

Figure 7.13a A condylar positioning device maintaining the relationship between the ramus and the zygoma.

Figure 7.13b Insertion of a condylar positioning device.

Bone removal from the anterior border of the proximal segment will be required in mandibular setbacks to allow appropriate overlap and adequately fix the bone segments.

Asymmetric advancement of the mandible tends to lead to lateral displacement of the proximal segment on one side. Due to the shape and angulation of the mandibular rami in relation to the mid-sagittal plane, lateral displacement of the condylar segments may also occur following symmetrical mandibular advancement. Torquing of the condylar segments (proximal segments) medially to achieve bony contact during fixation should be avoided. In these cases removal of bone from the medial surface of the proximal segment would be indicated to improve the adaptation between the osteotomy segments during fixation, thus minimising the torque on the proximal segment. This should reduce the incidence of TMJ dysfunction following surgery, unwanted excessive remodelling of the condyle and ultimately mandibular relapse.

For most cases drains are not required following sagittal split ramus osteotomy. Resorbable sutures are

Figure 7.13c Positioning the condylar segment in the articular fossa by gentle extra oral vertical pressure at the angle of the mandible and light intra oral posterior force at the anterior border of the ramus.

used for closure of the intraoral incision and 5 (0) Ethilon for the trans-buccal skin incision of the cheek. Light elastics should be applied to guide the mandible into its new postoperative position.

7.4.4 Complications

Surgical

The most common surgical complication of this osteotomy is an unfavourable split of the mandible which can manifest as one or a combination of the following:

1. Fracture of the lingual plate of the distal segment of the mandible.
2. Fracture of the buccal cortex of the proximal segment.
3. Failure to separate the proximal from the distal segments.
4. Fracture of the ascending ramus of the mandible.

Excessive force during splitting of the mandible is the likely cause of this complication. Anatomical variations may also play a role especially in syndromic cases and may cause an unfavourable split. The use of preoperative cone beam CT, which is routinely obtained for our cases, it allows the assessment of the medio-lateral thickness of the ramus and the position of the inferior dental nerve to minimise the risk of this complication and damage to inferior dental nerve (Figure 7.12l). It has been shown that early removal of mandibular wisdom teeth can minimise the risk of unfavourable sagittal split osteotomy.

These complications could be avoided by careful planning, meticulous bone cutting and the avoidance of excessive pressure during splitting of the ramus from the body of the mandible. Fracture of the lingual plate would necessitate the use of buccal bone plate for fixation of the osteotomy segments. The fractured lingual segment may be kept in place provided the surrounding mucoperiosteum is intact. A fractured buccal plate may be replaced and fixed back into its position using mini plates, small segments could be safely removed or left to act as bone graft. Horizontal fracture of the ramus may require fixation before final splitting of the mandible. In unusual cases where a sagittal split of the ramus cannot be achieved the surgeon may abort the procedure and consider a vertical subsigmoid osteotomy in cases where a mandibular set back is required or body osteotomy and bone graft could be used to achieve the required mandibular advancement.

Damage to the inferior dental nerve can occur with the sagittal split osteotomy due to the following:

1. Insufficient knowledge of the position and course of the nerve which can only accurately be achieved from analysis of the preoperative CBCT (Figure 7.12l).
2. Excessive force applied during splitting of the proximal segment of the ramus.
3. Extending the depth of the buccal bone cut beyond the outer cortex.
4. Cutting more than the inferior border of the mandible vertically in an occlusal direction beyond the cortex.
5. Penetration of the bundle and nerve during screw fixation.

A cut nerve during a sagittal split osteotomy may require the nerve to be repaired. A contused nerve would gradually recover, but patients may suffer from residual alteration of sensation which can manifest as paraesthesia rather than complete numbness.

Immediate postoperative complications

The most common immediate postoperative complications are pain, swelling and limitation of mouth opening. These are likely to improve within a few days of surgery. The more serious complication is immediate relapse upon the release of intermaxillary elastic fixation. This could be manifested as one of the following clinical features:

1. Anterior open bite.
2. Displacement of the mandible toward one side with mouth opening.
3. Posterior displacement of the mandible with an increase of overjet.

The cause for these immediate postoperative complications is usually displacement of condylar segment during internal fixation. Postoperative radiographs would show displacement of the condylar segment which would require further surgical intervention to reseat the condylar segment into its correct position.

Long term complications

Alteration in the sensation of the lower lip is the most common complication reported by the patients who had had sagittal split osteotomy. The manifestation ranges from localised alteration of sensation at a particular area to complete numbness of the lower lip. In most of the cases patients show a high level of adaptation to this complication and it is unlikely that altered lip sensation following sagittal split osteotomy would affect the quality of their life. This may not be the case if the lip numbness is secondary to removal of wisdom teeth.

Delayed relapse is the second most common complication following sagittal split osteotomy and research has proved the following factors to contribute to this complication:

1. The magnitude of mandibular advancement.
2. Quality of postoperative occlusion.
3. Condylar position during fixation of sagittal split osteotomy.
4. Rigidity of sagittal split fixation.
5. Stretching of the supra hyoid muscles due to anticlockwise rotation of the distal segment.
6. Bone quality and postoperative infection.
7. Preoperative condylar shape and size.

This could be minimised with appropriate planning, accurate execution of the surgery, avoidance of condylar displacement, stable internal fixation and excellent postoperative occlusion.

Numbness of the tongue and submandibular region has been reported due to damage to the lingual nerve and damage to the nerve to mylohyoid muscle which supplies innervations to the mental area. Infection and exposure of the fixation plates and screws have been reported in about 10% of the cases and they would require surgical removal of the fixation device. Scarring at the site of the skin incision of the transbuccal approach has been noted in some cases.

7.5 Vertical Subsigmoid Osteotomy (VSSO) (Figure 7.14)

7.5.1 Indications

1. Correction of mandibular prognathism.
2. Correction of mandibular asymmetry where a unilateral VSSO may be performed with or without a sagittal split osteotomy on the opposite side.
3. Management of TMJ dysfunction syndrome.
4. Where it is essential to minimise loss of sensation of the lower lip.

7.5.2 Procedure

This technique has been developed and modified to be performed intra-orally for correction of mandibular prognathism. The procedure is performed under general anaesthesia. Through an intra-oral approach the outer surface of the ramus is exposed from the sigmoid notch to the angle of the mandible. Specific retractors need to be used (Bower's retractor for the sigmoid notch and a Levasseur-Merril retractor for reflection of retro-mandibular soft tissues (Figure 7.14a)) to provide protection of the saw as it cuts the the ramus vertically. Excellent illumination is mandatory to perform this surgical technique safely. An oscillating right angle surgical saw (Figure 7.14b)

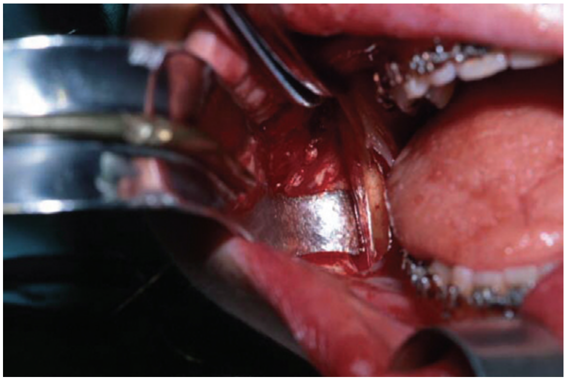

Figure 7.14a Levasseur-Merril retractor is inserted intra orally for reflection of retro-mandibular soft tissues and also to provide protection of the saw as it cuts the ramus vertically.

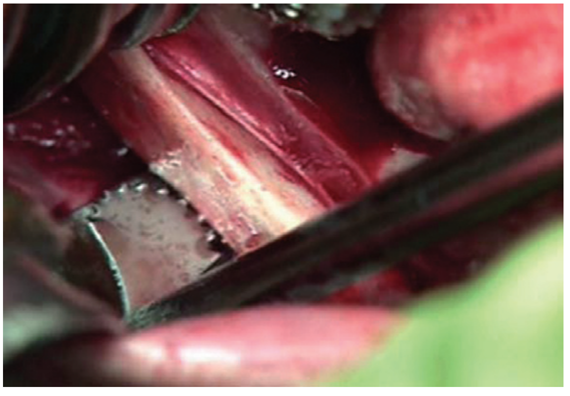

Figure 7.14b The application of an oscillating right angle surgical saw for vertical cutting of the ramus.

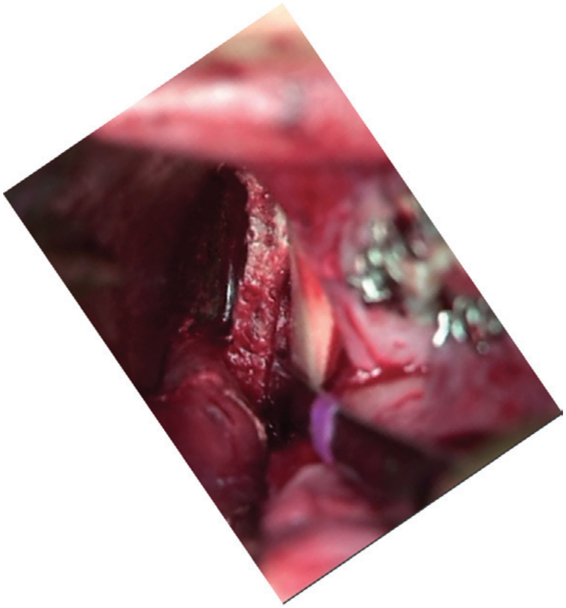

Figure 7.14c Insertion of a periosteal elevator to laterally mobilise the condylar (proximal) segment in relation to the ramus of the mandible.

Figure 7.14d VSSO with the proximal segment kept lateral to the ramus.

facilitates bone cutting from the sigmoid notch to the inferior border of the mandible just anterior to the angle of the ramus and posterior to the lingula. Once the cut is complete, a periosteal elevator is inserted at the sigmoid notch to laterally mobilise the condylar (proximal) segment in relation to the ramus of the mandible (Figure 7.14c). The attachment of the medial pterygoid muscle is reflected to allow posterior movement of the distal segment. The proximal segment is kept lateral to the ramus (Figures 7.14d,

Figure 7.14e Radiographic appearance of the VSSO.

7.14e) attached to the lateral pterygoid muscle and the capsule of the condyle. To avoid extensive lateral flaring of the condylar segment a non-resorbable stitch may be applied to approximate the segment to the buccal surface of the ramus of the mandible and promote satisfactory initial bone healing, it also prevents sagging of the condylar segment. The classic method of fixation of vertical subsigmoid osteotomy is by inter-maxillary fixation and the condylar segments would find their own presurgical anatomical position. However, surgeons have attempted internal fixation of the condylar segment using bicortical screws and plates to avoid the inconvenience associated with wiring the maxillary and mandibular teeth together. Internal fixation may require trans-buccal approach to allow direct access for application of plates or screws.

The VSSO had been introduced and adopted by surgeons to avoid the following complications which were associated with sagittal split osteotomy for a mandibular set back:

1. Damage to the inferior dental nerve.
2. Anterior relapse.
3. Displacement of the condylar segment.

However, damage of the inferior dental nerve during surgery has not been totally eliminated with VSSO and inter maxillary fixation may compromise immediate postoperative recovery and undoubtedly does cause significant inconvenience for the patient. Delay of applying IMF for a few days after surgery has been suggested to facilitate postoperative recovery, but there are risks for the proximal segment to be displaced inferiorly and for anterior open bite to occur. Reducing the length in IMF for three weeks has been considered by some surgeons.

7.5.3 Complications

The most common operative complication of the VSSO is the poor direction of the saw position and fracture of the proximal segment across the posterior border of the mandible. This should be avoided by full exposure of the lateral surface of the ramus of the mandible, the use of the designated retractors for this procedure and bone cutting using the correct right angle surgical saw. Plating of the fractured segment may be difficult if it is high and near the condyle. In this case intermaxillary fixation should be applied and the case is treated as a sub-condylar osteotomy/ fracture. Fracture of the posterior border near to the inferior border of the mandible may require internal plate fixation.

Displacement of the condylar segment medially and extensive bleeding have been reported among the operative complications of VSSO. The condylar segment has to be retrieved and positioned laterally to allow the posterior shift of the mandible. Haemostasis has to be achieved and it may be easier to control the bleeding once the osteotomy is completed and the proximal segment is mobilised laterally. The use of mini drains is recommended for the first 24 hours following surgery.

The most common immediate postoperative complication following VSSO is slight inferior displacement of the condylar segment which may require further surgical intervention to trim its inferior end; this is easily prevented by checking this prior to closure and improving of its adaptation to the mandible using an inter osseous wire or a heavy non-resorbable stitch. Rarely a second surgical intervention is required to adjust the condylar segment; remodelling at the lower border will occur with time.

Relapse is the most common long term complication due to bilateral inferior sagging of the condylar segment per-operatively which would manifest as an anterior open bite and reduction of the achieved overjet. This can be avoided with proper seating of the condylar segment during surgery and it may be necessary to trim the ramus to allow this to happen. Adequate reflection of the attachment of the medial pterygoid muscle from the condylar segment should allow an unobstructed posterior shift of the mandible.

Alteration of sensation of the lower lip has been documented following VSSO. This can be easily avoided with careful planning and maintaining the vertical bone cut posterior to the anti-lingula notching using the Levasseur-Merill retractor. Rarely this may be due to anatomic variations in asymmetry cases which can be diagnosed by the assessment of submento-vertex radiograph or cone beam CT scan prior to surgery. For minor degrees of asymmetry, the easy side of the mandible, where the ramus is more flared laterally, should be osteotomised first as it renders the other side better access. Patients should be warned if there is a problem it is always possible to complete surgery with external submandibular approach.

7.6 Mandibular body osteotomy

7.6.1 Indications

1. Correction of prognathism due to an increased body length of mandible.
2. Unilateral correction of asymmetric mandible with or without ramus osteotomy of the opposite side.

This method provides good bony contacts between the proximal and distal segment. Damage to the inferior dental nerve is minimal and the reported long term stability is excellent.

7.6.2 Procedure

This osteotomy is carried out under general anaesthesia via an intra-oral approach. A full buccal and lingual segment is removed with the preservation of the integrity of the inferior alveolar nerve for reduction of the mandibular body length. The first molar region is a good site for a body ostectomy, however, this would depend on the location of the edentulous area or an extraction and the pre-planned final occlusion. In some cases extraction of the first premolar provides an adequate reduction of the mandibular length and this avoids the necessity for exposing the inferior dental canal and bundle. A buccal mucoperiosteal flap is raised to allow full exposure of the body of the mandible from the alveolar crest to the inferior border at the preplanned osteotomy site. The adjacent lingual mucoperiosteum is raised and protected with a periosteal elevator without reflection of a full mucoperiosteal flap.

A surgical fissure bur is used to cut two vertical osteotomy lines, which represent the width of the bone segment to be removed and a horizontal line 2–3mm above the level of the inferior dental nerve (Figure 7.15a). Guided by the preoperative radiograph the bone above the inferior dental nerve is cut and removed (Figure 7.15b). The cuts are limited to

Figure 7.15a Two vertical bone cuts which represent the width of the bone segment to be removed and a horizontal line 2–3 mm above the level of the inferior dental nerve.

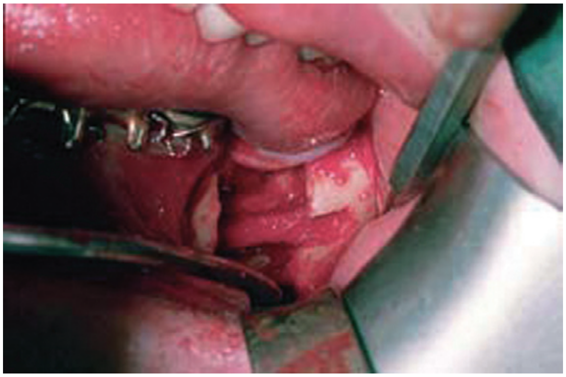

Figure 7.15c Removal of the bone above and below the inferior dental nerve.

Figure 7.15b Removal of the bone above the inferior dental nerve is cut and removed.

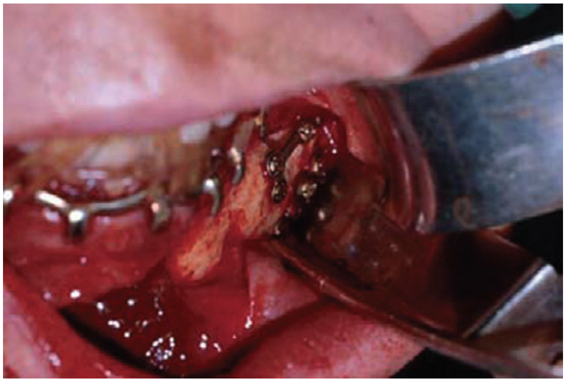

Figure 7.15d Fixation of the osteotomy segments in their final position using two plates.

the buccal cortex, the inferior border is kept intact at this stage. Removal of the buccal bone segment with its underlying cancellous bone around the mandibular canal will expose the inferior dental nerve and the lingual plate of bone. The nerve is carefully dissected off the lingual bone using blunt plastic instruments. This provides direct access to the lingual plate of the body of the mandible. The lingual bone is cut using a surgical fissure bur in two segments, one above and one below the inferior dental nerve (Figure 7.15c). The two segments are approximated and fixed in their final position using two plates (Figure 7.15d), one above and one below the inferior dental nerve. A window is usually cut on the buccal surface of the proximal segment or cancellous bone is removed to allow careful seating of the inferior dental nerve. It is helpful on the first side cut to leave a small horizontal piece of bone lingual to the inferior dental nerve to protect it while the other side is prepared, removing the former at the end.

The method has also been used for lengthening the body of a hypoplastic mandible. In these cases a step shaped cortical bone cut is performed to allow the insertion of bone graft in the space created by moving the distal segment forward and this is done anterior to the neurovascular bundle to avoid stretching of the inferior dental nerve, two mini plates are used for fixation.

7.6.3 Complications

The complication that may be associated with this technique is the damage to the inferior dental nerve which is readily avoidable with appropriate planning and careful execution of the surgical technique.

Figure 7.16a Profile and frontal photographs of one of the cases demonstrating the changes in facial appearance following inverted L osteotomy and allowing protection of the inferior alveolar nerve.

7.7 Inverted L ramus osteotomy

(Figure 7.16)

This is the most reliable method for advancement and lengthening the vertical height of the ramus of the mandible. The method is also used when significant mandibular advancement is required beyond the scope of sagittal split mandibular advancement. A bone graft is required and an extra-oral incision may be necessary.

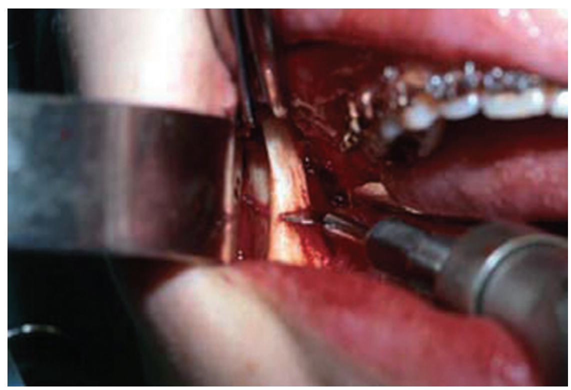

Figure 7.16b The horizontal osteotomy through both lingual and buccal cortices of the ramus just above the level of lingual using surgical saw.

7.7.1 Indications

1. Anterior open bite due to severe reduction of posterior vertical height and deficiency of the vertical length of the ramus of the mandible.
2. Correction of asymmetric mandibular deficiency with or without ramus surgery on the opposite side.
3. Significant mandibular advancement beyond the scope of a sagittal split ramus osteotomy (Figure 7.16a).

7.7.2 Procedure

Most of the osteotomy cuts can be carried out via an intra oral approach. A standard mucoperisoteal flap is reflected to expose the buccal surface of the ramus of the mandible. In addition, a lingual mucoperiosteal flap is reflected to expose the lingula and allow protection of the inferior alveolar nerve. The first horizontal osteotomy cut is carried out using a fissure bur or a surgical saw (Figure 7.16b) through both lingual and buccal cortices of the ramus just above the level of lingula. The posterior border of the mandible is kept intact. The vertical bone cut is usually undertaken via an extra-oral approach and extends from the posterior end of the horizontal cut to the angle of the mandible (Figure 7.16c). A right angle oscillating surgical saw can be used to achieve this vertical cut via an intra-oral approach. This cut also includes both the buccal and lingual cortices of the ramus of the mandible. The distal segment is mobilised both antero-posteriorly and vertically to achieve the required lengthening of the vertical height and an advancement of the ramus of the mandible. The proximal segment is kept in its presurgical position. The created gap with the shape of an inverted L is grafted with cortical autogenous iliac bone. Two plates, one above and one below the inferior dental nerve may be used for the fixation of the mandibular ramus (Figure 7.16d). The access to apply these plates is usually via a combined intraoral and extra oral approached. Trans-buccal approach may facilitate the insertion of bicortical screws.

The extra-oral access is usually achieved via a submandibular approach to keep the incision line in a skin crease below the inferior border of the ramus of the mandible after lengthening.

7.7.3 Complications

Occasionally with this technique there is damage to the marginal mandibular branch of the facial nerve. This complication can be minimised with careful surgical technique. The other complication is the scarring due to the extra oral skin incision, this could be avoided if an intra-oral approach is adopted which may not be easy for complex mandibular deformities.

Figure 7.16c Extra-oral approach to undertake the vertical bone cut is usually from the posterior end of the horizontal cut to the angle of the mandible to facilitate fixation.

7.8 Anterior mandibular osteotomies

7.8.1 Lower anterior segmental osteotomy

The procedure is designed to move the lower anterior dento-alveolar segment in any direction while maintaining the integrity of the inferior border of the mandible.

Indications

1. Correction of a steep curve of Spee to facilitate the antero-posterior surgical movement of the mandible.
2. Excessive or deficient lower incisor show at rest and with a maximum smile.
3. Decompensation where orthodontic correction of the axial inclination of the lower incisors is not possible.

Procedure

A labial mucoperiosteal flap is raised to expose the labial surface of the chin and the vertical osteotomy site which is usually in the first premolar region. This is achieved by a curved incision of the mucosal surface of the inner surface of the lower lip that extends to the site of the planned vertical bone cut. This is connected with a distal releasing incision above the level of the mental foramen posterior to the site of the vertical bone cut. The anterior labial incision depends on cutting the periosteum covering the chin. The dissection posteriorly is carried out after identifying and protecting the mental nerve and its branches. This allows the bone above and below the nerve to be exposed with minimal stretching of the mental nerve. The final incision is along the gingival sulcus of the first premolar and the adjacent teeth to facilitate the tunnelling of the attached

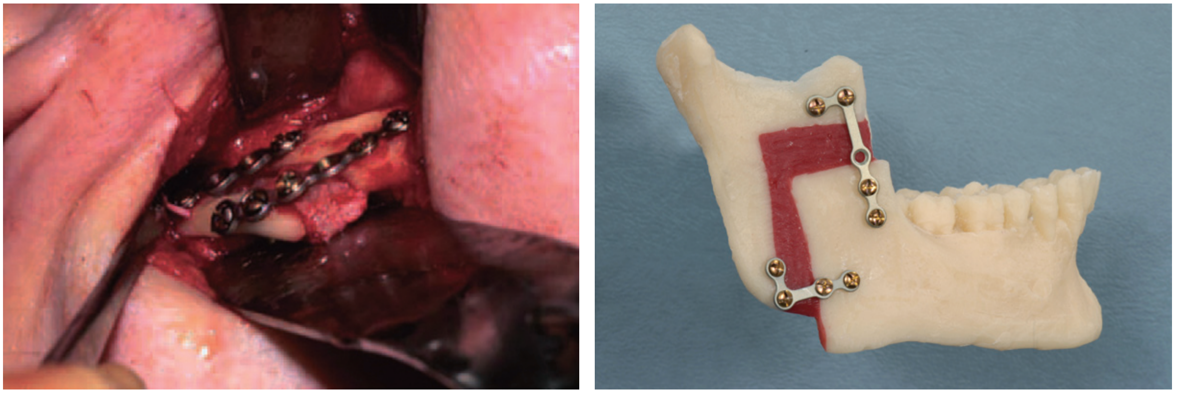

Figure 7.16d The application of two plates for fixation of an inverted L osteotomy.

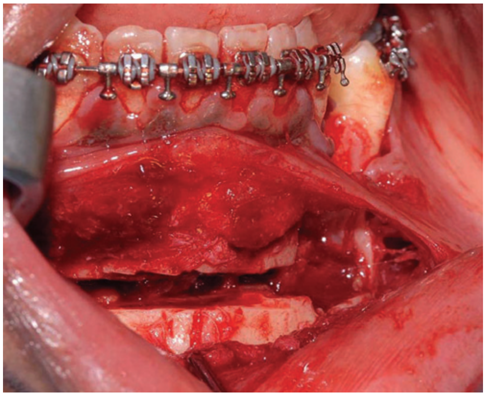

Figure 7.17a Lower anterior subapical osteotomy.

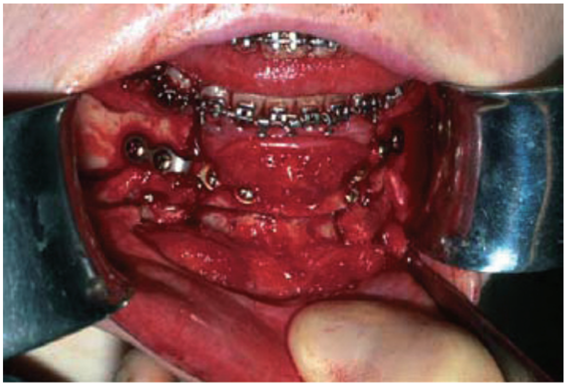

Figure 7.17b Anterior segmental osteotomy and the use of two plates on each side for fixation.

gingivae at the planned vertical osteotomy site (Figure 7.17a).

The bone cut is achieved using a surgical fissure bur or a fine saw, it starts at the vertical osteotomy site to involve bone of the buccal and lingual cortices with full protection of the lingual mucoperiosteum using a Howarth periosteal elevator. Extraction of the first premolar may be considered at this stage to guide the vertical bone cut. The horizontal cut is achieved using a reciprocating surgical saw about 5mm below the apices of the teeth and extended to connect with the two vertical bone cuts. The depth of the horizontal bone cut should include the lingual cortex of the chin.

The segment can be mobilised using a Smith spreader and this is facilitated with spatula osteotomes. The mobilised segment is pedicled on the attached gingiva labially and on the mucoperiosteum and genial muscles lingually. Guided by an occlusal

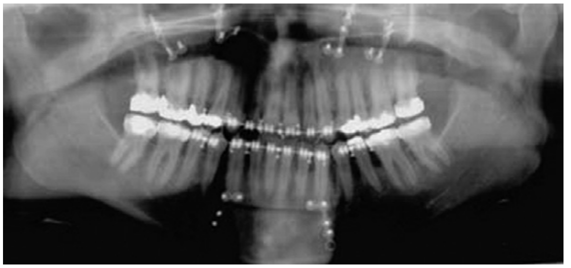

Figure 7.17c Radiographic picture of lower anterior segmental osteotomy.

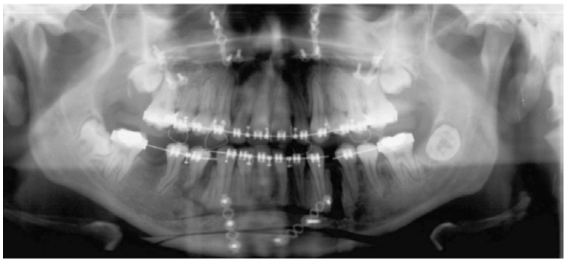

Figure 7.17d Radiographic picture of lower anterior segmental osteotomy and genioplasty.

wafer and temporary intermaxillary fixation the segment is seated into its final position before fixation with mini plates (Figures 7.17b, 7.17c). The wound is closed in layers starting with the mentalis stitching to the mucoperiosteal flap using 4(0) Vicryle suture.

The procedure can be combined with a genioplasty to allow independent adjustment of the chin and maintaining the integrity of the mandible as one piece (Figure 7.17d).

7.8.2 Anterior mandibulotomy (Figures 7.18a, 7.18b)

The procedure allows the surgical movement of the lower anterior segment of the mandible including the inferior border.

Indications

It has a similar scope of application to the anterior segmental procedure but it also allows simultaneous adjustment of the inferior border of the mandible. It is indicated where surgical movement of the anterior dento-alveolar segment of the mandible is required in cases complicated by deficiency of the lower anterior vertical height of the mandible that prevents adequate segmental movement without damage to the apices of the teeth.

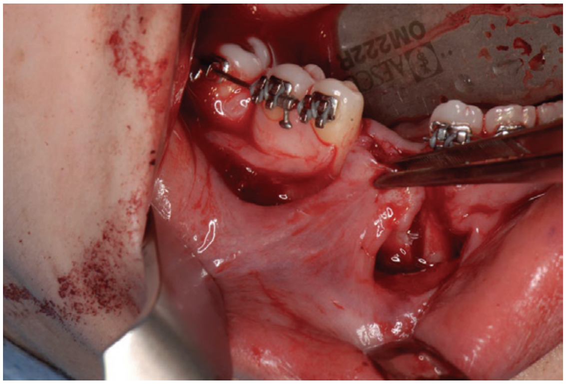

Figure 7.18a Mucoperiosteal flap for anterior mandibulotomy.

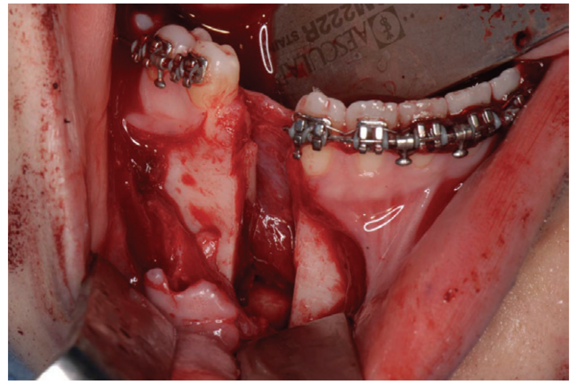

Figure 7.18c Completed anterior mandibulotomy leaving an intact lingual mucoperiosteum.

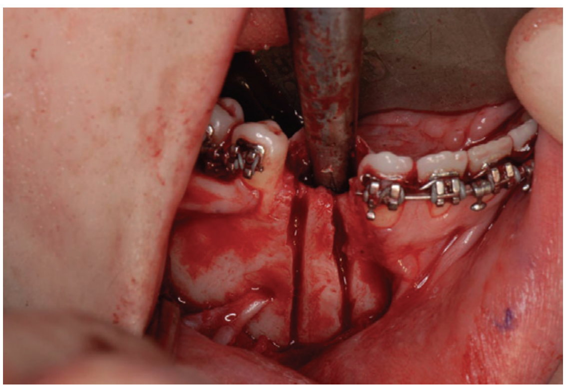

Figure 7.18b Protection of the lingual mucoperiosteum and buccal bone cuts anterior to the mental nerve.

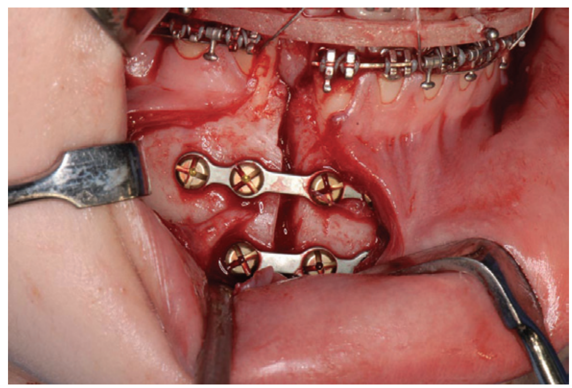

Figure 7.18d Fixation of the anterior mandibulotomy using two plates, one above and one below the mental nerve.

Procedure

A buccal mucoperiosteal flap is raised starting from the gingival crest at the edentulous area, connects anteriorly with a semi-vertical incision which extends to the muco-labilal fold and connects distally with a curved posterior incision across the attached ginigiva (Figure 7.18a). This allows the full exposure of the osteotomy site and direct observation of the mental nerve. The lingual mucoperiosteum is protected using Howarth's periosteal elevator. Using a fissure surgical bur or a surgical micro saw two vertical bony cuts are made on the buccal cortex to allow the planned posterior movement of the anterior mandibular segment (Figure 7.18b). The osteotomy is completed after removal of the lingual cortex using a surgical fissure bur or by spatula osteotome, it is essential to maintain the lingual mucoperiosteum intact during this procedure (Figure 7.18c). Adequate

Figure 7.18e Radiograpic appearance and a diagram showing anterior mandibulotomy.

fixation is achieved using two plates, one above and one below the mental nerve (Figures 7.18d, 7.18e).

The procedure can be combined with a genioplasty (Figure 7.18f) to allow a four-part mandibulo-genioplasty where the lower genial segment is moved

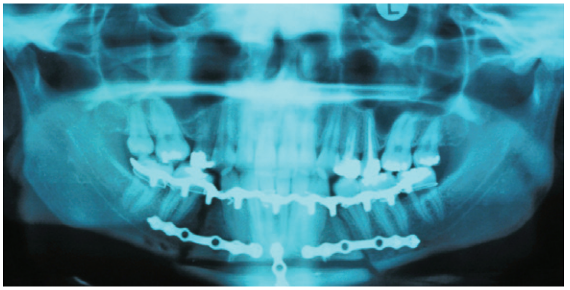

Figure 7.18f Radiographic picture of anterior mandibuloplasty and genioplasty which splits the mandible into four segments.

in a direction different from that of the dento-alveolar anterior segment. Fixation of the four segments is complex, the use of an occlusal wafer and temporary intermaxillary fixation is essential to achieve the required relationship of the incisal, right posterior and left posterior mandibular segments. Mini plates are required for the fixation of the anterior dento-alveolar segment with the body of the mandible above the mental nerves with similar plating of the genial segment to the inferior body of the mandible below the mental nerves.

7.8.3 Complications

1. Damage to mental nerve

This should be avoided by careful exploration and protection of the nerves during surgery. Fixation plates and fixation screws should be applied away from the mental foramen and the course of the inferior dental nerve.

2. Bone exposure

Careful reflection of the mucoperiosteum and avoiding the damage of the attached gingival would minimise this risk. Careful multi-layer stitching of the muscle and mucoperiosteum would facilitate healing and maintain the blood supply to the osteotomy segments.

3. Loss of the lingual blood supply to the segment can lead to devitalisation of the teeth and affected bone segment with its necrosis which would cause severe deformity. Great care must be taken with movements of the segments and to ensure the mucoperiosteal flaps are not damaged.

7.9 Genioplasty

This is the most versatile surgical technique for correction of chin deformities. The procedure is normally performed under general anaesthesia, however, genioplasties have been carried out successfully under local anaesthesia and sedation in some countries.

Figure 7.19a Exposure of the chin after reflecting a labial mucoperiosteal flap extending from the right to the left first premolars.

7.9.1 Indications

1. Correction of retrogenia.
2. Correction of progenia.
3. Vertical reduction in cases of increased lower anterior facial height.
4. Vertical augmentation in cases of anterior deficient vertical height of the mandible.
5. Correction of an asymmetric chin.
6. Simultaneously with maxillary or mandibular osteotomies which bring the chin into more favourable position.

7.9.2 Procedure

Exposure of the chin is achieved via an intra-oral approach after reflecting a labial mucoperiosteal flap extending from the right to the left first premolars (Figure 7.19a). The labial mucosa is cut first followed by the mentalis muscle which should be carefully sectioned and resutured with the flap at the end of the procedure. The mental nerves are identified and protected. Vertical and horizontal marks on the labial surface of the bony chin are achieved using a narrow fissure bur to guide the surgical movement of the genial segment. The osteotomy is usually undertaken using a straight reciprocating surgical saw. This allows cutting of both the labial and lingual cortices with minimal damage to the bony surfaces. Based on the desired movement the genial segment can be moved forward, backward, and rotated in a right or left direction to correct mediolateral asymmetry (Figure 7.19b). Vertical reduction genioplasty is achieved by

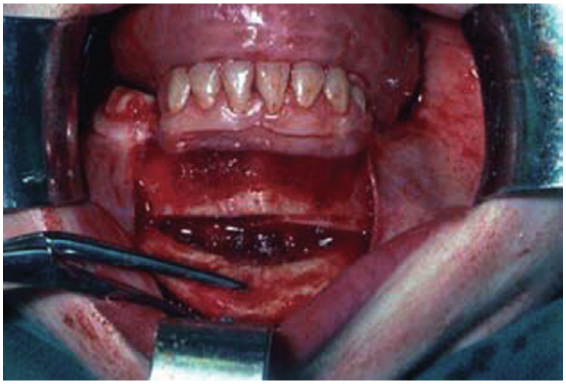

Figure 7.19b Moblisation of the genial segment to the desired position.

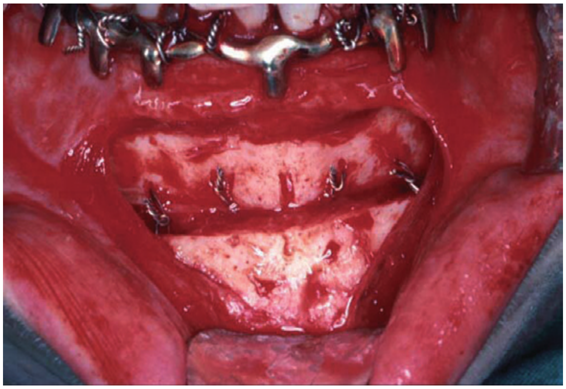

Figure 7.19d The use of three inter-osseous wires for fixation of the advanced genial segment.

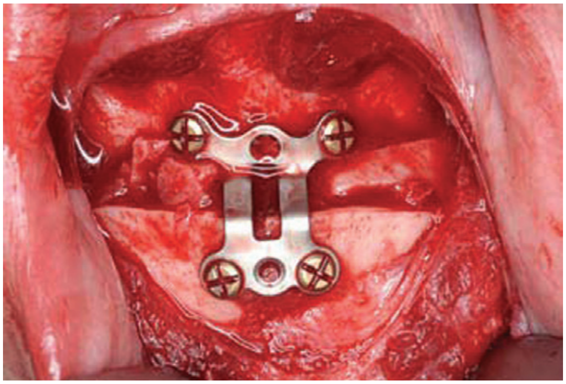

Figure 7.19c The use autogernous bone graft to fill the created gap in vertical augmentation genioplasty and fixation using pre-bent plate.

removing a middle segment of the bony chin. Vertical lengthening of the chin is achieved by inferior repositioning of the genial segment and the insertion of Hydroxappatide blocks or autogenous bone graft to fill the created gap (Figure 7.19c).

Various methods of fixation have be successfully used for fixation of the bone segments which includes three to four inter-osseous wires (Figure 7.19d), bicortical screws, pre-bent genioplasty plates (Figure 7.19c) as well as standard 2mm titanium plates. The surgical wound should be closed in layers with careful approximation of the mentalis muscle to avoid lip ptosis.

7.9.3 Complications

The most common complication is the excessive bleeding during bone cutting of the genial segment due to damage to the genioglossus muscles which are attached to the medial cortex of the chin. Haemostasis should be achieved using standard techniques. Some numbness of the lower lip is a reported complication following genioplasty. This can be largely avoided with careful protection of the mental nerves during bone cuts.

7.10 Medical preoperative/intraoperative considerations and general postoperative care

7.10.1 Informed consent

Patients should be adequately informed of the details of the surgical procedure, expected postoperative clinical features and complications. The consenting procedure should be informed and detailed with provision of an information sheet describing surgical procedures and potential complications. Teaching video clips and interactive tablet applications have been used recently to ensure that patients are fully informed and adequately prepared for surgery. The signed consent form by both the patient and surgeon should be kept within the patient case notes for medico-legal purposes.

7.10.2 Blood tests

a. A routine coagulopathy profile should be considered for all patients before orthognathic surgery. Abnormal bleeding tendencies and coagulation disorders need to be detected before surgery, with replacement of deficient factors.
b. A full blood count and haemoglobin concentration should be measured.
c. Urine analysis and liver function tests are essential for patients with chronic liver diseases and a history of alcohol abuse.

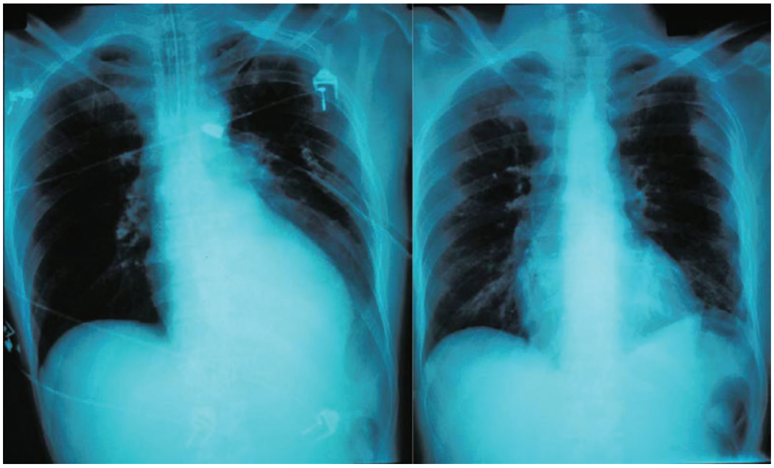

Figure 7.20 AP chest radiograph showing the unequal expansion of the right and left lobes of the lung due to respiratory obstruction and full expansion of both sides following physiotherapy.

d. Electro-cardio gram and chest radiograph are required for elderly patients or as deemed necessary according to the medical history.
e. Despite the fact that blood transfusion is unlikely following orthognathic surgery it is safe to group and save blood before complex orthognathic procedure.
f. The preoperative use of low molecular weight heparin to avoid the risk of deep venous thrombosis would depend on the age, sex, BMI of the patients as well as smoking habit, expected length of the surgical and the need for iliac crest bone graft.

7.10.3 Operative considerations

Minimise blood loss

Operative blood loss can be significantly reduced with hypotensive anaesthesia and the application of local anaesthesia with Adrenalin 1/80.000. The use of antifibrinolytic agents and the use of bipolar diathermy would minimise blood loss.

Minimise facial swelling (Antioedema)

Dexamethasone 8mg (Solumderon 250mg) is given IV with the anaesthetic induction, this is repeated 6 hourly for the first 24 hours following surgery. The intramuscular injection of a long acting steroid, Depomedron 80mg, four hours after the last dose of Dexamethasone would further reduce postoperative facial swelling and facilitate recovery during this crucial stage.

Pain

Subcutaneous or intravenous administration of an opiate (morphine) may start immediately following surgery, a dose of 10 mg p.r.n. which may be repeated every 4 hours to control pain. Appropriate precautions should be taken with the use of opiates. The use of long acting local anaesthesia during surgery would also reduce postoperative pain.

7.10.4 General postoperative care

Airway and breathing

It is essential to ensure that the airway is not obstructed following surgery. The reduction of oxygen saturation in the blood, increased respiratory rates and unequal expansion of the right and left lobes of the lung are the manifestations of respiratory obstruction (Figure 7.20). Antero-posterior chest radiographs should be taken to confirm the diagnosis. Aspiration of blood into the main bronchus may cause partial collapse of the affected position of the lung. The application of 100% oxygen, nebulizers and starting physiotherapy are essential. In some cases aspiration of the blood clot using brochoscope may be essential.

Circulation

Loss of blood and fluids should be monitored carefully preoperatively and during the first 24 hours following surgery.

The application of urinary catheter is indicated in long surgical procedure to monitor fluid balance. The use of antiemetic medications as Metoclopromide 10 mg would reduce vomiting which is distressing to patients and another cause for fluid loss. The intravenous infusion with Hartmann's solution would maintain fluid balance in addition to blood transfu-

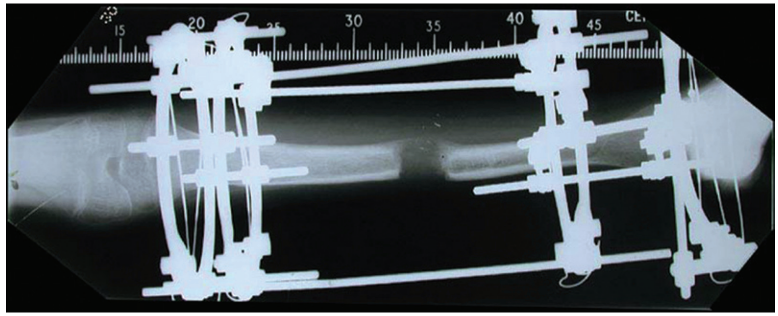

Figure 7.21a Ilizarove device for lengthening of bone by distraction osteogenesis.

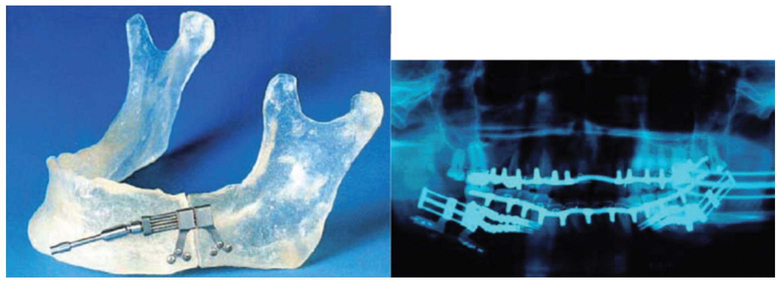

Figure 7.21b Intra-oral distraction device for antero-posterior lengthening of the mandible.

sion as may be deemed necessary due to a significant drop in the haemoglobin level.

Antibiotics

The use of intravenous antibiotics during a stay in the hospital would minimise postoperative infection especially in cases when bone grafts has been applied. The use of postoperative antibiotics is limited to grafted cases.

Feeding

Patients are encouraged to take clear fluids orally for a few hours following surgery. Hartmann's solution may be continued for the first 24 hours to maintain patients' hydration. Patients are then instructed to keep on fluids and soft diet for the first few days following surgery. A highly caloretic blended diet should always be considered, Chlorhexidine 0.2% mouth rinse should commence as soon as possible and maintaining oral hygiene using a soft narrow tooth brush is recommended.

7.11 Distraction osteogeneis

The method depends on a gradual and controlled separation of two bony segments at a rate of 1 mm/day. This creates an active metabolic environment for formation of a healthy callus between the segments. Through a cascade of osteogenic and haematopoietic reactions the soft callus is populated with cells of osteogenic lineage to start bone formation between the distracted segments. Ilizarov popularised distraction osteogenesis in long bones (Figure 7.21a) and this method is used nowadays for lengthening the jaw bones. The following are the basic principles of this method for bone lengthening:

1. Bone cut

This should be performed at the site where bone lengthening is required. The direction of the osteotomy line influences the pattern of bone formation. The periosteum should be kept intact tomaintain the blood supply and give the maximum osteogenic potential to the site of distraction.

2. Vector of distraction

This is the pre-planned direction of separating the two bony segments. Based on the vector distraction osteogenesis could be mono-directional (antero-posterior (Figure 7.21b), vertical (Figure 7.21c) or medio-lateral (Figure 7.21d)), bi-directional (Figure 7.21e), or multi-directional (Figure 7.21f).

3. Latency period

This is the time interval following the osteotomy and before starting distraction to allow the formation of healthy blood clot and soft callus. This is usually between four and seven days dependent on the type of bone and the age of the patient.

4. Rate of distraction

This is the magnitude of separating the bone segments which is usually 1 mm/day. This also depends

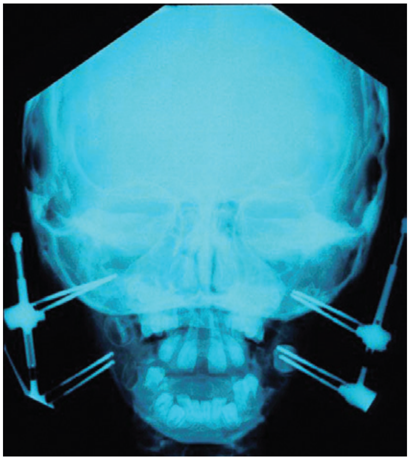

Figure 7.21c Mono-direction vertical distraction of the ramus of the mandible.

Figure 7.21d Mono-direction distraction of the body of the mandible in medio-lateral direction.

Figure 7.21e Bi-directional ditrsction osteogenesis to lengthen the bertical height of the ramus and the natero-posterior length of the body of the mandible.

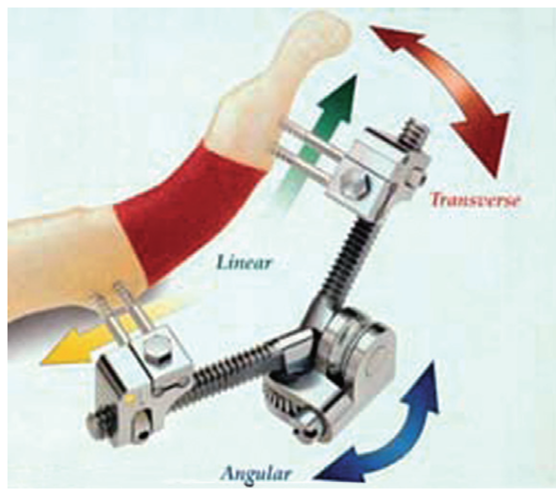

Figure 7.21f Multi-directional distraction osteogeneis which allows moulding of the callus vertically, horizontally and medio-laterally.

on the age of the patient and osteogenic potential of the distracted tissue.

5. Frequency

This represents the number of steps/increments required to achieve the distraction rate. In most of the cases it is split into 0.5 mm every 12 hours. Increasing the frequency of distraction and the number of increments would improve the quality of bone formation.

6. Retention period

After completion of the required lengthening of the bone segment the distraction device is left in place to allow the consolidation and remodelling of the bone between the segments. This retention period is dependent on the magnitude of distraction, the patient's age, and the quality of the formed bone. This retention period is usually four times the length of the active distraction phase.

7.11.1 Mandibular distraction osteogenesis

Indications

1. Severe mandibular retrognathism or hypoplasia beyond the scope of advancement using a conventional sagittal split osteotomy.
2. Deficiency of the vertical ramus height.
3. Mandibular asymmetry due to unilateral shortness of the vertical height of the ramus or deficiency of the antero-posterior length of the body of the mandible in one side.
4. Narrow mandibular width.

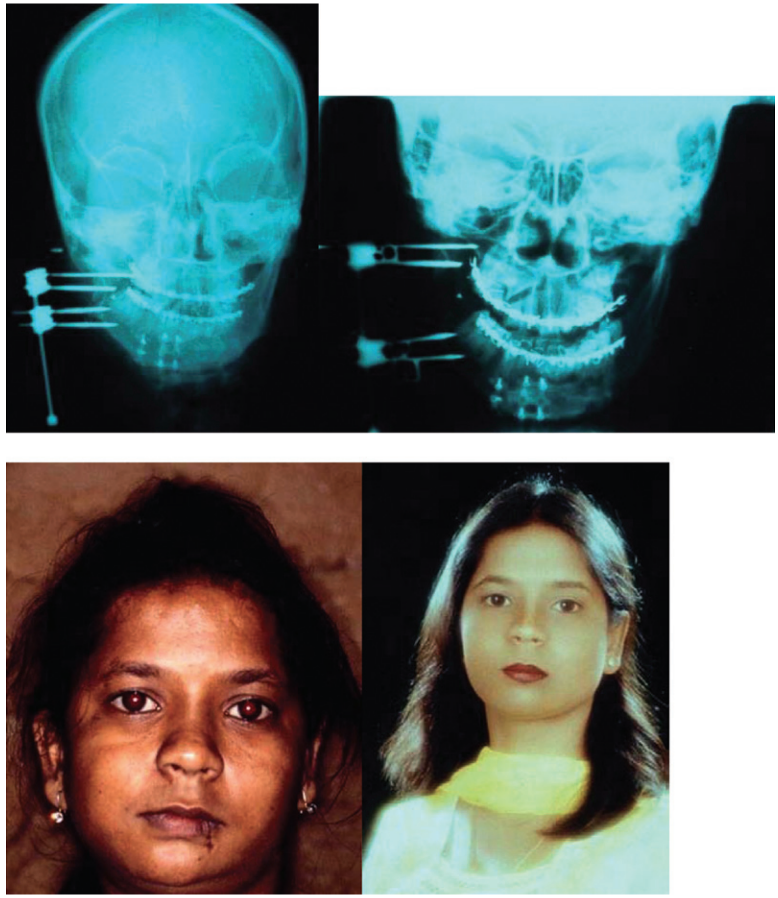

Figure 7.22a Radiographs showing the lengthening of the right vertical height of the ramus using unilateral extra-oral distraction osteogenesis and the achieved correction of facial asymmetry.

Figure 7.22b Lateral cephalograph and profile photograph before and after correction of severe mandibular deficiency using extra-oral bilateral mandibular distraction osteogenesis.

5. Following condylectomy to create a new condylar process.
6. Segmental mandibular defect.
7. The need to avoid the harvest of autogenous bone graft.

Mandibular lengthening by distraction osteogenesis can be achieved by using extra-oral devices, unilaterally (Figure 7.22a), or bilaterally (Figure 7.22b). The main complications associated with extra oral devices are the scarring, potential facial nerve damage, infection from the transcutaneous pins, lack of acceptance by patients and finally the difficulty that patients face socially. However, they offer the advantage of better control of the distraction vector. The use of intraoral devices (Figure 7.23) may interfere with the application of oral hygiene measures and patient co-operation is essential to avoid infection at the surgical site. Mandibular lengthening has also been achieved using automatic continuous distraction osteogenesis (Figures 7.24a, 7.24b), this

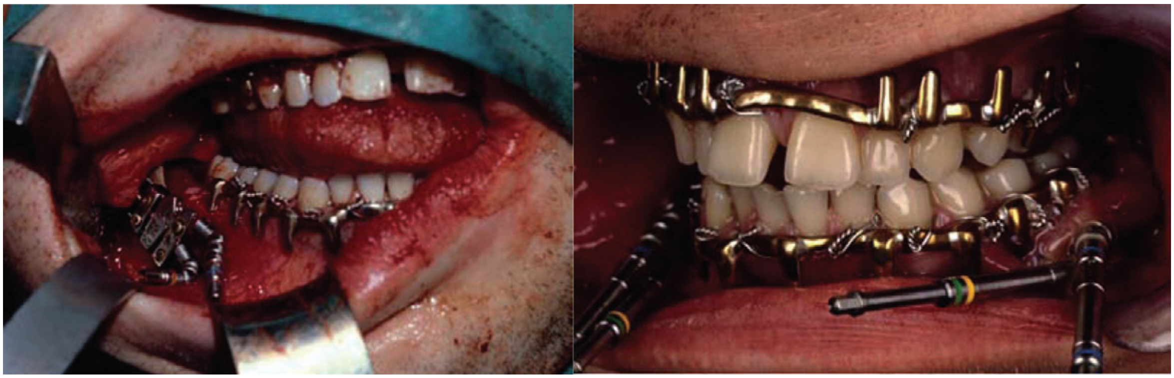

Figure 7.23 Bi-directional intra-oral distraction osteogenesis, one rod is used for antero-posterior distraction and the other for the vertical adjustment.

Figure 7.24a Postero-anterior radiographs and facial photographs before and after correction of facial asymmetry due to deficiency of the berticla height of the right ramus using automatic continuous distraction osteogenesis. Source: Ayoub, A.F., Richardson, W. and Barbenel, J.C. (2005) Mandibular elongation by automatic distraction osteogenesis: the first application in humans. *Brit J Oral Maxillofac Surgery*, **43**, 324–328. Reproduced with permission of Elsevier.

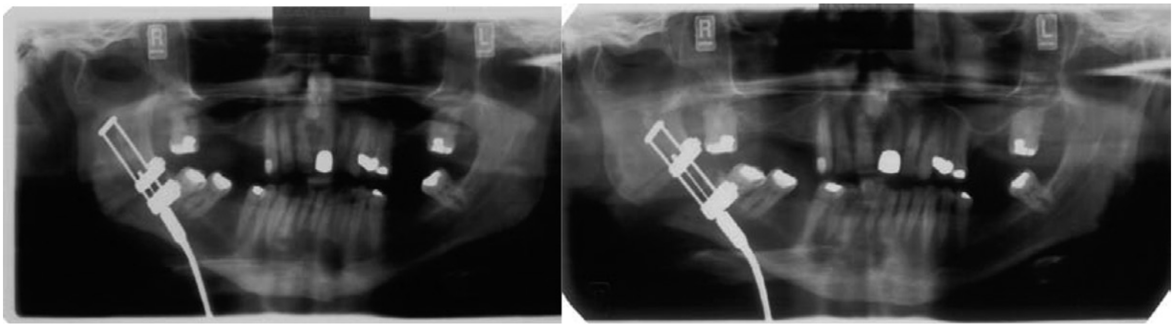

Figure 7.24b Panoramic radiographs before and after completion of the automatic continuous distraction osteogenesis for correction of mandibular asymmetry. Source: Ayoub, A.F., Richardson, W. and Barbenel, J.C. (2005) Mandibular elongation by automatic distraction osteogenesis: the first application in humans. *Brit J Oral Maxillofac Surg*, **43**, 324–328. Reproduced with permission of Elsevier.

Figure 7.25a A case of cleft lip and palate showing maxillary hypolasia and collapse of the dental arch. Source: Jayade *et al.* (2006). Reproduced with permission of Elsevier.

approach has the advantage of multi-incremental distraction without patients' interference.

7.11.2 Maxillary distraction

Distraction osteogenesis is an efficient method for advancing the maxilla at a Le Fort I level.

Indications

1. Cleft lip & palate cases (Figure 7.25a) due to excessive scar formation of the lip and/or the palate, as well as the limited bone stock in width and height.
2. In non-cleft cases where the magnitude of maxillary advancement osteotomy is beyond the conventional Le Fort I osteotomy.
3. Eliminate the need for bone graft in cases which require significant maxillary advancement more than 10 mm.
4. In children to avoid the use of internal fixation using metal plates which would interfere with facial growth.

Extra-oral distraction osteogenesis (Figure 7.25b) usually achieves satisfactory stability (Figure 7.25c). The stability of maxillary advancement is improved

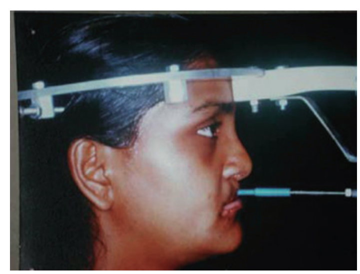

Figure 7.25b The application of the Glasgow Extra-oral Distraction (GED) device for correction of maxillary hypoplasi. Source: Jayade *et al.* (2006). Reproduced with permission of Elsevier.

with distraction osteogenesis due to the gradual expansion of the soft tissue envelop throughout the course of treatment.

7.11.3 Compression bifocal and multifocal distraction osteogenesis

Distraction osteogeneis can be successfully utilised to reconstruct segmental bone defect. An osteoperiosteal bone segment (transport disc) is cut and gradually distracted across the defect. The tissue is

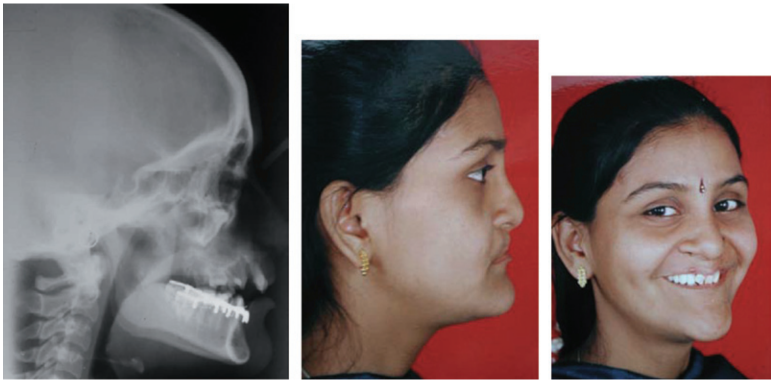

Figure 7.25c Radiographic and photographic appearance of the face after completion of maxillary distraction osteogenesis. Source: Jayade *et al.* (2006). Reproduced with permission of Elsevier.

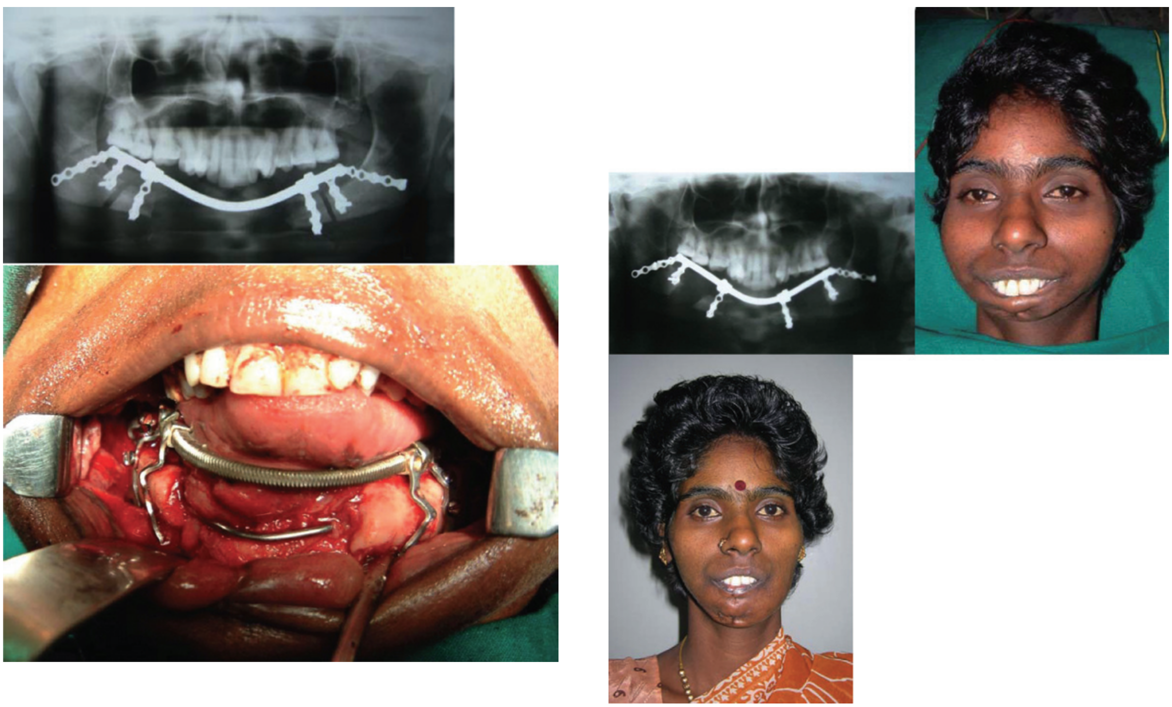

Figure 7.26 Preoperative and postoperative panoramic radiographs, and intra-oral photograph showing the mandibular continuity defect and its reconstruction by tri-focal intra-oral distraction osteogenesis using two transport discs and its impact on improving facial appearance.

compressed mesial to the transport disc and the soft callus is distracted distal to the disc. Tri-focal distraction is achieved by cutting two transport discs, one proximal to and one distal to the segmental defect (Figure 7.26). Bone will be formed by distraction osteogenesis between each of the transport discs and its adjacent bone segment. In addition, the tissue between the two transport discs would be gradually compressed until they meet together at the centre of the defect, the method has been used successfully for reconstruction of mandibular continuity defect and improved the facial appearance (Figure 7.26). Freshening the edges of the transport discs as they meet may be required to achieve complete bone union.

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8 High level osteotomies

Chapter overview

Intended learning outcomes

By the end of this chapter the reader should:

- Have an understanding of the usage and indications for standard and high level osteotomies and the principles of timing for surgery.
- Have an explanation of the basic surgical procedures and the principles behind them.
- Recognise the surgical limitations, risks and possible complications that can occur.
- Have an understanding of the reasons for long term follow up and the necessity for repeat procedures as a result of failure of growth after birth.
- Have a basic knowledge for information to patients searching for treatment.

8.1 Introduction

There are a variety of osteotomies that may be used in the midface for the correction of deformity which have a small place in the repertoire of the maxillofacial surgeon primarily for the correction of craniofacial and asymmetric deformity. The principal ones are the Le Fort II and Le Fort III osteotomies outlined here.

Le Fort II and III osteotomies are based on the fracture lines which occur following trauma and these have been modified over the last 40 years to correct congenital deformities of the midface. They also may be used for post traumatic, secondary cleft and iatrogenic deformities (e.g. post radiotherapy) and they can be extensively modified to correct asymmetric deformity and for localised osteotomies in the craniofacial area.

8.2 Indications

8.2.1 The Le Fort II osteotomy (Figures 8.1a, 8.1b)

This is most effective where there is central midface (naso-maxillary) hypoplasia with both anteroposterior and vertical deficiency without significant orbital hypoplasia or ocular proptosis. There may be

Handbook of Orthognathic Treatment: A team approach, First Edition. Ashraf Ayoub, Balvinder Khambay, Philip Benington, Lyndia Green, Khursheed Moos, and Fraser Walker.

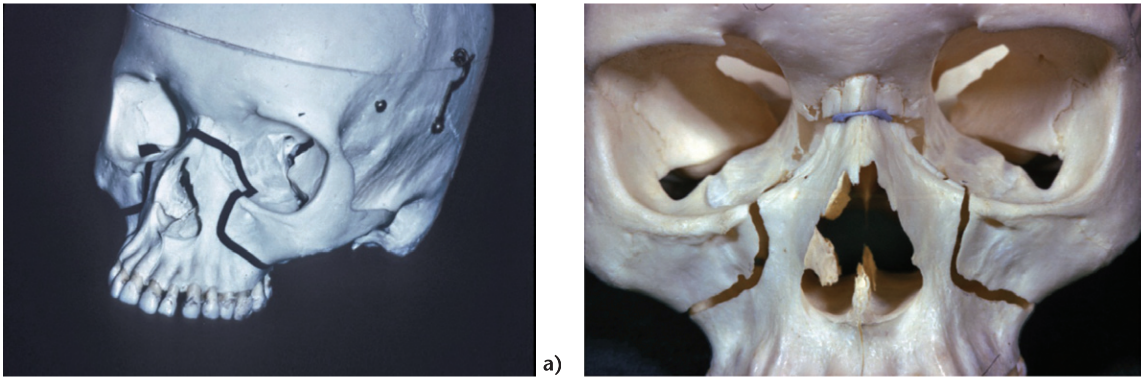

Figure 8.1 Le Fort osteotomy cuts.

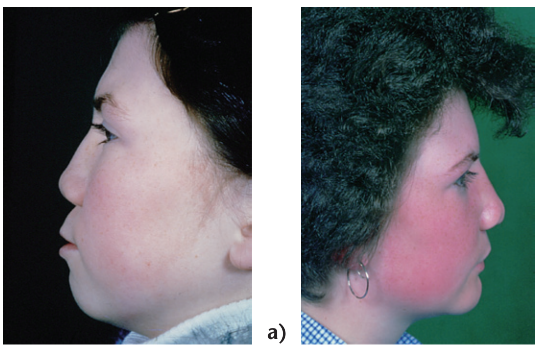

Figure 8.2 von Binder syndrome pre- and post-op.

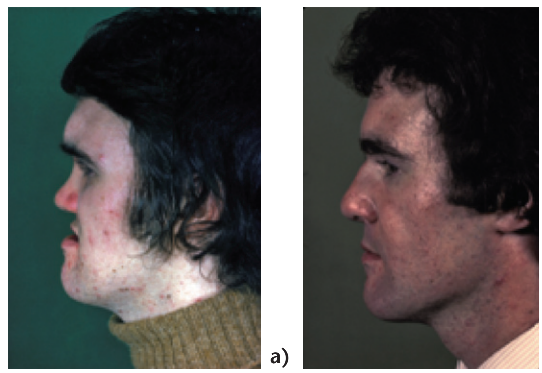

Figure 8.3 Malunited fracture corrected by Le Fort II osteotomy.

a degree of telecanthus or hypertelorism. It is most effective in von Binder's syndrome (maxillo-nasal dysplasia), (Figure 8.2) and post traumatic cases (Figure 8.3). When there is infraorbital hypoplasia the procedure may be extended laterally, but there is a risk of damage to the infraorbital nerve. It is most useful for cases with a short hypoplastic nose, with moderate vertical and anteroposterior deficiency.

8.2.2 The Le Fort III osteotomy

This is primarily indicated for total midface hypoplasia, where there is deficiency affecting maxillae, malars and nasoethmoidal complex, especially in the presence of exorbitism. This is typically seen in syndromic and non-syndromic craniosynostosis, where the base of skull and the coronal sutures are affected. Many milder degree cases may be corrected by a subcranial procedure. This can also be used for untreated post-traumatic deformity and for major craniofacial clefting defects. An additional Le Fort I osteotomy is often required to increase the maxillary vertical dimension or to improve the dental occlusion. (The Kufner modification where the nasoethmoidal complex is left in its original position and the malars and maxillae are advanced is occasionally helpful but often it is difficult to obtain a good dental occlusion, and it is then better to do two malar osteotomies with a separate Le Fort I procedure.)

The Le Fort III osteotomy is widely used either subcranially or transcranially for deformities associated with the craniosynostotic syndromes of Crouzon, Apert, Carpenter, Pfeiffer and Saethre-Chotzen. Care needs to be taken when there is only slight exophthalmos associated with major midface hypoplasia which is sometimes seen in Apert's syndrome. Any major advancement with distraction osteogenesis can lead to enophthalmos and then bone grafting of the orbits will be necessary. Distraction osteogenesis is particularly useful for severe maxillary retrusive deformity, as it largely avoids the necessity for extensive bone grafting. The latter is difficult to do when the child is very young, that is, between 1 and 5 years when surgery is necessary at that stage.

8.3 Timing of surgery

If surgery is to be carried out for aesthetic reasons this is best done at the end of the growth period (females 17 to 18 years and males 18 to 19 years) as a single procedure with pre and post surgical orthodontic care. However in most syndromic cases early release of cranial sutures is required between 8 and 15 months of age to allow the brain to grow. It triples its volume in the first year, after that there is only a small increase in its size. Premature suture closure will lead to raised intracranial pressure, brain damage and loss of vision. Early surgery for release of cranial sutures and frontal (supraorbital) advancement is then required. Following this the facial deformity appears much worse and sometimes this is complicated by postnasal choanal atresia accompanying the midface retrusion with airway problems and obstructive sleep apnoea. Early (<18 months) midface advancement surgery is difficult with poor control of the facial bones and it is better if possible to wait until 5 to 10 years. A tracheostomy or a CPAP machine may be required to improve the airway until surgery is carried out. Prior to any early surgery, it is essential to exclude other congenital anomalies, for example, cardiac, respiratory and neurological and to check the family history especially for other recessive and dominant conditions. A psychological assessment of children and young adults should always be considered before this type of surgery.

8.4 Special investigations

Prior to surgery a neurological check for raised intracranial pressure should be made with CT/MRI scanning. CT scanning of the mid- and upper face with three-dimensional, axial and coronal cuts is necessary. Any suspected or identified intracranial problems are additionally likely to require magnetic resonance imaging as well as the usual posteroanterior and lateral cephalograms for orthognathic planning purposes. If there is asymmetry of any significance then stereolithography is helpful. Intraoral dental views may be required as well as an orthopantomograph and dental models. From the general medical point of view a chest x-ray, routine haematology and biochemistry would be appropriate as well as a preoperative neurosurgical and anaesthetic assessment and a check for other systemic disease. A team approach is adopted for all orthognathic cases.

8.5 Le Fort II surgical procedure

(a) **Approach**

An intraoral incision from right to left malar buttresses as for the Le Fort I osteotomy is made. Mucoperiosteal flaps are raised to expose the infraorbital margins and the nasomaxillary area and the whole of the pyriform aperture. Bilateral oblique canthal (medial) incisions are made through skin onto the frontal process of the maxillae just lateral to the external angular veins. The subperiosteal stripping is continued over the bridge of the nose, elevating the soft tissues well into the orbits without damaging the infraorbital nerves, nasolacrimal ducts and lacrimal sacs.

(b) **Osteotomy-bone cuts, mobilisation and reconstruction**

The bone cuts are made with burs starting midway between the infraorbital nerve and naso-lacrimal duct on each side slightly obliquely and inferiorly then horizontally across the zygomatic buttresses to the pterygo-maxillary junctions on both sides (Figure 8.1). Via the canthal incision a bur cut is made through the infraorbital margin and is then extended medially behind the naso-lacrimal duct with a small chisel. The bur cut is completed medially through the lateral wall of the naso-ethmoid elevating the soft tissues with an Aufricht retractor and across the bridge of the nose below the fronto-nasal suture to join a similar cut from the opposite side. The medial canthi remain intact and attached to the elevated periosteum. A curved Tessier chisel is then directed inferiorly through the canthal incision on one side to section the nasal septum and vomer completing the cut into the nasopharynx, at the same time checking its position in the nasopharynx. The lower portion of the pterygoid plates are separated from the maxillae with Tessier chisels. With Rowe's disimpaction forceps the midface is mobilised, taking care to avoid tearing the naso-lacrimal ducts. This can be difficult in post-traumatic and secondary cleft deformities. In that case Smith spreaders can be helpful in the zygomatic buttress areas and for advancement Tessier mobilisers. The maxillary dentition is checked into its new position with an interocclusal wafer and the vertical and horizontal positions are fixed using two mini plates on each side. Some trimming of bone in the nasal bridge area is usually required and small bone grafts are inserted at the infraorbital margins, nasal bridge, medial orbital and anterior maxillary osteotomy sites. With major shifts inferiorly and anteriorly it can be helpful to use pin fixation with a Levant frame attached to an upper arch bar to fix the maxilla correctly in space then applying plates and bone grafts after which the pin fixation may be removed before soft tissue closure.

(c) **Other reconstructive procedures**

For secondary cleft deformity bone grafting of the pyriform aperture and nasolabial areas may be required before closure of the nasal and oral cavities. In von Binder's syndrome, the bony deficiency in the nasal sill area is corrected following extensive mucoperiosteal elevation of the nasal floor and nasolabial areas which often requires periosteal release and cuts to allow insertion of a wing shaped bone graft (cranial or ileal) to provide an anterior nasal spine when this is absent. The columella skin is sectioned vertically to insert a columella strut attached to the wing shaped bone graft, to give a nasal tip projection. From the frontonasal suture area a long bony strut can be inserted through a small midline vertical frontonasal incision. This is fixed into position with a small mini or micro plate. Standard skin and mucoperiosteal closures are then carried out.

8.6 Le Fort III surgical procedure

8.6.1 Indications

Total midface advancement and midface lengthening with onlay bone grafting is usually applicable. If craniectomy and cranial suture release or other intracranial procedures are required a transcranial approach is to be used (but this is not considered here), otherwise if no intracranial intervention is required the approach should be subcranial. Accompanying midface lengthening frequently requires a Le Fort I osteotomy which can be carried out sequentially. These procedures are used primarily for syndromic craniofacial synostosis and occasionally for other deformities, for example, achondroplasia and post-traumatic deformity (Figure 8.4).

(a) **Approach**

Essentially the approach is made via a long coronal incision carried down low into the preauricular area. To reduce the significant scar in the hairline a zigzag incision is widely used down to the temporal fascia laterally and to the pericranium coronally. The

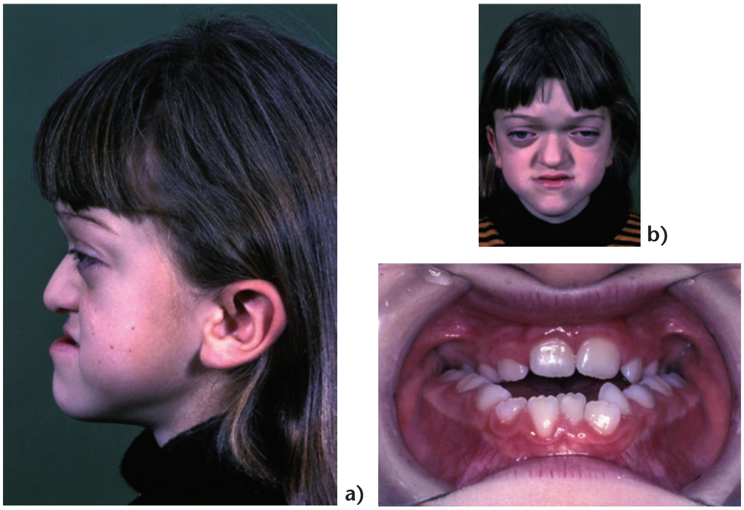

Figure 8.4 Crouzon deformity requiring a Le Fort III correction.

pericranium is then incised 2–3 cm above the supraorbital ridge from the temporal fascia from one side to the other and then the pericranium is elevated into the orbits tunnelling to expose both malar complexes, the zygomatic arches and the nasoethmoid. The supraorbital nerves are freed from the superior orbits with a small chisel and the nasoethmoidal complex is exposed with a midline vertical periosteal incision, then laterally into the orbits, the lateral canthi are marked with a suture. The medial canthi are elevated subperiosteally from the naso-orbital ethmoidal complex, followed by extensive periorbital stripping to include the orbital floor. If this is difficult it can be accessed inferiorly through a lower transconjunctival approach. The temporalis muscles are stripped subperiosteally out of the temporal fossae but not detached. To give better access to the zygomatic arches the outer layer of the temporal fascia is split laterally avoiding the facial nerve (temporal branch) and the arch is exposed through the fat. Additional access to the malar complex is through two vestibular mucoperiosteal incisions in the molar regions to approach the pterygo-maxillary junctions on both sides.

(b) Bones cuts

The malar bones may be either mobilised entirely with the maxillae or be sagittally split, the former is easier especially when they are small in the young child (Figure 8.5). The temporal fossa is very shallow and it is essential when making lateral orbital cuts to avoid entering the middle cranial fossae. The zygomatic arches are sectioned through the suture or just posterior to the main body of each malar. The lateral orbits are sectioned through the frontozygomatic sutures then down the lateral orbital wall extending these cuts infraorbitally on each side down towards the infraorbital fissures. The cut may then be picked up through the transconjunctival incision and taken across the orbital floor avoiding damage to the infraorbital nerves to just posterior to the lacrimal sac. The nasal bones are cut across at or close to the frontonasal suture directing the bur cut slightly inferiorly to avoid entering the cribriform plate area and passing intracranially. The cuts in the nasoethmoidal areas are then directed inferiorly through the medial wall of the orbit to pick up the infraorbital cut, making sure to avoid any damage to the nasolacrimal apparatus. This is usually abnormally positioned in a funnel shaped antero-medial wall defect. A curved Tessier chisel is passed through the frontonasal bone cut and is directed firmly downwards and slightly backwards to section the septum, guided by a transoral finger in the nasopharynx to avoid damage there. The pterygoid plates are separated from the back of the maxilla with a curved Tessier chisel through the vestibular incisions. In young children this may be more easily achieved from above by passing the chisel under the zygomatic arch and protecting it with a finger.

(c) Mobilisation

Mobilisation of the midface is carried out with Rowe's disimpaction forceps, sometimes considerable but controlled force is required assisted by using chisels in the osteotomy sites especially the frontonasal/frontozygomatic areas and Smith spreaders applied in the zygomatic buttress areas can be helpful. For advancement of the midface Tessier mobilisers are used in the retromolar areas on both sides. Care of the airway is essential at this stage as bleeding is sometimes significant. Slight figure of eight movements of

a)

b)

Figure 8.5 Le Fort III bone cuts.

the midface with Rowe's disimpaction forceps can be helpful during mobilisation and disimpaction.

Excessive tension on the globes must be avoided, often indicated by slowing of the pulse rate. Once the midface is free, intermaxillary fixation with an interocclusal splint provides an intraoperative rest period for stabilisation of the patient.

(d) **Reconstruction**

This can be carried out either by distraction osteogenesis at 2–3 days following the insertion and use of a distraction device which will advance the midface and nasoethmoidal complex (Figure 8.6). This may be fixed to the teeth and superiorly to the nasoethmoidal complex in the young adult. The alternative is to manually advance the midface stabilising the occlusion and the vertical position of the face with intermaxillary fixation and titanium mini plates at the frontozygomatic suture, zygomatic arches and at the frontonasal osteotomy site. Cranial bone graft is used to fill in defects in the lateral orbits, orbital floor, medial orbit, frontonasal area and zygomatic arches. The cranial bone graft is normally harvested from the outer plate of the parietal bones. Following this the intermaxillary fixation is removed.

The medial canthi are identified through a small horizontal incision of the skin at the medial canthus. A fine wire is passed through and around the canthal ligament and both ends are then passed through a fine cannula or needle posterosuperiorly to the opposite medial orbit and are attached to a micro plate placed vertically from the supraorbital ridge. This is repeated on the other side. This allows the canthus to correctly position slightly more posteriorly and superiorly and then a further screw may be placed in the plate to fix their position posteriorly and vertically from the supraorbital ridge. This is repeated on the other side.

The lateral canthi are picked up by a fine wire passed through the lateral canthi from the skin surface on each side which is then passed back through the skin to be attached laterally to the supraorbital ridge on each side. Throughout, protection of the eyes must be maintained often with a Frost suture. Forced duction testing of globe movements is essential to avoid subsequent diplopia and to ensure there is no prolapse of orbital contents into any floor defect. Prior to this where there has been gross proptosis, the periorbita should be cut circumferentially to allow the orbital fat to flow into the enlarged orbits. Any orbital dystopia or orbital asymmetry should be corrected or dealt with prior to closure and defects in the orbital walls are filled with cranial bone graft.

Two cranial suction drains are placed over the frontal bones. The pericranium and temporal fascia are closed on both sides with subcutaneous resorbable sutures followed by replacement of the coronal flap taking care to suture the galea back into place and Raney clips are used to close the coronal skin incision (Figure 8.7, Figure 8.8).

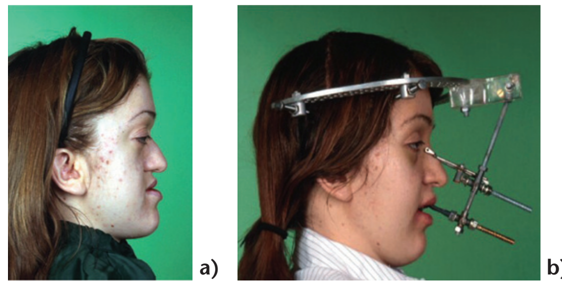

Figure 8.6 Crouzon deformity pre- and post-op distraction.

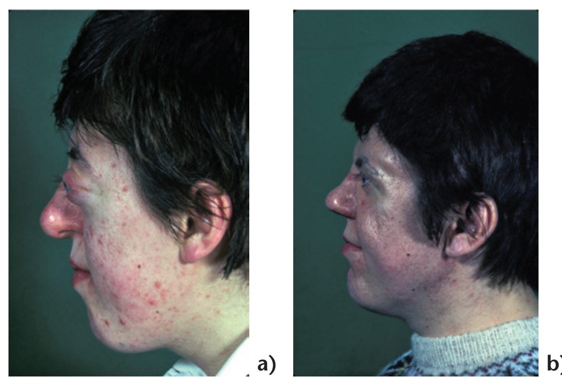

Figure 8.7 Apert deformity pre- and post-op.

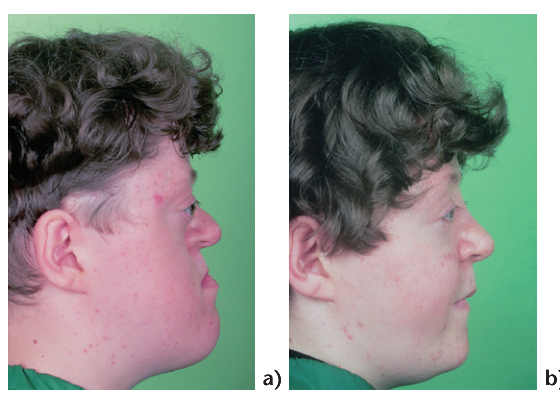

Figure 8.8 Apert deformity pre- and post-op.

If there is significant shortage of midface height, this is usually best corrected by a Le Fort I osteotomy which should be undertaken after completion of the Le Fort III through a standard vestibular incision. Separation is easy and the vertical defects are filled with bone graft after plating of the maxilla. Again cranial or ileal grafts are commonly used. The vestibular incision is then closed in the standard way after checking the vertical and horizontal dimensional changes using an inter-occlusal splint. The intermaxillary fixation may then be released.

Occasionally onlays of bone graft over the malars are required. These can be inserted after the Le Fort I osteotomy and may be fixed with screws or plates and screws.

If any surgery to the mandible is required, this should be done at this stage.

Prophylactic antibiotics and high dose steroids for a short period are normally given to reduce swelling and the risk of infection. Appropriate eye monitoring and protection is required.

Modifications: consideration should be given to the Kufner procedure and the use of bilateral malar osteotomies, onlay bone grafts, reduction of prominent supraorbital ridges, reshaping of orbital margins at a later stage. Also minor degrees of hypertelorism and telecanthus may be corrected. Nasal lengthening and increased prominence of the nasoethmoidal complex with a bone strut is commonly undertaken. Correction of orbital dystopia in association with Le Fort III osteotomy especially when associated with a plagiocephaly requires a transcranial approach to obtain an optimal result.

8.7 Advantages and disadvantages of subcranial Le Fort III osteotomy

(a) **Disadvantages**
- does not correct deformity of the superior orbit and frontal area;
- any severity of orbital dystopia and hypertelorism cannot be corrected;
- difficult to correct significant asymmetry or plagiocephaly. For this a transcranial procedure is required.

(b) **Advantages**
- less risk of infection;
- reduced risk of intracranial complications, CSF leak, meningitis, anosmia;
- no need for neurosurgical intervention or dural repair;
- much shorter operation, lowers infection risk, frontal sinuses not involved;
- if early surgery at 11–12 years is undertaken. This can be repeated at the end of growth period.

8.8 Complications related to anatomy of area

1. Persisting deformity – asymmetry; relapse – inadequate mobilisation and poor fixation, temporal hollowing – failing to advance a portion of temporalis muscle onto the lateral orbit during closure.
2. Orbital complications
   (a) diplopia due to muscle trapping with bone grafts or just poor ocular muscle development this may require ophthalmic – ocular muscle surgery.
   (b) blindness due to “trauma” or retrobulbar haemorrhage.
   (c) en- or exophthalmos – failure to manage satisfactorily the orbital contents.
   (d) ptosis – often initially present but masked by exophthalmos – will require upper lid reduction and some levator surgery.
   (e) corneal ulceration. Failing to protect the globe intra- and post-operatively.
3. Canthal drift
   (a) failure to correct fully telecanthus especially when the ligaments are rudimentary.
   (b) failure to find/reposition lateral canthi – normally requires slight over correction.
4. Cranial – CSF leak and meningitis – inadvertent communication in the cribriform plate area.
5. Damage to cranial nerves
   (a) damage of nerves to extraocular muscles may lead to diplopia of III IV VI nerves and this may be due to narrowing of the superior orbital fissure.
   (b) damage to olfactory nerves I loss of sense of smell and to optic nerves II leads to blindness.
   (c) anaesthesia – as a result of damage to infra and supraorbital nerves as well as to the zygomaticofacial/temporal nerves, V- first and second branches leads to anaesthesia.
   (d) facial weakness – rarely damage to temporal branches of VII.
6. Lacrimal – glands rarely affected, but risk of damage to nasolacrimal apparatus, notably the duct and sac – can lead to epiphora and recurrent dacryocystitis.

7. Nasal – problems with obstruction synechiae (fibrous bands), infection of paranasal sinuses and unsatisfactory appearances.
8. Dental – malocclusion, anterior open bite and trismus – as a result of inaccurate planning, failure to fully mobilise the midface and unstable orthodontic treatment.

8.9 Other facial deformities

8.9.1 Treacher Collins Syndrome

This is a dominant hereditary disorder with variable penetrance sometimes occurring sporadically. It is typified by clefting defects of the zygomatic arches and either the infraorbital or lateral orbital margins which is accompanied by severe bilateral malar hypoplasia with an antimongoloid slant to the eyes. There is also poor mandibular development affecting the condyles and causing severe mandibular retrusion and retrogenia, with short mandibular rami and marked antegomial notching. There is also a variable degree of maxillary hypoplasia and sometimes a cleft palate and a poor nasal airway. Pinna formation is bilaterally poor with a crumpled appearance and there is an auditory conduction defect as a result of failure of first and second branchial arch structures to develop normally. In early life obstructive sleep apnoea may be a prominent feature requiring early tracheostomy and very early mandibular advancement by distraction osteogenesis. Colobomata affecting eyes and lower lids and absent cilia are frequently seen. For the older child, osteotomy surgery with malar bone grafting, closure of the cleft defects and onlay bone grafting are frequently required. Mandibular and genial advancement will routinely be required at an age dependent on the expression of the syndrome with gross underdevelopment of the auditory and pinna development. Bilateral bone anchored hearing aids will be required and if ear reconstruction is not feasible, bone anchored prosthetic ears should be constructed (Figure 8.9).

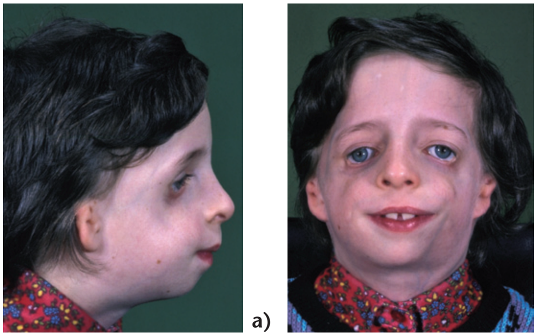
a) b)

Figure 8.9 Treacher Collins deformity.

8.9.2 Craniofacial (hemifacial) microsomia

This is the second most common facial deformity after cleft lip and palate and will only be considered briefly here in relation to the midface and mandible. It occurs sporadically with no hereditary basis and it is a very variable first and second arch developmental deformity. Rarely is it bilateral in Goldenhar's syndrome, which gives a more symmetrical appearance to the individual. This is usually accompanied by ocular defects, superolateral orbital dermoid cysts and vertebral anomalies as well as bilateral conductive deafness. The unilateral deformity is very variable and principally affects the ear and mandible as well as adjacent soft tissues which are hypoplastic. It may involve the midface with hypoplasia extending into the orbit with poor ocular development, appearance and function. The muscles of mastication are normally hypoplastic on the affected side and the salivary glands may be absent or small in size. The defect may also affect the temporal bone and the pinna on the affected side and in severe cases it may be absent or grossly hypoplastic and there may be agenesis of the external auditory meatus and middle ear. There are ear tags commonly unilateral macrostomia and a clefting defect of the lip commissure may be present. This is accompanied by a three-dimensional failure of growth of the facial structures on the affected side which is very variable in relation to site and extent.

Use of the Pruzansky classification is helpful if the deformity is primarily mandibular in giving guidance to the surgeon as to the best surgical options. Type 1 can be treated by osteotomy surgery, Type 2a often by distraction osteogenesis, Type 2b often with a costo-chondral graft, and Type 3 by a full reconstruction of the condyle. This takes no account of soft tissue defects or other facial bone defects and for that the OMENS classification may prove to be more helpful (Figure 8.10).

Treatment is based on reconstruction of the mandible and the ear, correction of the asymmetry which may be complicated sometimes by a facial nerve paresis from birth. Orbital reconstruction and midface surgery is commonly required because of vertical and horizontal hypoplasia. Distraction is often helpful

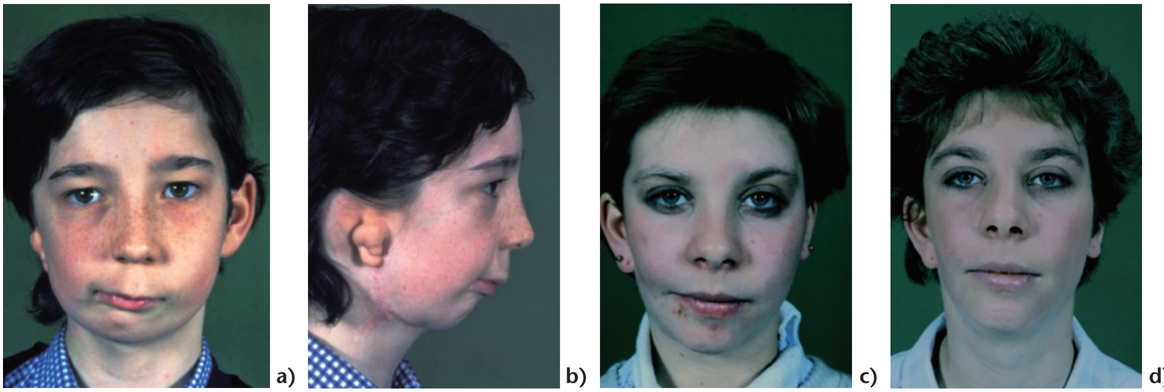

Figure 8.10 **(a)** & **(b)** Preoperative appearance, **(c)** & **(d)** show immediate postoperative and final facial appearance at 5 years.

and may be repeated to increase the bone volume otherwise large defects may be reconstructed by the use of composite free flaps commonly the deep circumflex iliac, arterial flap with bone, muscle, fat and skin, the latter of which may be removed at a later stage. There is still considerable discussion over the timing of treatment and its nature. Rarely is there any intracranial involvement.

8.10 Further reading

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Ward, P., Booth, S., Schendel, A. and Hausamen, J-E. (1999) *Maxillofacial Surgery*, Churchill Livingstone: London.

9 Case reports

Handbook of Orthognathic Treatment: A team approach, First Edition. Ashraf Ayoub, Balvinder Khambay, Philip Benington, Lyndia Green, Khursheed Moos, and Fraser Walker.

Case 9.1
Class II, division 2 malocclusion

Presentation

Caucasian male, 27 years old with a clear medical history.

No psychological contra-indications to treatment.

Patient's concerns

Functional:
- Deep and traumatic overbite.

Aesthetic:
- Lower jaw too far back.
- "Collapsed" lower face.

Facial features (Figure 9.1.1)

Antero-posterior:
- Class II skeletal jaw relationship.
- Mandibular retrusion.
- Increased naso-labial angle.
- Progenia.

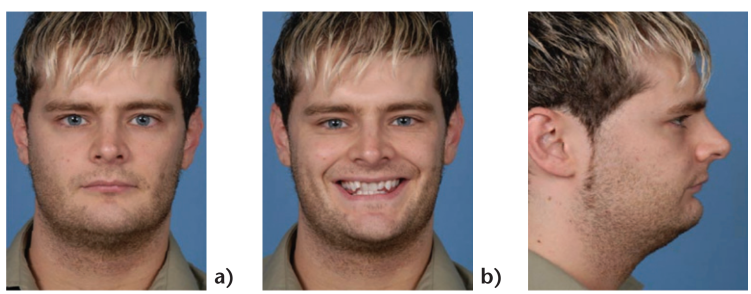
Vertical:
- Upper incisor show slightly reduced.
- Reduced lower anterior face height.
- Acute labio-mental fold.
- Reduced gonial angle.
- Shallow mandibular plane.

Transverse:
- No obvious facial asymmetry.

Intra-oral features (Figure 9.1.2a)

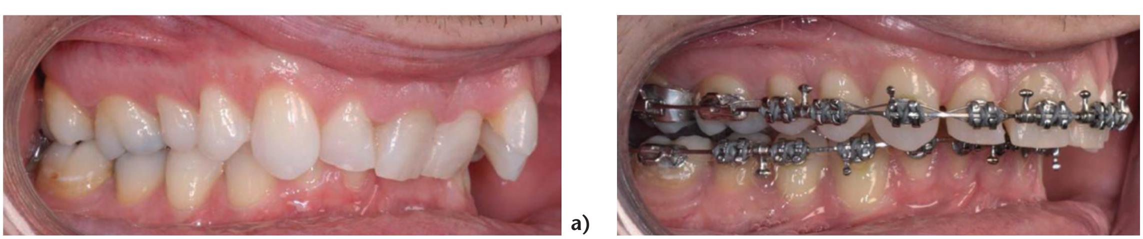
Dentition:
- Upper incisors retroclined and severely crowded.
- Lower incisors of average inclination and aligned.
- Accentuated lower curve of Spee.

Occlusion:
- Severe class II, division 2 incisor relationship.
- Overbite 100%, complete and traumatic.



a) b) c)

Figure 9.1.1 Frontal view of the face at rest **(a)** shows the reduced lower anterior face height. A smiling view **(b)** suggests slightly reduced upper incisor show. The profile view **(c)** shows a deep labiomental fold accompanied by progenia and the characteristic features of a short facial type.



a) b)

Figure 9.1.2 Intra-orally the upper incisors are retroclined **(a)**, but the presence of severe crowding is favourable for enabling proclination as part of orthodontic decompensation **(b)**.

- Overjet minimal.
- Buccal segments greater than a full unit class II bilaterally.

Initial combined plan

Desired soft tissue changes and provisional dento-skeletal movements

1. Upper incisor and maxillary position.
   Reduce naso-labial angle and increase incisor show:
   - *Normalise inclination of upper incisors.*
   - *Downgraft anterior maxilla by 2 mm.*
2. Occlusion and mandibular position.
   Advance the mandible by about 10 mm, improve lip posture and increase LAFH:
   - *Advance mandible 10 mm (BSSO).*
   - *Correct occlusion to "three-point landing".*
3. Maxillo-mandibular complex rotation.
   Steepen mandibular and occlusal planes:
   - *Clockwise rotation.*
4. Chin position.
   Achieve optimal vertical proportions and profile balance.
   - *Vertically augment the chin (genioplasty).*

Key objectives of pre-surgical orthodontic treatment

- Procline upper incisors beyond their normal inclination, to compensate for the planned backward maxillary rotation.
- Maintain lower incisor inclination, since backward surgical rotation of the mandible will procline them effectively, relative to the true vertical plane.
- Achieve 10–11 mm overjet (this will allow 10 mm mandibular advancement).
- Maintain lower curve of Spee to allow "three-point landing".
- Expand maxillary arch to coordinate arches if possible.

Final surgical plan

On completion of pre-surgical orthodontics (Figures 9.1.2b and 9.1.3):

- The upper incisors were at greater than normal inclination (120°).
- The overjet was 11 mm.
- The lower curve of Spee was largely maintained.
- The fit of the occlusion was acceptable, but it was not possible to achieve ideal transverse arch coordination orthodontically.

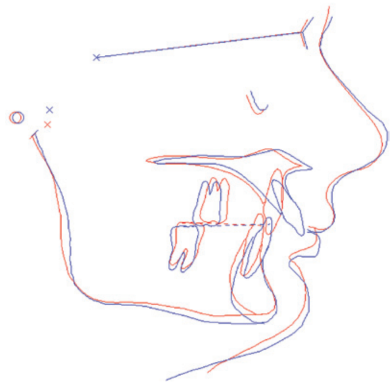
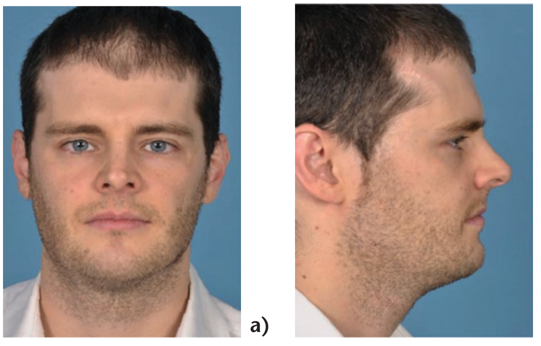


Figure 9.1.3 Superimposition of pre-treatment (red) and pre-surgical (blue) cephalometric tracings shows that the severely retroclined upper incisors were fully decompensated. (Produced using OPAL, British Orthodontic Society).



a) b)

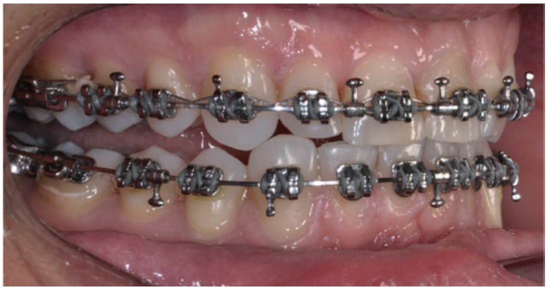
Figure 9.1.4 End of treatment views illustrate that a good improvement in the vertical facial proportions **(a)** and soft tissue profile **(b)** were achieved.

The surgical plan was finalised, with the aid of model surgery and photo-cephalometric software, as follows:

- Le Fort I anterior downgraft (2 mm) and posterior impaction 2 mm producing some backward (clockwise) rotation of the maxilla. No advancement was possible due to the limitation of mandibular advancement to approximately 10 mm.
- Bilateral sagittal split mandibular advancement 10 mm to three-point landing (Figure 9.1.5a).
- Vertical augmentation genioplasty 3 mm.

Treatment outcome (Figures 9.1.4–9.1.7)

The fact that maxillary advancement was not possible meant that no advancement of the upper lip


a)


b)

Figure 9.1.5 **(a)** The "three-point landing" shortly after surgery and **(b)** the final occlusion, following debond of orthodontic appliances. The lateral open bites were largely closed through a combination of vertical extrusion of the posterior teeth and settling of the overbite.

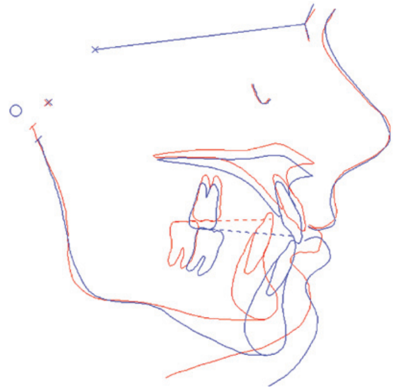


Figure 9.1.6 Cephalometric superimposition of pre-surgical (red) and post-surgical (blue) lateral cephalograms. Both the maxilla and the mandibular body have been rotated downwards and backwards (clockwise), resulting in a steepening of the occlusal and mandibular planes. A vertical augmentation genioplasty has been carried out to achieve optimal vertical proportions. (Produced using OPAL, British Orthodontic Society).

Figure 9.1.7 The vertical position and inclination of the upper incisors are aesthetically pleasing on smiling.

occured. Some rotation of the maxillo-mandibular complex was acheived with a corresponding steepening of the mandibular plane. The occlusion was largely corrected and dental aesthetics were very satisfactory.

Case 9.2
Vertical maxillary excess

Presentation

Caucasian female, 16 years old with a clear medical history.

No psychological contra-indications to treatment.

Patient's concerns

Functional:
- Some minor problems chewing.
- Lips do not meet together easily.

Aesthetic:
- Too much gum on show when smiling.
- Lower jaw too far back.

Facial features (Figure 9.2.1)

Antero-posterior:
- Class II skeletal jaw relationship.
- Mild maxillary deficiency.
- Increased naso-labial angle.
- Mandibular deficiency.

Vertical:
- Vertical maxillary excess with excessive gingival display both at rest and on smiling.
- Short upper lip.
- Increased lower anterior face height.
- Steep mandibular plane.
- Retrogenia with obtuse labio-mental fold.

Transverse:
- No obvious asymmetry.

Intra-oral features (prior to orthodontic treatment)

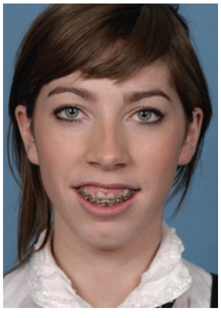
Dentition:
- Upper incisors upright and mildly crowded.
- Lower incisors of average inclination and mildly crowded.

Occlusion:
- Class II, division 1 incisor relationship.
- Overjet 8 mm.
- Buccal segments a full unit class II bilaterally.

Initial combined plan

Desired soft tissue changes and provisional dento-skeletal movements

1. Upper incisor and maxillary position.
   Reduce gingival display at rest and on smiling.
   Lengthen upper lip as much as possible.
   Increase the prominence of the para-nasal regions by 2–3 mm.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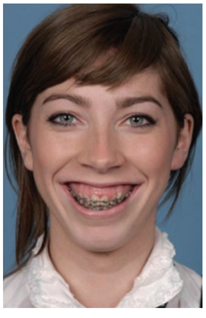
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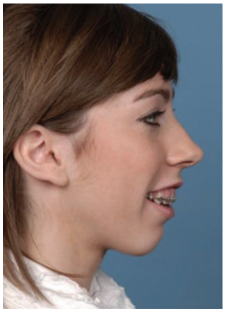

c)

Figure 9.2.1 Frontal view of the face at rest **(a)** and on smiling **(b)** showing the increased lower anterior face height, the presence of vertical maxillary excess and a short upper lip. The profile view **(c)** confirms that there is a high FMPA and a downward and backward rotation of the mandible.

- *Anterior maxillary impaction of 5 mm.*
- *V-Y incision closure.*
- *Maxillary advancement of 4 mm at Le Fort 1 level.*

2. Occlusion and mandibular position.
   Advance mandible to optimal occlusion, reduce LAFH and improve lip posture.
   - *Mandibular autorotation and advancement of 10 mm (which will also require posterior maxillary impaction to achieve positive overbite).*
3. Maxillo-mandibular complex rotation.
   Reduce steepness of occlusal and mandibular planes.
   - *Anti-clockwise rotation.*
4. Chin position.
   Achieve optimal vertical proportions and profile balance.
   - *Advancement and vertical reduction genioplasty.*

Objectives of pre-surgical orthodontic treatment

- Maintain upper incisor inclination to allow for differential posterior impaction of the maxilla.
- Level upper and lower arches.
- Maintain lower incisor inclination. Auto-rotation of the mandible will effectively retrocline the lower incisors relative to vertical.
- Achieve target overjet of 8 mm. This should allow class I incisors to be achieved with approximately 4 mm of maxillary advancement and 10 mm of mandibular advancement plus auto-rotation.

Final surgical plan

On completion of pre-surgical orthodontics (Figure 9.2.2):

Figure 9.2.2 Pre-surgical orthodontics produced only minor changes in the incisor inclinations. An overjet of 8 mm was achieved, which enabled the planned amount of mandibular advancement.

- The upper incisor inclinations were still slightly upright.
- The overjet was 8 mm.
- Arch coordination was good.

The final surgical moves, planned with the aid of model surgery and photo-cephalometric software, were as follows:

- Le Fort I maxillary impaction 5 mm anteriorly and 2 mm posteriorly, with 4 mm advancement.
- Mandibular auto-rotation followed by advancement of 10 mm.
- Genioplasty with 6 mm advancement and 4 mm vertical reduction.

Treatment outcome (Figures 9.2.3–9.2.6)

The degree of gingival display on smiling was greatly reduced, partly due to the maxillary impaction and partly due to upper lip lengthening. The lower anterior face height was reduced significantly but the mandibular plane angle remained steep, because of the short length of the rami. Chin position and lip competence were improved and the occlusion and dental aesthetics were satisfactory.

Figure 9.2.3 The end of treatment frontal view **(a)** shows improved vertical proportions and lip posture. The profile view **(b)** shows that there was still a high FMPA, with a degree of profile convexity, but full correction of these features would have been difficult to achieve. Some upper lip lengthening was achieved.

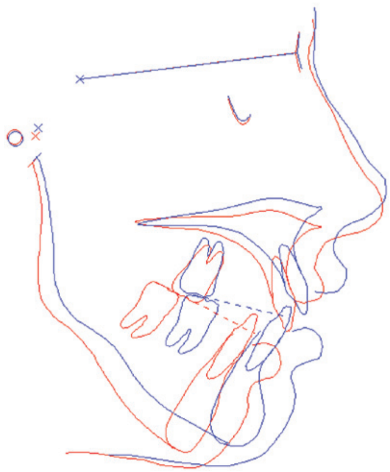


Figure 9.2.4 Superimposition of the pre-surgery (red) and post-surgery (blue) cephalometric tracings confirms that a substantial amount of anterior maxillary impaction and mandibular advancement were achieved. (Produced using OPAL, British Orthodontic Society).

Figure 9.2.5 End of treatment occlusion. A positive overbite and satisfactory inter-digitation were achieved.

Figure 9.2.6 Smiling frontal view showing a normal vertical relationship of the upper incisors to the upper lip.

Case 9.3
Class III malocclusion

Presentation

Caucasian female, 16 years old, with clear medical history.

Upper first premolars previously extracted as part of earlier upper arch alignment.

No psychological contra-indications to treatment.

Patient's concerns

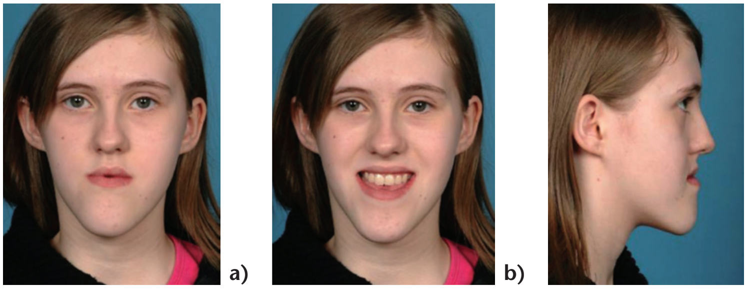
Functional:
- Unable to bite between front teeth.

Aesthetic:
- Prominent lower jaw.

Facial features (Figures 9.3.1 and 9.3.2)

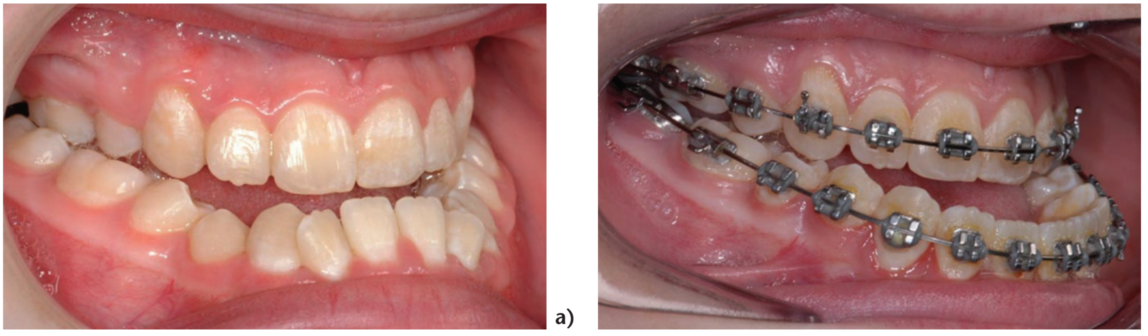
Antero-posterior:
- Severe class III skeletal jaw relationship.
- Para-nasal hollowing.
- Lack of lower lip curvature.

Vertical:
- Short upper lip with lip incompetence.
- Increased upper incisor show at rest and gingival display on smiling.
- Increased lower anterior face height.
- Steep mandibular plane.



a) b) c)

Figure 9.3.1 Frontal views of the face at rest **(a)** and on smiling **(b)**. Note the mandibular asymmetry and the cant of the lips as well as the increased lower anterior face height. The lateral view **(c)** shows the features of severe class III skeletal jaw relationship as well as a steep mandibular plane.



a) b)

Figure 9.3.2 Pre-treatment occlusion **(a)**. Note the crowding of the retroclined lower incisors, which was helpful in achieving orthodontic decompensation **(b)**.

Transverse:
- Mandibular asymmetry, with chin shifted to right.
- Inter-labial line canted down to the left.
- Narrow alar base.

Intra-oral features (Figure 9.3.2a)
Occlusion:
- Severe class III incisor relationship.
- Reduced overbite.
- Reverse overjet of 4 mm.
- Buccal segments greater than a full unit class III bilaterally even with previous loss of upper premolars.

Dentition:
- Upper incisors proclined and mildly crowded.
- Lower incisors severely retroclined and crowded.
- Both upper and lower centrelines shifted to the right be 2 mm.

Initial combined plan

Desired soft tissue changes and provisional dento-skeletal movements

1. Upper incisor and maxillary position.
   Advancement of the upper lip and para-nasal regions by 4–5 mm.
   Normalisation of upper incisor show.
   Lengthening of upper lip.
   - *Advancement of maxilla by 7 mm, with rotation to left 2 mm, at Le Fort 1 level.*
   - *Anterior impaction of 2 mm.*
   - *V–Y incision closure.*
2. Occlusion and mandibular position.
   Set back mandible to achieve optimal occlusion and correct asymmetry.
   Reduce lower anterior face height.
   Improve lower lip curvature.
   - *Procline lower incisors.*
   - *Mandibular autorotation followed by Asymmetric setback (BSSO) of 6 mm (which will also require posterior maxillary impaction to achieve positive overbite).*
3. Maxillo-mandibular complex rotation.
   Reduce steepness of occlusal and mandibular planes.
   - *Anti-clockwise rotation.*
4. Chin position.
   Acheive optimal vertical proportions and profile balance.
   - *Advancement and vertical reduction genioplasty*

Key objectives of pre-surgical orthodontic treatment

- Partially decompensate lower incisors, allowing for increased post-treatment mandibular plane angle.

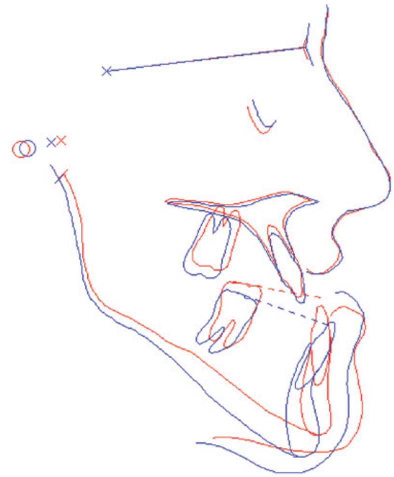


Figure 9.3.3 Superimposed pre-treatment (red) and pre-surgical (blue) cephalometric tracings show the degree of proclination of the lower incisors achieved through pre-surgical orthodontics. There has also been some extrusion of the upper molars as well as some further vertical growth. (Produced using OPAL, British Orthodontic Society).

- Maintain upper incisor inclinations.
- Achieve a reverse overjet of 10 mm. This should allow approximately 13 mm of total jaw movement at the level of the incisal edges.
- Achieve transverse arch coordination.

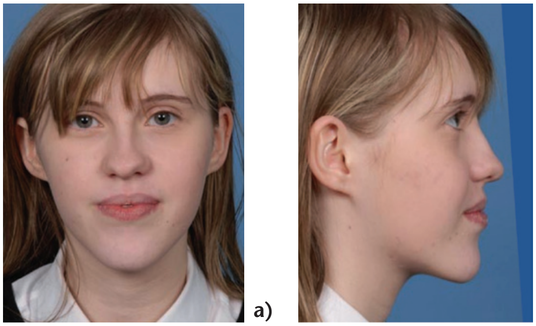
Final surgical plan

On completion of pre-surgical orthodontics (Figures 9.3.2b and 9.3.3):
- The lower incisors were slightly retroclined (83°).
- The target reverse overjet of 10 mm has been achieved.
- Arch coordination is satisfactory.

The final surgical moves, planned with the aid of model surgery and photo-cephalometric software, were as follows:
- Le Fort I maxillary advancement 7 mm, anterior impaction 2 mm and posterior impaction 2 mm.
- Mandibular autorotation and asymmetric BSSO mandibular setback 6 mm.
- Genioplasty with 6 mm advancement and 4 mm vertical reduction.

Treatment outcome (Figures 9.3.4–9.3.7)

The soft tissue objectives were largely achieved. The maxillary deficiency and the position of the upper



a) b)

Figure 9.3.4 The end of treatment facial views from the front **(a)**, and in profile **(b)**, illustrate a dramatic improvement in facial aesthetics and symmetry.

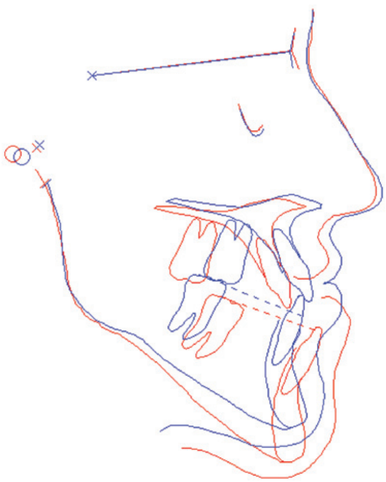


Figure 9.3.5 Superimposed pre-surgical (red) and post-surgical (blue) lateral cephalograms show that the required bi-maxillary movements were largely achieved. The advancement and reduction genioplasty was essential in achieving profile balance and improved vertical proportions. (Produced using OPAL, British Orthodontic Society).

Figure 9.3.6 End of treatment occlusion. The incisor relationship and arch coordination achieved were satisfactory.

Figure 9.3.7 Post-treatment frontal smiling view. The relationship of the upper incisors to the upper lip is satisfcatory.

incisors were largely corrected and the chin position and profile was pleasing. The lower anterior face height remained slightly increased but was aesthetically acceptable. This could have been improved with a vertical reduction genioplasty. The steepness of the mandibular plane was reduced to some extent and the occlusion and dental aesthetics were satisfactory.

Case 9.4
Mandibular asymmetry with 3D planning

Presentation

Caucasian male, 17 years old with clear medical history.

Mandibular asymmetry no longer progressive.

No psychological contra-indications to treatment.

Patient's concerns

Functional:
- Would like bite between front teeth to be better.

Aesthetic:
- Crooked lower jaw.

Facial features (Figure 9.4.1)

Antero-posterior:
- Maxillary deficiency, indicated by malar and para-nasal hollowing.
- Mandibular prognathism with retrogenia.
- Reduced lower lip curvature.
- Increased gonial angle.

Vertical:
- Increased lower anterior face height.
- Increased mandibular plane angle.

Transverse:
- Transverse mandibular asymmetry with chin shifted to the right.
- Mild deviation of the nasal tip to the left.
- No cant of the maxillary occlusal plane.
- Increased naso-labial angle.

Intra-oral features (Figure 9.4.2a)

Dentition:
- Upper incisors mildly retroclined and mildly crowded.
- Lower incisors retroclined and mildly crowded.

Occlusion:
- Class III incisor relationship with 2 mm reverse overjet.
- Upper centreline shifted to the right by 2 mm.
- Lower centreline shifted to the right by 6 mm and coincident with mandibular midline.

Initial combined plan

Desired soft tissue changes and provisional dento-skeletal movements

1. Upper incisor and maxillary position.
   Advancement of upper lip and para-nasal regions by approximately 4 mm.
   Build up of malar regions.

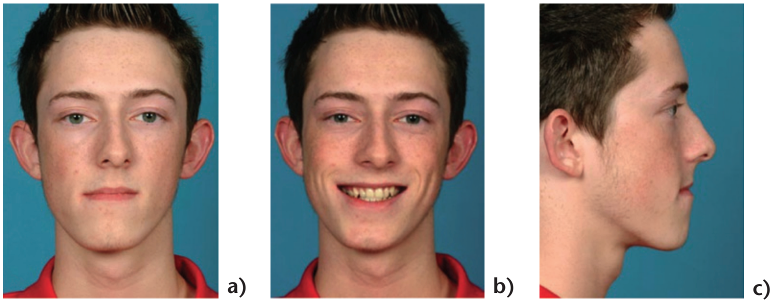


Figure 9.4.1 Frontal views of the face at rest **(a)** and on smiling **(b)**. The mandibular asymmetry is mainly in the transverse plane. The smiling view showws the upper incisors to be retroclined clinically and the upper centreline is shifted slightly to the right. The profile view **(c)** reveals maxillary and malar deficiency. There is an increased FMPA with a degree of retrogenia.

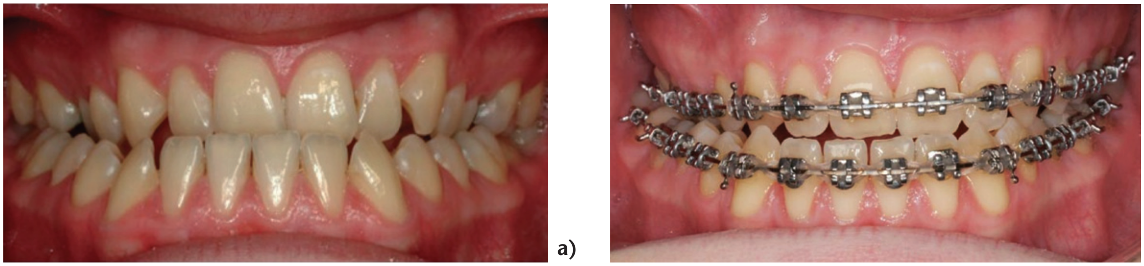


Figure 9.4.2 Pre-treatment occlusion **(a)**. Note the absence of lower arch crowding, which was unfavourable for incisor decompensation. The lower centerline is shifted significantly to the right as a result of the mandibular asymmetry. **(b)** A reverse overjet of 7 mm and satisfactory arch coordination were nevertheless achieved.

Correct upper dental centreline to middle of face.
- *Procline upper incisors to normal inclination.*
- *Le Fort 1 maxillary advancement 6 mm and rotation to left.*
- *Zygomatic onlay grafts.*

2. Occlusion and mandibular position.
Rotation and asymmetric setback of mandible to achieve optimal occlusion with coincident dental midlines.
Improve lower lip curvature:
   - *Procline lower incisors.*
   - *BSSO setback of 4 mm with rotation 6 mm to left.*
3. Maxillo-mandibular complex rotation.
   - *None required.*
4. Chin position.
   - *Reassess need for genioplasty at final surgical planning stage*

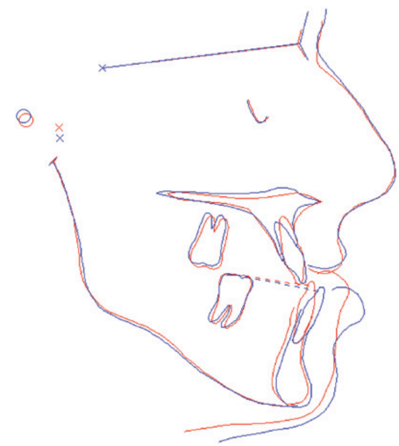


Figure 9.4.3 Superimposition of pre-treatment (red) and pre-sugery (blue) cephalometric tracings. Full lower incisor decompensation was achieved as well as correction of the upper incisor inclinations. (Produced using OPAL, British Orthodontic Society).

Key objectives of pre-surgical orthodontic treatment

- Procline upper incisors to normal inclination.
- Procline lower incisors to achieve reverse target overjet of 8 mm.
- Achieve transverse arch coordination.

Final surgical plan

On completion of pre-surgical orthodontics (Figures 9.4.2b and 9.4.3):
- The upper incisors were slightly proclined.
- The reverse overjet measured 7 mm.
- Arch coordination was satisfactory.

The final surgical plan was formulated with the aid of Maxilim® three-dimensional software (Figure 9.4.4), in addition to conventional model surgery, as follows:
- Le Fort I maxillary advancement (6 mm) and rotation to left (2 mm), with no vertical change.
- Asymmetric mandibular setback to achieve class I incisors and coincident centrelines.
- A genioplasty was judged to be unnecessary.
- Zygomatic onlay grafts.

Treatment outcome (Figures 9.4.5–9.4.8)

The mandibular asymmetry was largely corrected, although both upper and lower dental centrelines were still deviated slightly to the right. The soft tissue profile was acceptable, but there was still a suggestion of para-nasal hollowing with an increased naso-labial angle. An advancement genioplasty might have enhanced the profile balance.

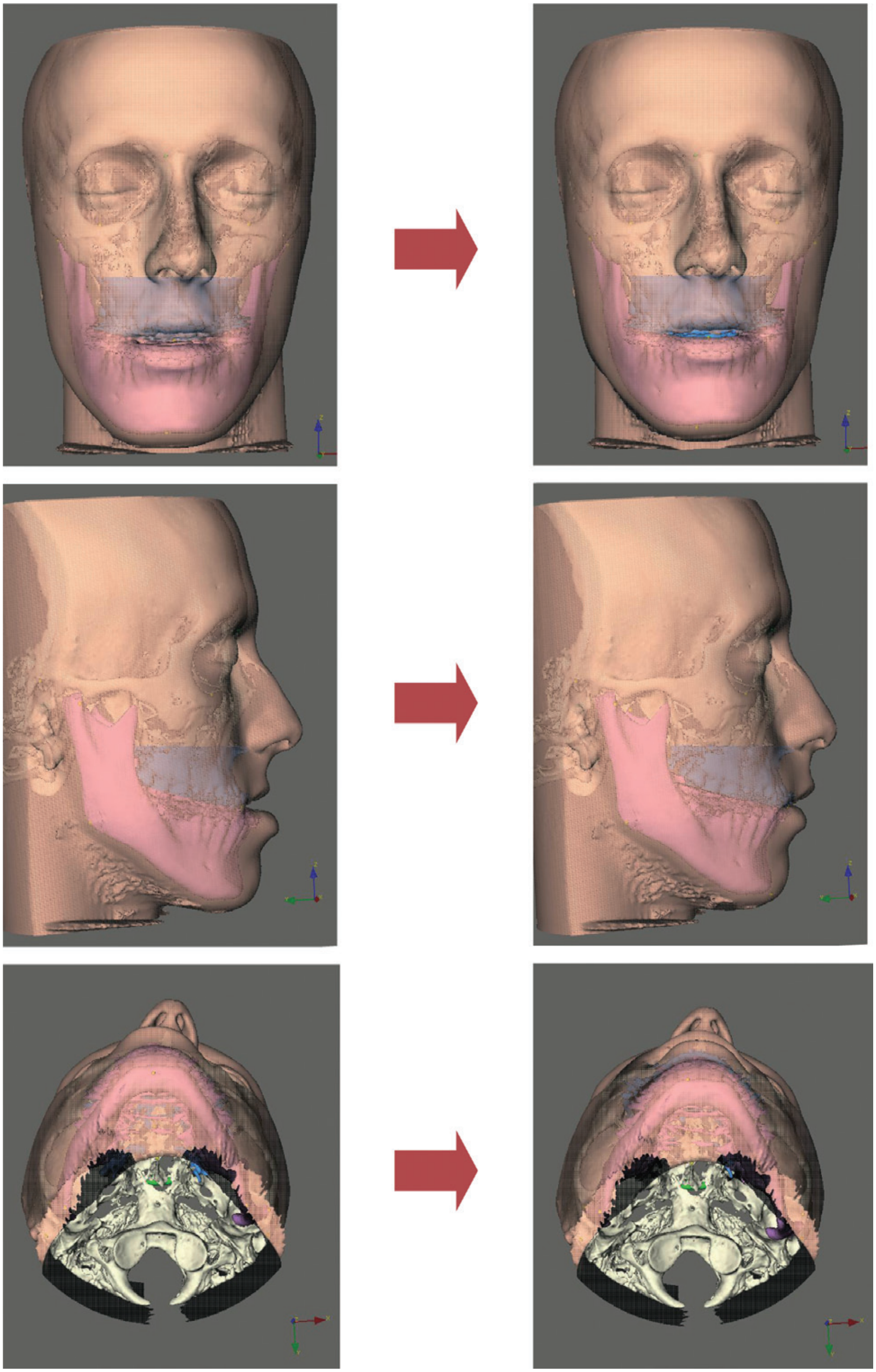
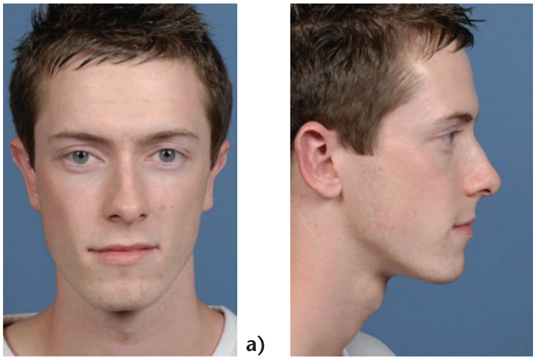


Figure 9.4.4 Representative views of 3-D surgical planning using Maxilim® software.



a) b)

Figure 9.4.5 End of treatment facial views. **(a)** The mandibular asymmetry was largely corrected. **(b)** The naso-labial angle remains slightly increased and an advancement genioplasty may have been indicated for ideal profile balance.

Figure 9.4.7 End of treatment occlusion. Coincident centerlines and a well inter-digitated occlusion were achieved.

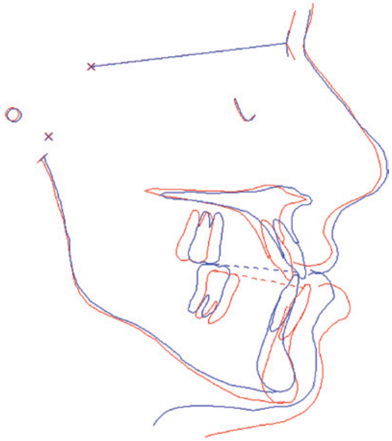


Figure 9.4.6 Super-imposed pre-surgical (red) and post-surgical (blue) cephalometric tracings show the antero-posterior and vertical surgical movements. The lower anterior face height was reduced significantly as a result of the mandibular setback, coupled with a small amount of autorotation. (Produced using OPAL, British Orthodontic Society).

Figure 9.4.8 Post-surgical view on smiling, showing pleasing facial and dental aesthetics.

Case 9.5
Anterior open bite

Presentation

Caucasian male, 23 years old with clear medical history.

Right thumb sucking habit as a child.

No psychological contra-indications to treatment.

Patient's concerns

Functional:
- Unable to bite between front teeth.

Aesthetic:
- Upper front teeth at different levels.
- No concerns regarding facial appearance.

Facial features (Figure 9.5.1)

Antero-posterior:
- Mild class III skeletal jaw relationship due to maxillary deficiency.
- Mild para-nasal hollowing.

Vertical:
- Reduced display of upper incisors on smiling.
- Lower anterior face height increased.

Transverse:
- No obvious asymmetries.

Intra-oral features (Figure 9.5.2a)

Dentition:
- Upper incisors of average inclination and aligned.
- Lower incisors retroclined and mildly crowded.
- Centrelines correct and coincident.

Occlusion:
- Class III incisor relationship with reverse overjet of 3 mm.
- Anterior open bite, measuring 4 mm maximum and extending back to the upper second premolars.
- Buccal segments a full unit class III bilaterally.

Initial plan

Desired changes and provisional dento-skeletal movements

1. Upper incisor and maxillary position.
   Advancement of the upper lip and para-nasal regions by approximately 4 mm.
   Correction of upper incisor show at rest and on smiling.
   - *Advancement of the anterior maxilla by approximately 6 mm at Le Fort I level, maintaining inclination of upper labial segment.*
   - *Anterior maxillary down graft 2 mm.*

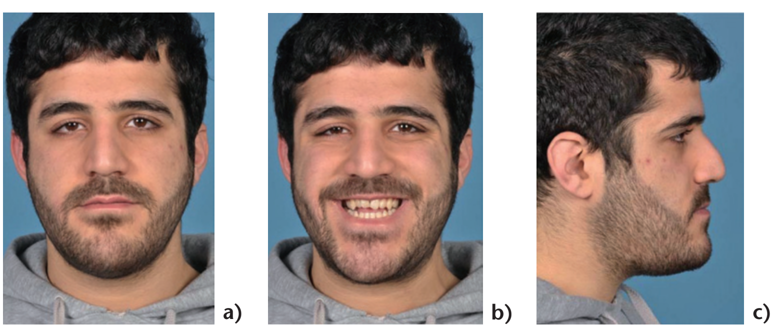


Figure 9.5.1 **(a)** Facial view at rest. The lower anterior face height is slightly increased but facial aesthetics are largely pleasing. The smiling view **(b)** shows the upper anterior teeth to be bowed upwards, reducing the display of the central incisors. **(c)** The profile view reveals a mild degree of maxillary deficiency, but this was not of concern to the patient.

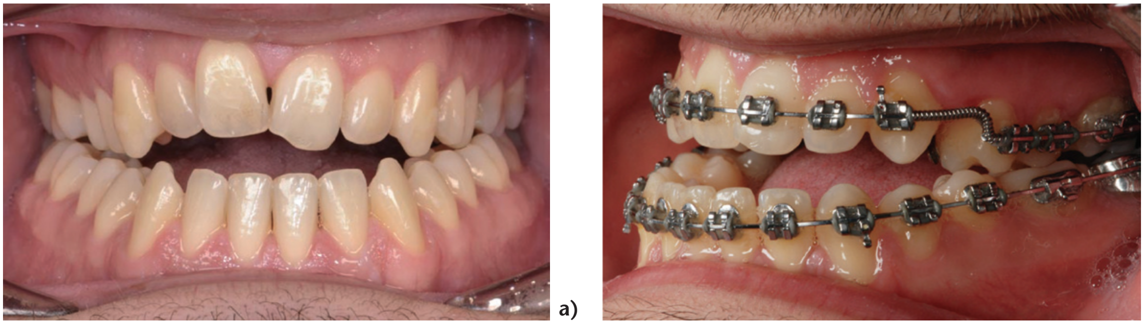


Figure 9.5.2 **(a)** Pre-treatment occlusion. The anterior open bite is partly due to the intrusion of the upper incisors and partly due to posterior maxillary excess. Some compensation is seen in the lower incisors. **(b)** Sectional mechanics were used in the preparation for segmental maxillary surgery with the aim of minmizing relapse of the anterior open bite. Note the space created distal to the canines for the surgical cuts.

2. Occlusion and mandibular position.
   Closure of anterior open bite and reduction in LAFH.
   - *Maintain lower incisor inclination.*
   - *Mandibular auto-rotation to achieve positive overbite (which will require posterior segmental maxillary impaction, simultaneously levelling the maxillary arch).*
3. Maxillo-mandibular complex rotation.
   - *Not applicable.*
4. Chin position.
   - *No adjustment likely to be required.*

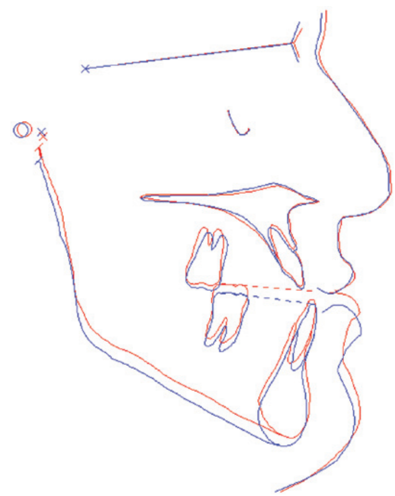


Figure 9.5.3 Superimposed pre-treatment (red) and pre-surgery (blue) cephalometric tracings show that the sectional leveling mechanics have produced some extrusion of the upper molars but no intrusion of the upper incisors. (Produced using OPAL, British Orthodontic Society).

Key objectives of pre-surgical orthodontic treatment

- Sectional leveling of upper arch to avoid potentially unstable extrusion of the upper incisors.
- Create space distal to the upper canine roots to accommodate the surgical cuts.
- Maintain lower incisor inclination.
- Achieve a target reverse overjet of 3–4 mm. This should produce 5–6 mm of anterior maxillary advancement.
- Achieve transverse arch coordination.

Final surgical plan

On completion of pre-surgical orthodontics (Figures 9.5.2b and 9.5.3):

- Segmental leveling of the upper arch had been achieved but with no intrusion of the upper incisors.
- The reverse overjet measured 4 mm.
- Transverse arch coordination was satisfactory.

The final surgical moves, planned with the aid of model surgery and photo-cephalometric software, were as follows:

- Two-part Le Fort I maxillary osteotomy to advance the anterior maxilla 6 mm, downgraft 2 mm anteriorly and segmentally impact 2 mm posteriorly.
- Allow mandibular auto-rotation to close anterior open bite.

Treatment outcome (Figures 9.5.4–9.5.7)

The closure of the anterior open bite was successfully achieved and the upper incisor show on smiling was normalised. The soft tissue profile improved through correction of the maxillary deficiency and pleasing dental aesthetics were produced. The lower anterior face height reduced a little and the curvature of the lower lip improved, although this was not a specific objective of treatment.

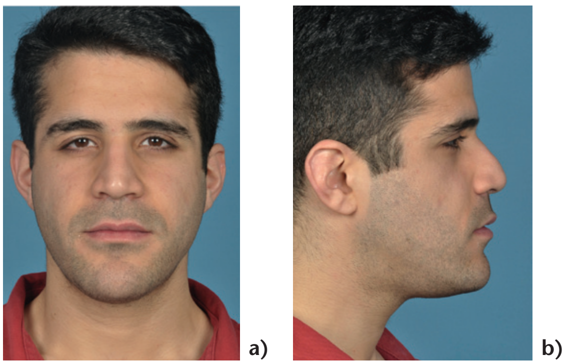


Figure 9.5.4 Post-surgery facial views. From the front **(a)** facial proportions are pleasing and the mild para-nasal hollowing has been corrected. The profile view **(b)** shows the upper lip to have moved forwards.

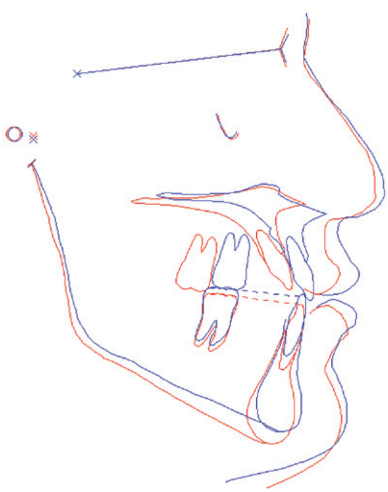


Figure 9.5.5 Superimposed pre- and post-surgical lateral cephalometric tracings confirm the anterior maxillary downgraft, the posterior maxillary impaction and the mandibular auto-rotation to close the anterior open bite. (Produced using OPAL, British Orthodontic Society).

Figure 9.5.6 End of treatment occlusion. A positive overbite and overjet were achieved and arch coordination was satisfactory.

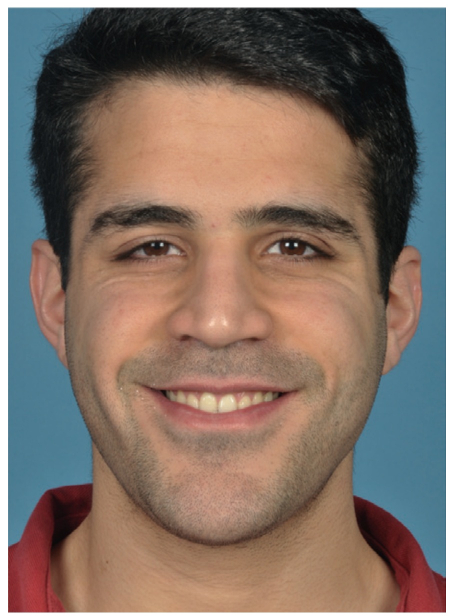


Figure 9.5.7 The vertical relationship of the upper incisors to the upper lip was normalised and pleasing dento-facial aesthetics were produced.

Case 9.6
Class II, division 1 with hypodontia

Presentation

Caucasian female, 15 years old with clear medical history.

No psychological contra-indications to treatment.

Patient's concerns

Functional:

- Finds lack of lower front teeth annoying.
- Upper front teeth dig into lower lip.

Aesthetic:

- Upper front teeth stick out.
- Gaps between front teeth.
- Lower jaw too far back.

Facial features (Figure 9.6.1)

Antero-posterior:

- Class II skeletal jaw relationship.
- Retrognathic mandible.
- Lower lip trap behind upper central incisors.

Vertical:

- Reduced lower anterior face height.
- Deep labio-mental fold.

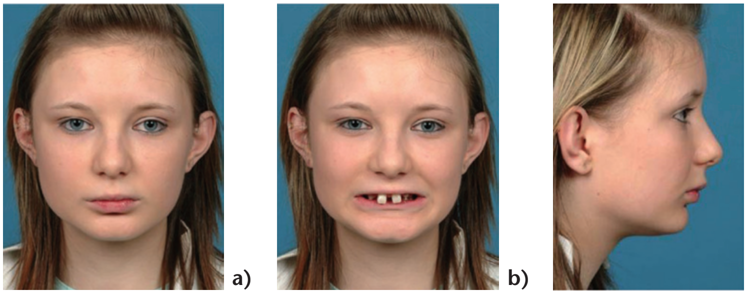
Transverse:

- No obvious asymmetry.

Intra-oral features (Figure 9.6.2a)

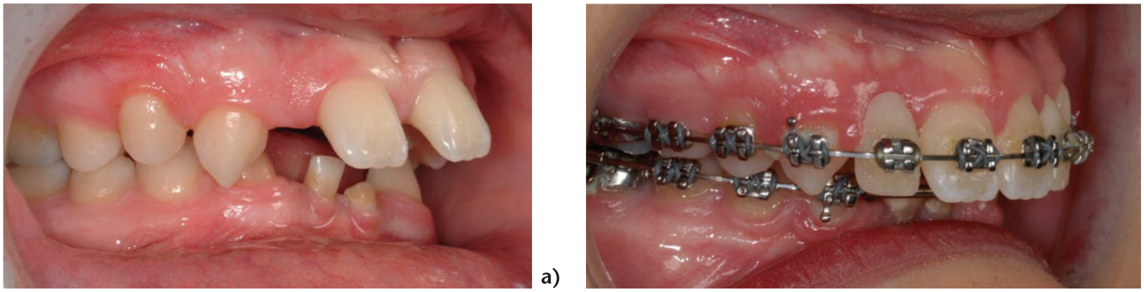
Dentention:

- Developmentally absent 12, 22, 31, 32, 41, 42.
- Upper incisors proclined with large midline diastema.



a) b) c)

Figure 9.6.1 Frontal views of the face at rest **(a)** and on smiling **(b)** show the reduced lower anterior face height and lower lip trap. The profile view **(c)** shows severe mandibular retrusion and an accentuated labio-mental fold.



a) b)

Figure 9.6.2 **(a)** Pre-treatment intra-oral view showing proclined upper central incisors and hypodontia. the overjet could not be measured conventionally but would clearly be increased if the lower incisors were present. **(b)** The dentition following pre-surgical orthodontics. Prosthetic upper lateral incisors were attached to the archwire.

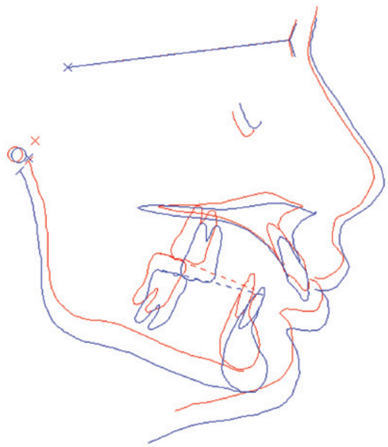


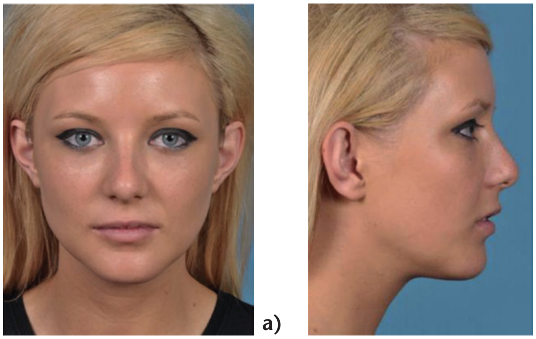
Figure 9.6.3 Superimposition of pre-treatment (red) and pre-surgery (blue) cephalometric tracings shows some retraction of the upper central incisors. Significant vertical growth has continued throughout this phase because of the patients relatively young age at the start of treatment. (Produced using OPAL, British Orthodontic Society).

Occlusion:
- Class II, divison 1 incisor relationship.
- Overjet difficult to define due to absent lower incisors.
- Buccal segments a full unit class II bilaterally.

Initial combined plan

Desired soft tissue changes and provisional dento-skeletal movements

1. Upper incisor and maxillary position.
   Accept maxillary position.
   Retrocline upper central incisors.
   - *Retraction of central incisors.*
2. Occlusion and mandibular position.
   Advance mandible to achieve optimal buccal segment occlusion in the absence of the lower permanent incisors.
   Eliminate lower lip trap.
   Increase LAFH and steepness of mandibular plane.
   - *Mandibular advancement (BSSO) of 8 mm.*
3. Maxillo-mandibular complex rotation.
   - *Not applicable.*
4. Chin position.
   Achieve optimal vertical proportions and profile balance.
   Improve lower lip curvature.
   - *Advancement and augmentation genioplasty.*



a) b)

Figure 9.6.4 End of treatment facial views. **(a)** The frontal view shows that the lower anterior face height was normalized. The side view **(b)** shows that a pleasing profile was achieved, with a more normal lower lip curvature.

Key objectives of pre-surgical orthodontic treatment

- Retract upper central incisors to normal inclination and close midline disatema.
- Redistribute space for prosthetic 12, 22, 31, 32, 41, 42.
- Achieve arch coordination.

Final surgical plan

On completion of pre-surgical orthodontics (Figures 9.6.2b and 9.6.3):
- The upper incisor inclinations were close to average.
- Spaces were correctly sized for prosthetic teeth.
- Arch coordination was such that achievement of a class I molar relationship would result in mandibular advancement of 8 mm.

The final surgical plan, finalised with the aid of model surgery and photo-cephalometric software, were as follows:
- Mandibular advancement 8 mm.
- Genioplasty with advancement of 2 mm and vertical augmentation of 4 mm.

Treatment outcome (Figures 9.6.4–9.6.7)

The profile was greatly improved, with the chin point placed in an aesthetically pleasing position and the lower lip curvature reduced. The lower lip rested in front of the upper incisors and the vertical facial proportions were restored to within the normal range. The absent teeth were restored using a combination of bridges, bone grafting and implants.

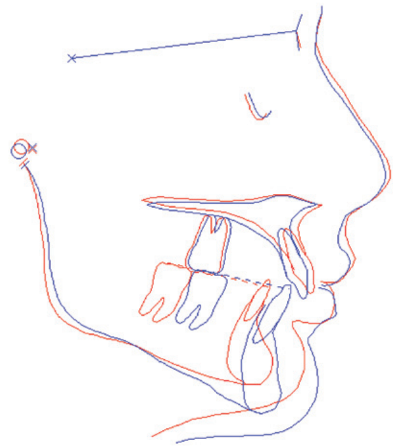


Figure 9.6.5 The pre-surgery (red) and post-surgery (blue) cephalometric superimposition shows the extent to which pogonion moved forwards and downwards. (Produced using OPAL, British Orthodontic Society).

Figure 9.6.7 End of treatment smiling view, showing pleasing upper incisor inclination and a normal lower lip position.

Figure 9.6.6 Intra-orally, the edentulous spaces were restored using implants, following bone grafting, and a satisfactory class I occlusion was acheived. Some minor relapse of the upper midline diastema occurred early on in retention, but the patient was unconcerned.

Index

Page numbers in *italics* denote figures, those in **bold** denote tables.

Handbook of Orthognathic Treatment: A team approach, First Edition. Ashraf Ayoub, Balvinder Khambay, Philip Benington, Lyndia Green, Khursheed Moos, and Fraser Walker.