

Horizontal bone-augmentation procedures in implant dentistry: prosthetically guided regeneration

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Experimental and clinical studies show osseointegration to be highly predictable, and dental implants currently represent a reliable means for restoring dental function in partially and completely edentulous patients (1, 16, 32). Although surgical and prosthetic procedures are well consolidated as a result of more than 30 years of clinical experience, treatment planning in oral implantology has, in recent years, undergone tremendous evolution. Implants were originally used in restoring fully edentulous patients based on the concept of 'surgically and anatomically driven implant placement'. Implant placement was primarily determined by the location of available bone, and the main goal was to allow adequate bone anchorage to provide a functionally efficient prosthetic rehabilitation. Following this concept, because osseointegration was the primary outcome of surgery, prosthetic rehabilitation did not fulfill the esthetic ideal. In these cases, dental restorations were often implant-supported overdentures or fixed implant-supported prostheses with distal cantilevers (Toronto bridge concept) and it was possible to compensate for inadequate implant position using acrylic flanges (9, 59).

As oral implants have also been used for the rehabilitation of partially dentate patients, esthetic outcomes have become more important because implant-supported partial prostheses have to integrate with the adjacent natural dentition, both from a functional and an esthetic point of view (6). A good esthetic result can be achieved only if the implant is placed in a carefully planned position, as determined by the prosthetic needs. Therefore, the concept of 'restoration-driven implant placement' has been introduced to optimize both function and esthetics (44). As correct implant position is vital in order to achieve a good esthetic result (14, 15), optimal

conditions of the alveolar bone, in terms of adequate volume, as well as optimal conditions of the surrounding soft tissues, are key prerequisites to obtain a good clinical outcome. When these conditions are lacking, because of hard- and soft-tissue deficiencies (for instance, following atrophy, sequelae of periodontal disease, traumas or congenital malformations), the bone volume and/or the surrounding soft tissues (keratinized mucosa) must be augmented.

A host of bone-augmentation techniques, such as guided bone regeneration (11, 48, 57, 74), bone-grafting techniques (10, 23, 29, 41, 51, 53, 60), and alveolar bone expansion (3, 31, 72), have been proposed and different systematic reviews have been published to evaluate the outcome of various bone- and soft-tissue augmentation procedures (2, 7, 27, 34, 56, 64). The aim of this article is to present a rational, evidence-based and prosthetically driven approach for the treatment of edentulous ridges affected by horizontal defects, using augmentation procedures and dental implants. A diagnostic protocol, a classification of bone defects and the main augmentation techniques will be described in detail. The selection criteria for different surgical techniques for different classes of bone defects will also be discussed.

Diagnosis and treatment planning for partially dentate patients with compromised alveolar ridges, following a prosthetically driven diagnostic protocol

As the rehabilitation (with implant-supported prostheses) of partially dentate patients affected by horizontal

defects of the residual alveolar ridge is often complex from prosthetic and surgical viewpoints, a team approach involving prosthodontists, periodontists, oral and maxillofacial surgeons, orthodontists and dental technicians is very important. The treatment plan should include different, consecutive steps.

Exclusion of local and general contraindications

Thorough analysis of the relative and absolute contraindications for implant therapy is a fundamental prerequisite before taking any further steps in treatment planning. It is beyond the scope of this chapter to analyze all the local and general factors that might contraindicate implant therapy. For more details, specific publications are available in the literature (42). Selection criteria used for standard implant therapy (edentulous sites with no significant bone defects) are also applied in the case of more complex situations, bearing in mind that increasing treatment complexity, from a surgical viewpoint, may correspond to a higher incidence of complications in patients with compromised health (i.e. partial or total loss of a bone graft in heavy smokers or bone graft infection in immunocompromised patients).

Examination of esthetic and functional needs of the patient

The next step in implant therapy should always be to analyze the individual needs and expectations of the patient. It is important to identify patients with exaggerated and unrealistic expectations, as in some cases these expectations may not be completely met in spite of treatment to an adequate standard, and the patient must be aware that a certain degree of compromise may be required and should be accepted. In some cases, it is important to explain to patients that the possibility of achieving a certain outcome is not only related to the quality of the surgical intervention but it may be compromised by initially unfavorable conditions. For the same reason, in the presence of a bone defect, patients must be informed that correction of the defect is vital to achieve a favorable final result. In order to improve communication with the patient, and to increase his/her involvement and compliance toward treatment, traditional and digital previsualization techniques are recommended. A wax-up simulation, placed directly in the patient's mouth, is a useful technique to achieve an agreement with the patient in terms of reasonable final results

(see 'Evaluation of prosthetic feasibility' in this section). Patient's compliance and collaboration during treatment must always be evaluated because where bone defects are present, staged, multiple surgical procedures and a longer treatment time are usually needed.

Preliminary clinical and radiographic examination

A preliminary clinical examination will allow the clinician to verify whether the patient is healthy from a periodontal and dental point of view, and whether the occlusal pattern is favorable. In the case of pathology in these fields, it is paramount to treat the pathology before any implant procedures. During the preliminary diagnostic phase, the presence of ridge defects should also be recognized. A panoramic radiographic and periapical radiographs are usually sufficient to achieve a preliminary 'overview' of the conditions of the patient's dental arches and to identify the presence of any bony pathology.

Evaluation of prosthetic feasibility

The concept of prosthetically driven implant dentistry is well recognized and represents the gold standard for implant-supported prostheses. In particular, a good match between the position of the implant and the future implant-supported restoration, in three dimensions, is considered a prerequisite in the treatment of partially dentate individuals and in the esthetic area (15, 21, 26, 44). Furthermore, several publications have underlined possible risks associated with inadequate implant positioning in the esthetic area (22, 46), and surgical techniques have been developed to manage these malpositioned implants (81). In many cases, it has been reported that failure, from an esthetic point of view, can be attributed to placement of implants in residual bone without considering the prosthetic position of the restoration (Fig. 1A,B).

As a general rule, the feasibility of an implant-retained restoration must be checked first from a prosthetic point of view. Mounted plaster casts can be used to provide a diagnostic wax-up that should simulate, with wax of different colors, the ideal ridge profile and the anatomy of dental units to be replaced. If the restoration involves only one side of the mouth, the contralateral side should be considered as a reference for the alveolar ridge and dental morphology. The wax-up allows the recognition of intermaxillary discrepancies or asymmetries between

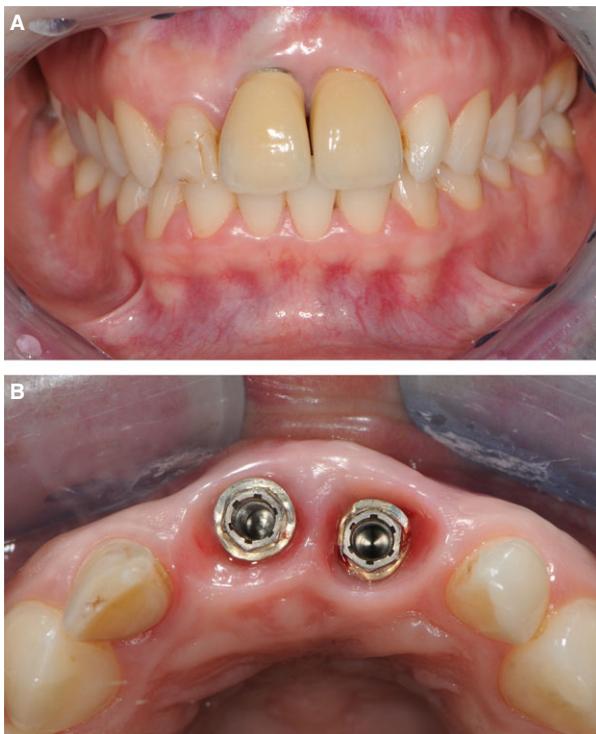


Fig. 1. Esthetic implant failure as a result of inadequate three-dimensional implant placement (A): two implants of excessive diameter have been positioned too far apically, too close each other and with a pronounced buccal inclination (B), with the aim to improve primary stability in the available bone.

the two sides of the dental arch (Fig. 2A,B). It also allows caliper measurement of the wax thickness simulating the vertical/horizontal augmentation that may be necessary to achieve the ideal morphology. Good communication with the dental technician is paramount to define, from the outset, a precise treatment strategy. Clinical intra-oral and extra-oral pictures should be included in the diagnostic protocol because they represent a very important tool for communication between the different components of the team as well as the patient.

The wax-up can also be used as a communication tool with the patient, in order for them to recognize anatomical discrepancies and the need for grafting procedures to achieve a good final outcome. When the esthetic area is involved in implant treatment, the final result can be previsualized by means of a fixed or a removable mock-up that is placed directly in the patient's mouth. The mock-up will be useful in collecting the patient's point of view regarding esthetic parameters (dimensions of teeth, smile-line, etc.) and will guide subsequent treatment steps. Pre-visualization of a reasonable treatment outcome will also be useful to guide patient's expectations and

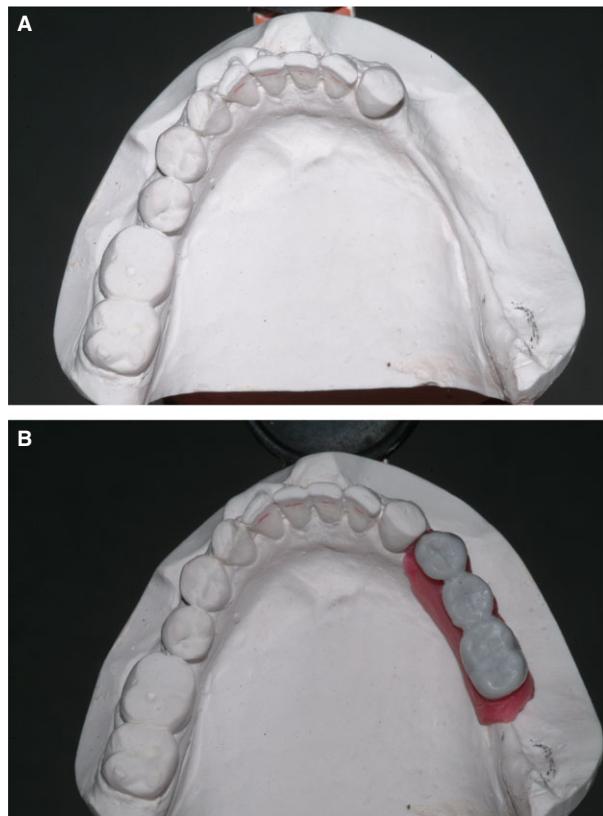


Fig. 2. Wax-up of the posterior mandible (A): the ideal ridge shape is primarily obtained with a layer of red wax. Teeth are then waxed on top of the corrected ridge (B).

will increase patient's motivation and involvement in the entire treatment process (Fig. 3A,B).

Nowadays, the diagnostic process can be started using digital treatment-planning techniques in which the clinician can provide the dental technician with specific digital information regarding the prosthetic project and subsequently the wax-up that can be created (35) (Fig. 4A–E).

Evaluation of surgical feasibility and planning of ridge-augmentation procedures

Once the prosthetic plan has been finalized and a ridge defect has been identified, the next step is to carry out a precise evaluation of the anatomy of the bony defect in relation to the prosthetic replacement. In other words, it is important to understand if the bone volume that the patient has is compatible with prosthetically driven implant placement (in order to achieve what has been planned with the wax-up) or if grafting procedures are needed. The wax-up will be duplicated to produce a diagnostic template with radiopaque tooth/teeth, reproducing the ideal tooth/teeth position. The



Fig. 3. Wax-up of different edentulous quadrants of the maxilla (A). The wax-up can also be used inside the oral cavity to previsualize the treatment outcome (B). Once again, teeth and alveolar ridge tissues have been reproduced with wax of different colors.

diagnostic template, constructed with sufficient retention, can be placed in the mouth at the time of computerized tomography. A 2-mm-diameter perforation

inside the radio-opaque tooth can be used to simulate the ideal axis for the planned implant. In the case of replacement of anterior teeth, as it is preferable to have a screw-retained, rather than a cement-retained restoration, the axis of implant placement should reflect this. In the posterior segments, the central perforation should be placed to correspond to the central fossa of the tooth to be replaced and should have a slight palatal/lingual inclination (Fig. 5A–E).

To maximize information, the computerized tomography scan should be analyzed using dedicated implant/dental software that allows virtual placement of implants. In particular, the following information can be obtained: (i) residual bone dimensions; (ii) localization of important anatomic structures; (iii) soft-tissue thickness; and (iv) the relationship between the residual bone and the planned restoration. This is the most important information as it verifies the possibility of placing implants in a prosthodontically driven way, with or without the need for bony augmentation. If the existing bone volume does not allow implant placement, depending on the existing defect, it will also be possible to choose the most appropriate augmentation procedure and the ideal diameter and length of the planned implants. The diagnostic template used for computerized tomography may be modified into a surgical template (the 2-mm-diameter perforation is usually widened, and flanges are eliminated to avoid interference with flap elevation). The template will help the surgeon to insert the implant in an ideal position from a prosthetic point of view.

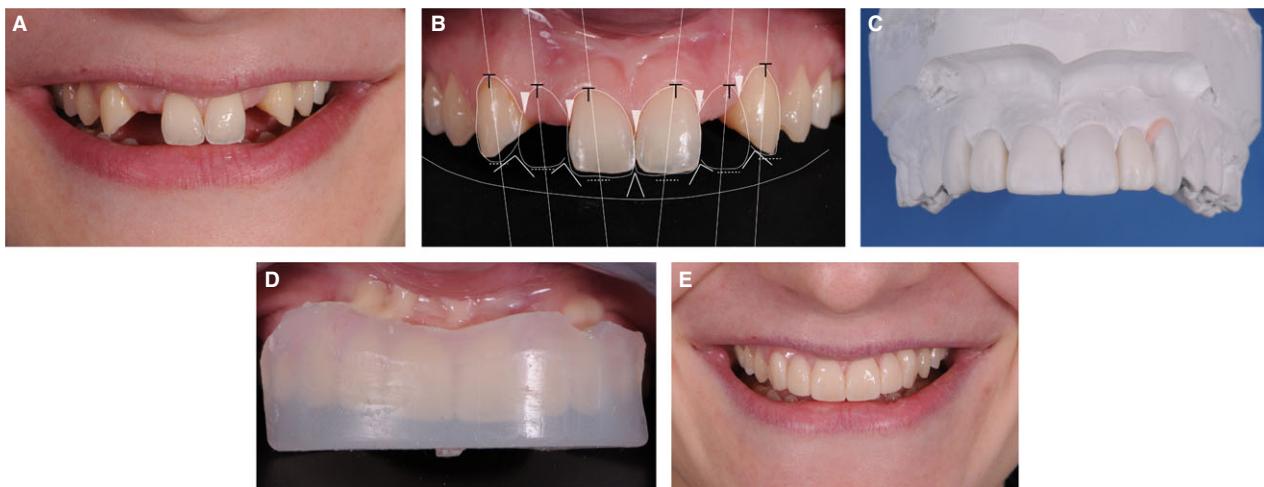


Fig. 4. The diagnostic process of this patient started with extra-oral and intra-oral photographs and impressions to create study casts (A). A digital design of the desired restorations is created with the aid of a presentation software (Keynote® Apple) (B) and transferred to the dental

technician to create a wax-up (C). A silicon index, based on the wax-up and filled with flowable composite (D), was then used to create a fixed mock-up in the patient's mouth to previsualize treatment outcome (E) (Dr Paolo Casentini).

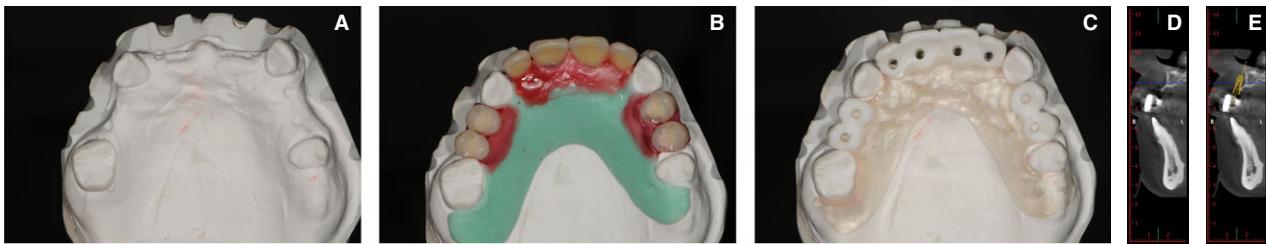


Fig. 5. (The same patient as shown in Fig. 3.) A radio-opaque diagnostic template is created from the wax-up, which also served as a mock-up (A–C). Cone-beam computerized tomography is performed with the diagnostic template *in situ*, allowing precise quantification of the horizontal

discrepancy between the residual bone volume and the ideal prosthetically determined implant position (D, E). In this case, a bone-augmentation procedure before implant placement will be needed in order to achieve the ideal implant-supported rehabilitation. B, buccal; L, lingual.

Classification of horizontal defects according to a prosthetically driven diagnostic protocol and surgical options

After an appropriate prosthetically driven diagnostic protocol, it should be possible to classify a clinical case into one of four classes (class 1–4), outlined in the following sections.

Class 1

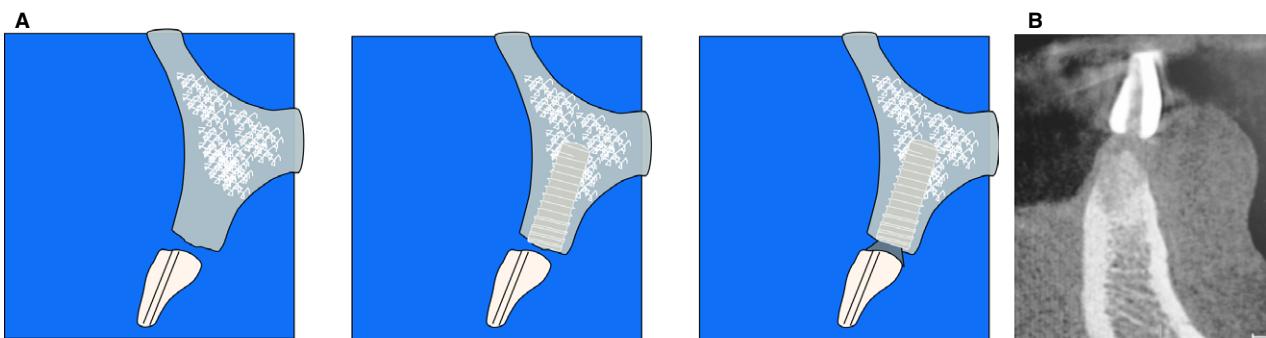
In class 1, no discrepancy exists between the ideal position of the implant(s), the implant-supported prosthetic unit(s) and the alveolar bone anatomy. In this class, no bone augmentation is required and implants can be placed directly into the residual bone, guided by the surgical templates. In this case, the implant will be completely surrounded by an adequate volume of bone ($> 1.5\text{--}2$ mm on every surface). Measurements on computerized tomography scans will allow the selection of ideal implant sites as well as the correct dimensions of implants (Fig. 6A,B). In reality, this situation is rarely encountered and, if found, is associated with immediate postextraction

sockets or recently healed sockets treated with ridge-preservation protocols (40, 47). In some cases, although the bone anatomy can be ideal to host an implant in the correct three-dimensional position, a cosmetic defect can still be present. In this case, a connective tissue graft is recommended to improve the final esthetic result (Fig. 7). This clinical situation is often present in the esthetic area (45) (Fig. 8A–D).

Class 2

In class 2, a moderate horizontal deficit is present. In this situation, implant(s) can be placed in the correct prosthetically driven position but a simultaneous hard-tissue-augmentation procedure is indicated. During preparation of the implant site, a fenestration or a dehiscence of the buccal plate is commonly seen, or the thickness of the residual buccal bony wall (< 1 mm) is not able to guarantee a favorable long-term prognosis (Fig. 9A,B).

The main therapeutic options in class 2 cases involve implant placement associated with guided bone-regeneration techniques using autogenous particulate bone and/or alloplastic materials in association with a semipermeable barrier (resorbable or nonresorbable), and sagittal osteotomy techniques



Class 1

Fig. 6. In a class 1 clinical situation no augmentation procedures are needed to modify the alveolar ridge profile: the implant can be inserted in an ideal, prosthetically driven position and it will be completely embedded in the residual alveolar bone (A, B).

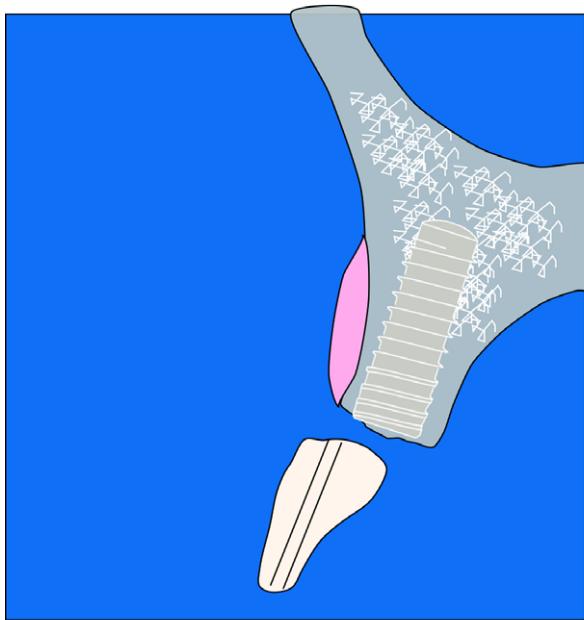
**Class 1+ CTG**

Fig. 7. In a class 1 clinical situation a connective tissue graft (CTG) can be indicated to correct a cosmetic defect.

and/or the use of osteotomes to expand the available bone volume. The use of reduced-diameter implants can be helpful in the management of horizontally atrophic ridges, provided that the implant is placed in the correct, prosthetically driven position (28, 70) (Fig. 10A–E). Hard-tissue-augmentation techniques can be combined with augmentation of soft tissues by means of a connective tissue graft taken from the palate. Once again, in the esthetic area, where a larger amount of soft tissue helps to achieve favorable morphology of the peri-implant mucosa, this procedure is often recommended to improve the final esthetic result (52) (Figs 11 and 12A–F).

Class 3

In class 3, a significant horizontal deficit is present and the residual bony anatomy does not allow the implant to be placed in an ideal prosthetic position and achieve primary stability (Fig. 13A,B). Following correction of the horizontal deficit, an adequate healing period should be allowed (4–9 months, depending on the technique selected and grafting material) before implant placement as a second-stage surgical procedure. The main surgical techniques that can be used for the correction of advanced horizontal deficits are: (i) guided bone-regeneration techniques using autogenous particulate bone and/or alloplastic materials in association with semipermeable barriers (resorbable or nonresorbable); and (ii) autogenous bone blocks harvested from intra/extr-oral donor sites,

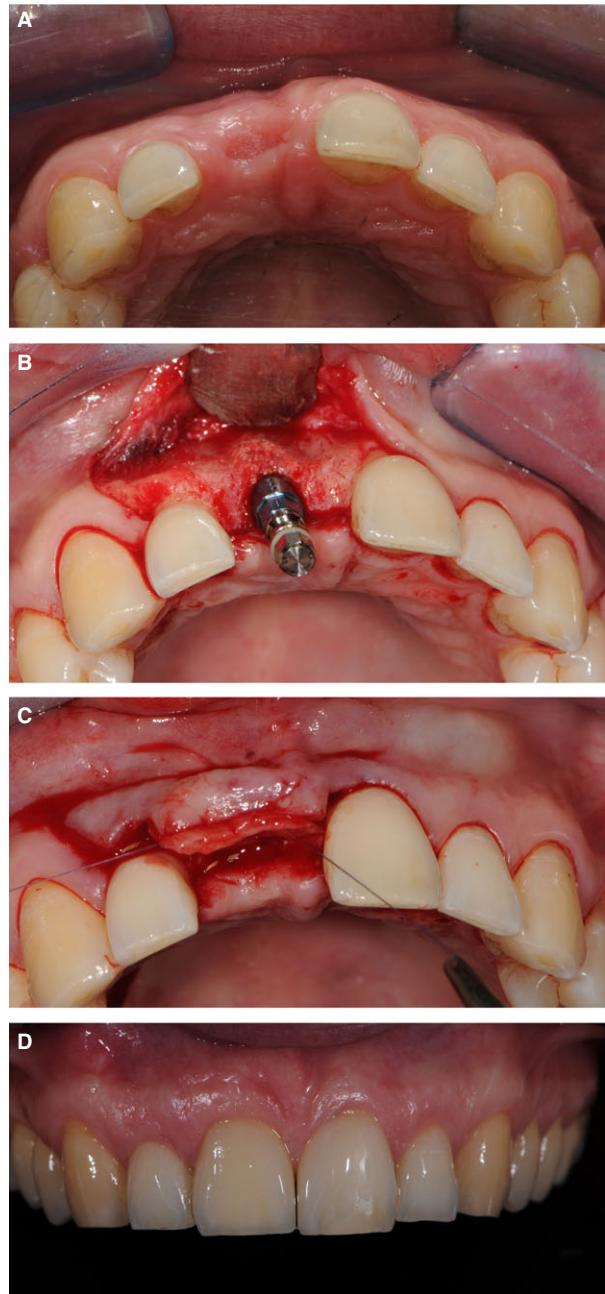


Fig. 8. In some cases, and commonly in the esthetic area, although the volume of the alveolar crest is adequate to guarantee an ideal implant position, a connective tissue graft is recommended to achieve a better esthetic result (A, B). The connective tissue graft is secured to the internal aspect of the mucoperiosteal flap by means of thin, 5.0 resorbable sutures (C). The final restoration demonstrates a favorable biomimetic integration of the implant-supported crown (D). (Surgery and prosthetic rehabilitation, Dr Paolo Casentini.)

and nonautogenous bone blocks. Techniques such as guided bone regeneration and reconstruction with autogenous bone blocks are supported by a significant bulk of literature, as demonstrated by some systematic reviews (27, 49). On the other hand, the use of nonautogenous bone blocks, including allografts and

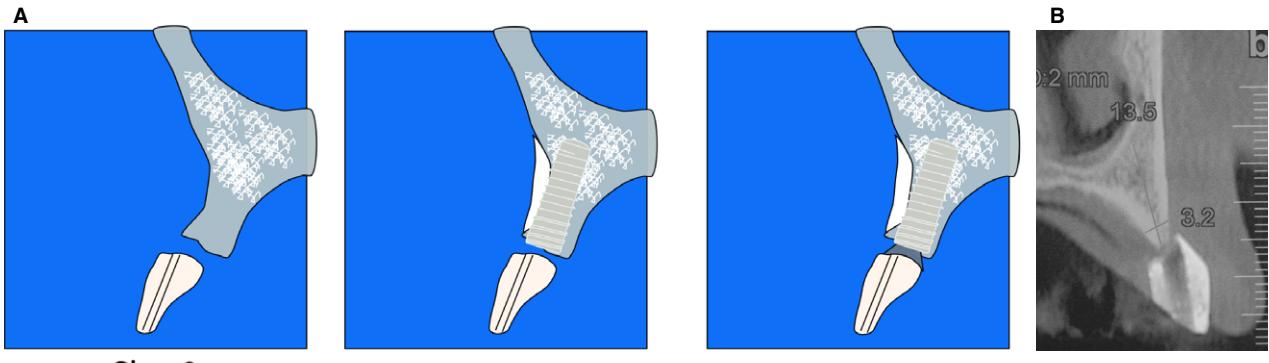
**Class 2**

Fig. 9. In a class 2 clinical situation, a certain degree of atrophy is present: the implant can be placed, but a simultaneous bone-augmentation technique is needed (A, B).

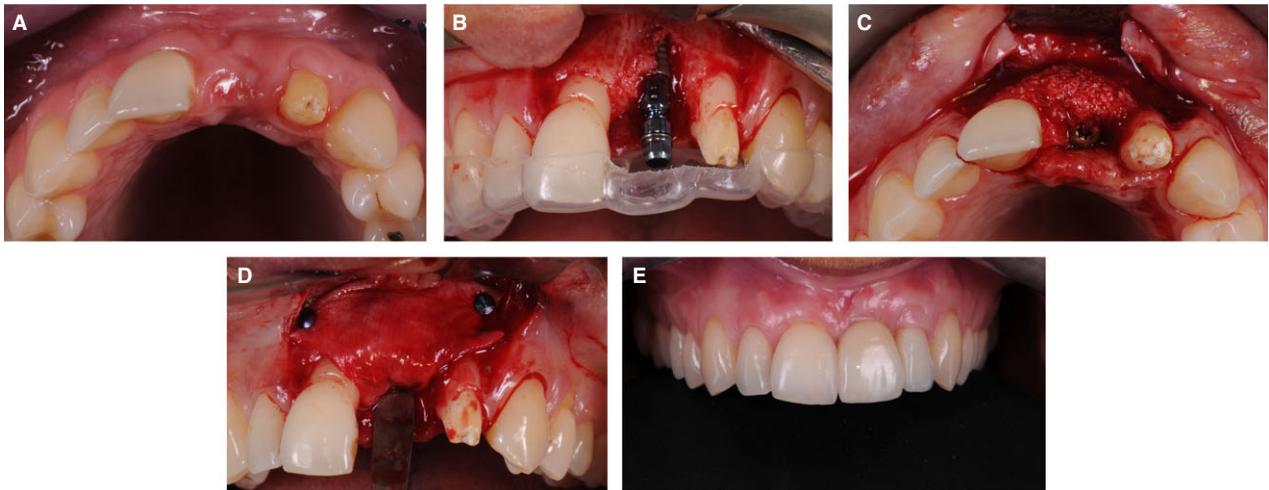


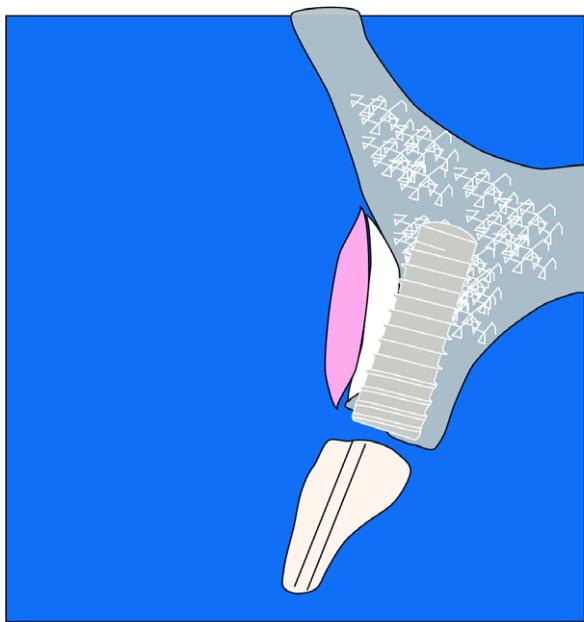
Fig. 10. To replace the missing left central incisor (A), a reduced-diameter implant was utilized. The implant was placed following the indications of a surgical template obtained from the wax-up (B). As the edentulous ridge presented moderate horizontal atrophy, a peri-implant dehiscence was produced on the buccal wall and a guided bone-regeneration technique was used. The defect was corrected by grafting a 50:50 mixture of autogenous bone particles harvested with a bone scraper (from the mandibular ramus) and particulate xenograft (deproteinized bovine bone – Mineral- Bioss®; Geistlich Biomaterials, Wolhusen,

Switzerland). A deliberate, slight overcorrection of the defect was performed to compensate for potential partial resorption of the graft during healing. The graft was then protected and separated from the soft tissues with a resorbable collagen membrane (Bio-Gide®; Geistlich Biomaterials) (C). In order to stabilize the graft, the membrane was fixed with titanium pins (D). The temporary implant-supported restoration shows favorable integration of the prosthesis (E). (Surgery, Dr Matteo Chiapasco & Dr Paolo Casentini; prosthetic rehabilitation, Dr Paolo Casentini.)

xenografts, is supported by less, and often contradictory, literature with some publications reporting positive results and others reporting questionable results (4, 5, 18, 30, 33, 36, 39, 61, 66, 67, 75, 79).

The choice between different bone-augmentation techniques is related to local defect morphology (discussed in the following section) and to the surgeon's preferences/skills. The bone-augmentation procedure should precisely follow the original prosthetic project, according to the concept of 'prosthetically guided regeneration' (21, 26). For this purpose, the use of a diagnostic template (rendered from a computerized tomography scan) during the bone-augmentation

procedure is recommended. The same template can be used to guide the second stage of implant placement. The continuity of the therapeutic flow, starting from the diagnostic process to bone augmentation, implant placement and the restorative phase, usually guarantees a favorable outcome for the patient. The use of reduced-diameter implants is recommended to avoid more aggressive implant site preparation in the reconstructed area (28) (Fig. 14A–F). Hard-tissue-augmentation procedures are often combined with soft-tissue grafts to achieve an optimal shape of the edentulous ridge before the placement of implant-supported restorations (Fig. 15A,B).



Class 2 + CTG

Fig. 11. In Class 2 clinical situations, implant placement and bone-augmentation procedures can be combined with a soft-tissue graft (connective tissue graft [CTG]), to improve the shape of the recipient site.

Class 4

In Class 4, a combined horizontal and vertical defect is present. Detection of the vertical component of the bone defect is highlighted by the prosthetically driven

diagnostic protocol where the wax-up reveals longer clinical crowns and/or a bulk of pink wax (Fig. 16A, B). Correction of vertical defects increases the complexity of treatment and necessitates the use of more demanding surgical techniques, which are associated with a higher incidence of complications (27, 34). The complexity and potential risks/drawbacks of treatment, such as early graft exposure, infection, resorption and increased morbidity, must be considered and discussed with the patient. In some cases, treatment can be simplified by limiting the reconstruction to the correction of the horizontal component of the defect. A quantity of pink ceramic may reproduce the missing, vertical soft tissues and achieve clinical crowns of the correct length. In some cases affected by extremely advanced horizontal and vertical atrophy, a certain amount of pink porcelain may be recommended, in spite of vertical and horizontal bone augmentation, to achieve a better esthetic and functional rehabilitation.

The main surgical alternatives for the correction of combined horizontal-vertical techniques are: (i) autogenous bone blocks harvested from intra/extr-oral donor sites (Fig. 17A–G); (ii) guided bone-regeneration techniques using autogenous particulate bone and/or alloplastic materials in association with semipermeable barriers (resorbable or nonresorbable); and (iii) Le Fort I osteotomy with advancement and lowering

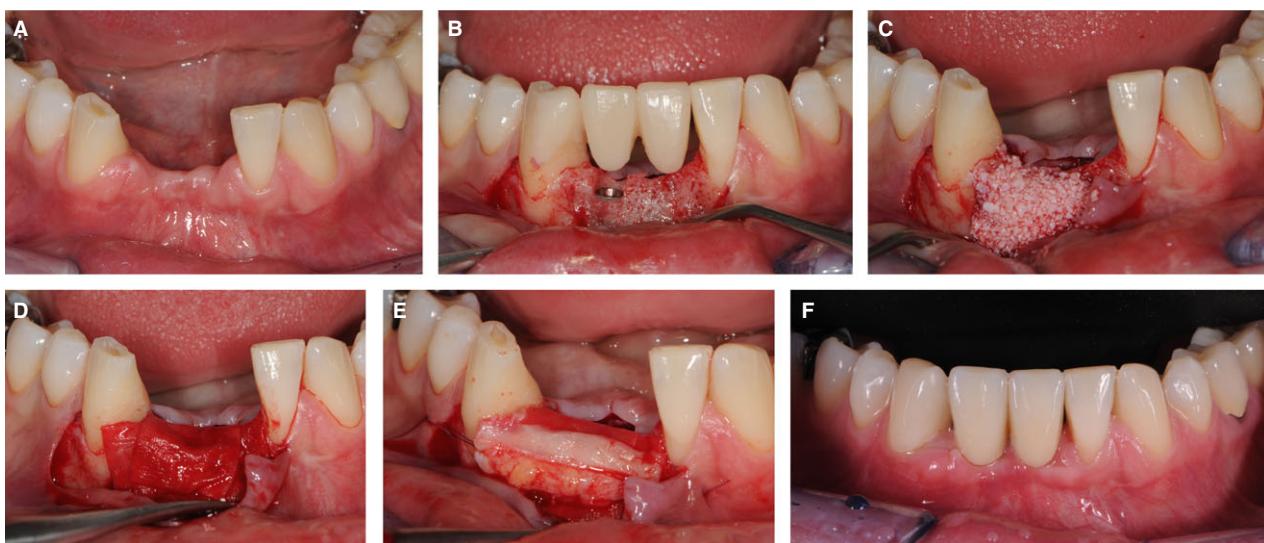
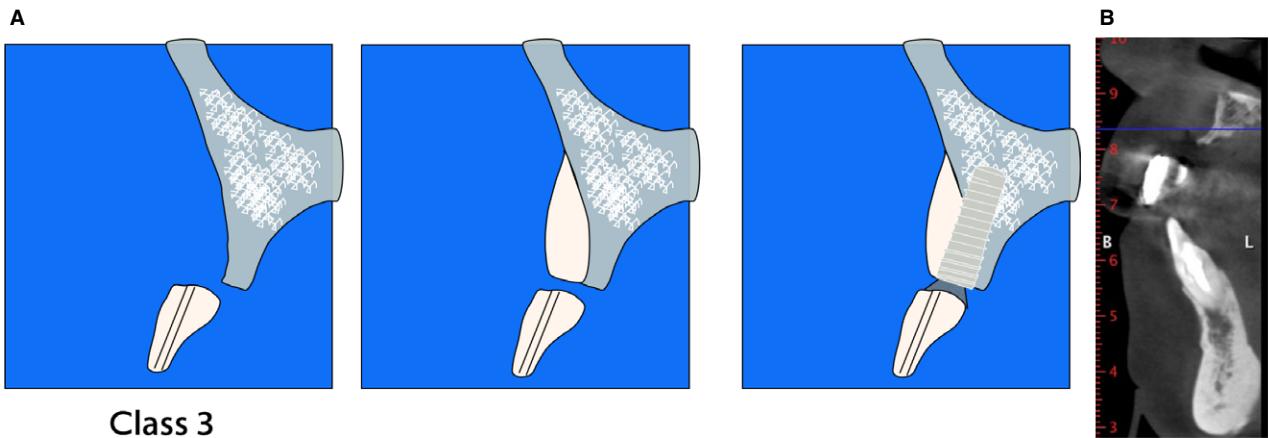


Fig. 12. The treatment plan for this partially edentulous anterior mandible (A) included one implant supporting one mesial cantilever and one lithium disilicate veneer on the right cuspid in order to achieve better management of the mesiodistal space. The implant was placed following the indications of a surgical template obtained from the wax-up (B). Despite the implant being fully surrounded by native bone, the residual buccal bony wall (less than 1 mm) was considered too thin to guarantee a favorable

long-term prognosis. As the presence of an atrophic ridge could also affect the final esthetic result, a guided bone-regeneration technique using a xenograft, covered with multiple layers of a collagen membrane, was performed (C, D). Moreover, as the thickness of the surrounding soft tissues was reduced, a connective tissue graft was used to optimize the peri-implant tissue quality and final esthetic outcome (E, F). (Surgery, Dr Paolo Casentini; prosthetic rehabilitation, Dr Martin Thürthenthaler.)



Class 3

Fig. 13. In class 3 clinical situations, the greater degree of alveolar atrophy prevents implant placement. Implants are placed with a delayed approach following bone-augmentation procedures and adequate healing (A, B). B, buccal; L, lingual.

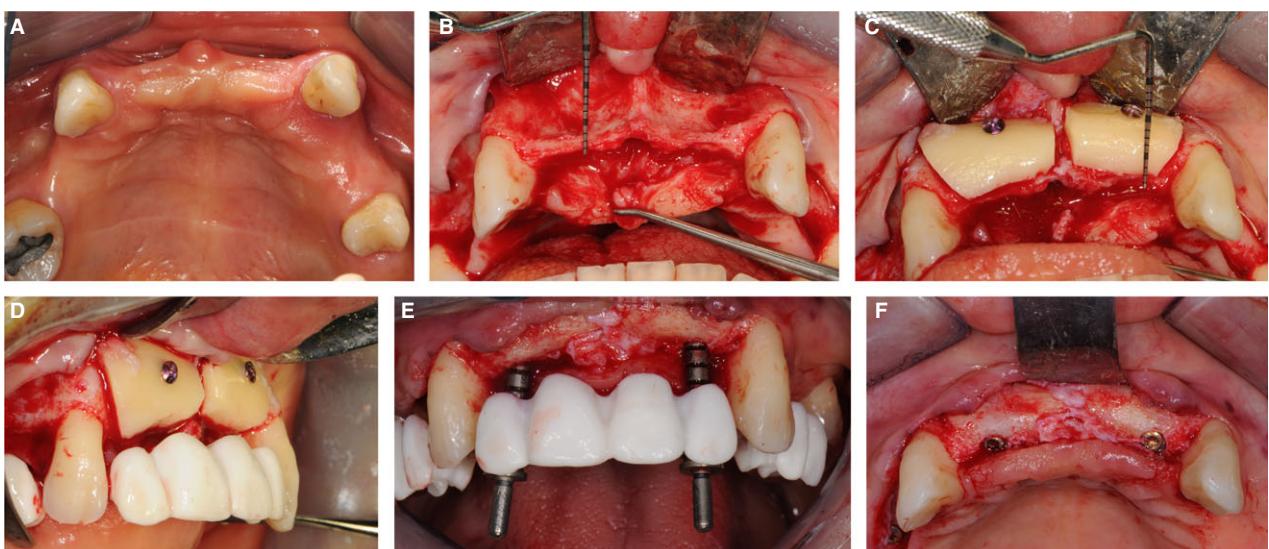


Fig. 14. (The same patient as shown in Figs 3 and 5.) After the diagnostic protocol confirmed a high degree of horizontal atrophy, which contraindicated implant placement (A), the defect in the anterior maxilla was corrected with two autogenous bone blocks harvested from the mandibular ramus (B, C). The diagnostic template, made following a computerized tomography scan, was

used to 'guide' the reconstructive phase (D). After a 6-month healing period, needed for adequate integration and revascularization of the grafts, the same template was used as a surgical guide during implant placement (E, F). (Bone-augmentation surgery, Dr Paolo Casentini & Dr Matteo Chiapasco; implant surgery, Dr. Paolo Casentini.)

of the maxilla and interpositional bone grafts (only for severe atrophy of the maxilla associated with increased interarch distance and maxillary retrusion).

in this section, aiming to highlight the benefits and limitations of each technique.

Choice between different surgical techniques in the treatment of horizontal defects

Once a defect has been classified following the diagnostic protocol, it will be easier to select the most appropriate surgical technique to treat the defect. The main surgical techniques will be briefly described

Guided bone regeneration with resorbable membranes

The principle of guided bone regeneration is based on the use of a barrier separating the deficient bone site from the surrounding soft tissues to create a protected space for bone regeneration. The protection of the membrane allows the bone defect to be populated by blood vessels and osteogenic cells coming from the bone marrow cavities and the bone surface

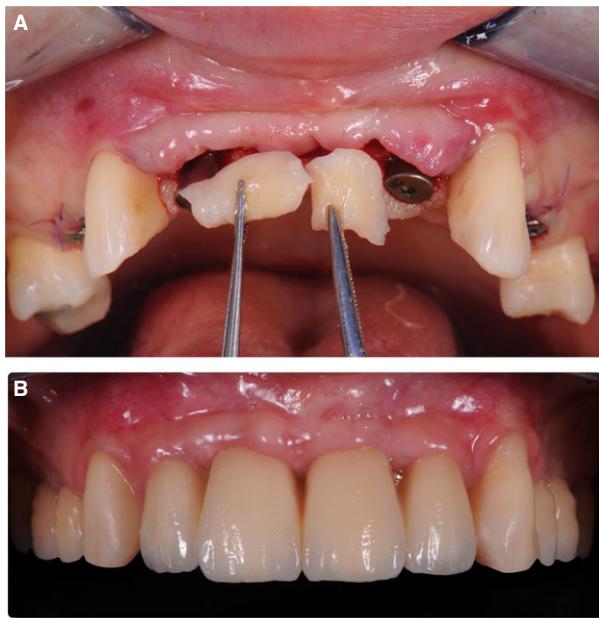


Fig. 15. (The same patient as shown in Figs 3, 5 and 14.) During abutment connection, a double connective-tissue graft, harvested from the maxillary tuberosity, can be used to improve soft tissues and final esthetic outcome the recipient site (A). The final photograph shows the temporary implant-supported restorations (B). (Soft-tissue augmentation and prosthetic rehabilitation, Dr Paolo Casentini.)

(8) and excludes any epithelial/soft-tissue infiltration of the area. In guided bone-regeneration techniques, the use of a membrane is combined with autogenous particulate bone and bone substitutes (discussed in the following section). Collagen membranes are the most common resorbable membranes used for guided bone regeneration (12, 17). However, as their barrier effect is lost in a few weeks, a multiple-layer technique is recommended to guarantee a prolonged

barrier effect (Fig. 12). A greater degree of stability of the membrane can be achieved by fixing the membrane using titanium pins.

Indications

Guided bone regeneration with a resorbable membrane is the preferred technique for the treatment of small peri-implant defects such as a dehiscence or fenestration. Following the classification presented above, guided bone regeneration is indicated in all class 2 cases when a moderate degree of horizontal alveolar atrophy is present. Guided bone regeneration with a resorbable membrane has also been applied successfully in class 3 cases when advanced horizontal atrophy is present and implant placement is delayed (77). Class 3 defects have also been treated following the principle of guided bone regeneration, combining collagen membranes with the use of titanium plates (63). When collagen membranes are used for the correction of class 3 advanced horizontal defects, a significant volume of particulate autogenous bone is recommended by the authors.

Surgical recommendations

Before applying the membrane, small perforations of the residual alveolar ridge cortex are recommended, to increase migration of osteogenic cells underneath the membrane and accelerate revascularization of the graft. If part of the implant surface is exposed, it is recommended to cover it with some autogenous particulate bone, collected from adjacent areas using chisels or bone scrapers, to improve and expedite the regeneration process (Fig. 18). The autogenous bone in contact with the implant surface should be covered with an osteoconductive bone substitute, such as

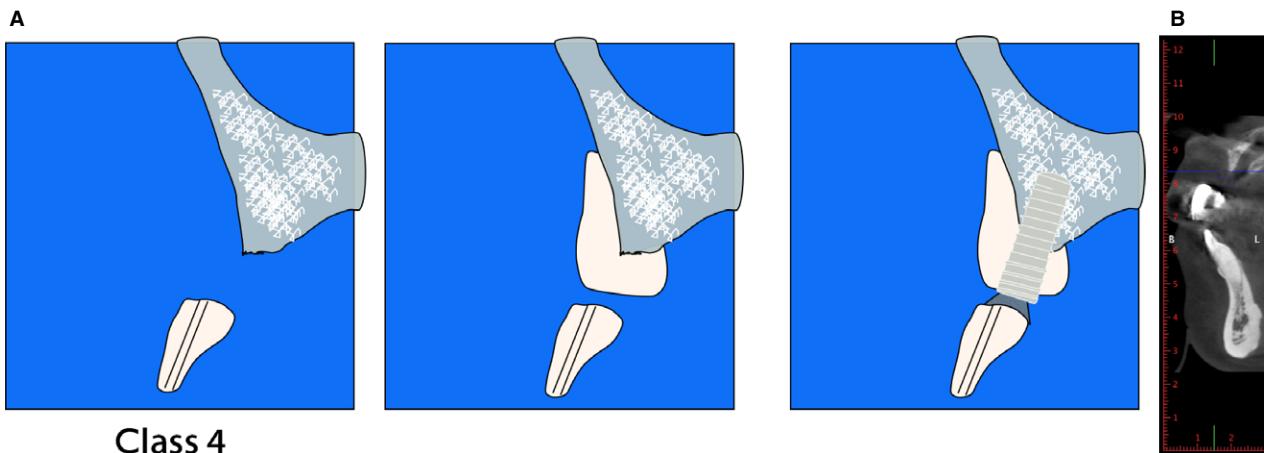


Fig. 16. In class 4 clinical situations, the horizontal alveolar atrophy is combined with vertical atrophy. It is not possible to insert implants in the correct three-dimensional position. As in class 3 cases, implants will be placed with a delayed approach following bone augmentation and healing (A, B). B, buccal; L, lingual.

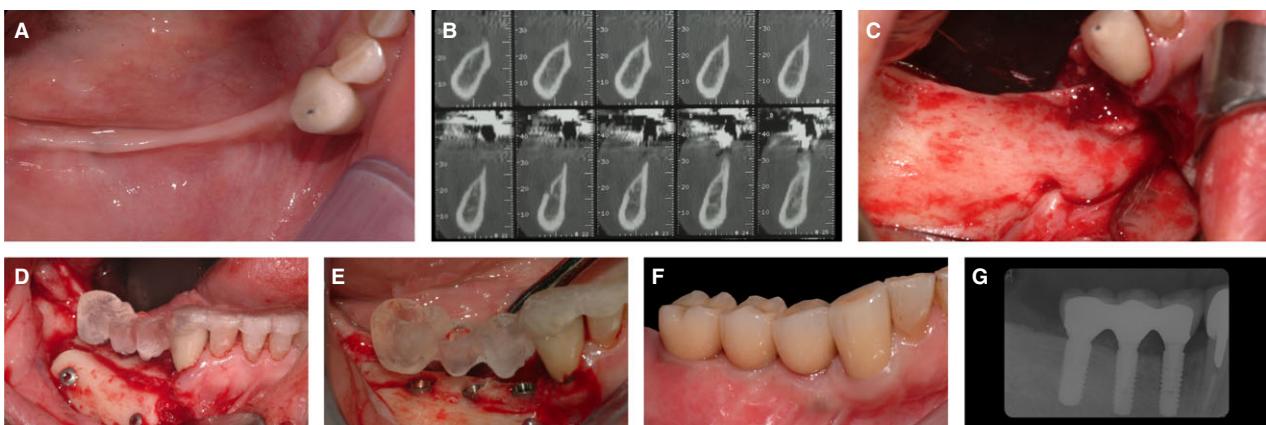


Fig. 17. Treatment of the posterior mandible affected by a combined horizontal-vertical defect and knife-edge ridge (the same patient as shown in Fig. 2) (A). Computerized tomography scan confirms the presence of severe bony atrophy, incompatible with implant placement (B). A wax-up is used to reproduce the ideal profile of the ridge and the missing teeth, from which a surgical stent is obtained (C). The bone-augmentation procedure, performed with autogenous bone blocks, is guided by the surgical stent.

After 6 months, adequate bone volume has been created and the graft appears well integrated (D). Preparation of implant sites is carried out with the aid of the same surgical stent used during the bone-augmentation procedure (E). Final clinical (F) and radiographic (G) appearances of the rehabilitated area show good integration of the implant-supported prosthesis. (Bone augmentation, implant and soft-tissue surgery, and prosthetic rehabilitation, Dr Paolo Casentini.)

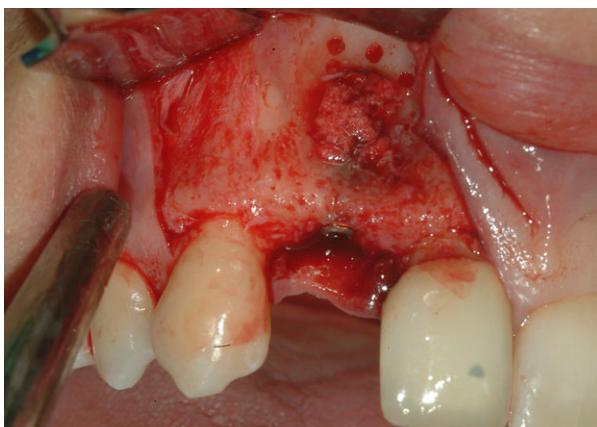


Fig. 18. After perforation of the buccal cortical layer, autogenous bone chips are placed to cover the exposed implant surface.



Fig. 19. (The same patient as shown in Fig. 18.) Placement of deproteinized bovine bone mineral.

deproteinized bovine bone mineral with a degree of ‘over correction’, in order to compensate for partial resorption of the graft during healing (Fig. 19). The collagen membrane is trimmed to the correct shape and adapted to cover the augmented site. Handling of the ‘dry’ membrane usually facilitates trimming and adaptation to the defect. Multiple layers are recommended to increase the barrier effect of the membrane (Fig. 20). During handling and adaptation of the membrane, where possible, the treated area should not be contaminated with saliva. Although it has been shown that guided bone regeneration can work without primary wound closure (57), it is recommended to provide a sealed, tension-free closure of

the wound. For the same reason, the use of ‘bone level’ submerged implants is recommended. In every bone-augmentation procedure, as the local volume increases, the periosteal layer of the flap must be released to achieve tension-free primary wound closure (Figs 21 and 22). During the healing phase, the treated area should be protected from pressure; for this purpose, temporary prostheses must be modified in the majority of cases.

Benefits and limitations

Guided bone regeneration with a resorbable membrane for treatment of small defects is a ‘user friendly’ technique that requires a low degree of surgical skill.



Fig. 20. (The same patient as shown in Figs 18 and 19.) Placement of a collagen membrane in multiple layers is recommended to increase the barrier effect of resorbable membranes.



Fig. 21. (The same patient as shown in Figs 18–20.) In every augmentation procedure, tension-free, primary intention wound closure is recommended.



Fig. 22. (The same patient as shown in Figs 18–21.). Clinical appearance of the treated area after rehabilitation. (Implant and augmentation surgery, Dr Paolo Casentini; prosthetic rehabilitation Dr Martin Thurthchenthaler.)

Surgery can usually be performed under local anesthesia. Complications of this technique (such as exposure of the membrane) are limited and they are usually easily dealt with (e.g. by local disinfection with chlorhexidine gel). Treatment of more advanced defects (class 3) is more demanding but resorbable

membranes can still be used for these defects. However, resorbable membranes are not indicated for defects that present a vertical component (class 4). These aspects need to be discussed with the patient who must read and sign a detailed informed consent form, in which the indications, advantages, disadvantages, potentials and limits, as well as alternatives to each proposed modality of treatment, must be thoroughly described for each type of augmentation procedure, be it routine or complicated.

Guided bone regeneration with nonresorbable membranes

The benefits of nonresorbable membranes derive from the greater stiffness that guarantees a longer barrier effect that lasts until the membrane is removed. For this reason, these membranes are utilized for correction of more severe alveolar bone defects, including those with a vertical component. Expanded-polytetrafluoroethylene membranes reinforced with titanium (11, 13, 23, 73, 74) or titanium meshes (38, 68, 69) have been used as nonresorbable barriers. Unfortunately, the greater stiffness of this kind of barrier is associated with a higher rate of complications, such as membrane exposure and partial or total failure of the augmentation procedure. In the case of exposure of a nonresorbable membrane, unlike exposure of a collagen barrier, in the majority of cases the membrane must be removed (43).

Indications

Guided bone regeneration with nonresorbable membranes is indicated in the correction of class 3 and 4 defects, with a significant horizontal and/or vertical component in partially edentulous patients. The application of this technique in fully edentulous patients is not supported by sufficient literature. In particular, this technique is indicated when the defect has an irregular shape and it would be difficult to adapt an autogenous block graft (Fig. 23A,B). The use of a mixed graft, composed of autogenous particulate bone and a bone substitute, is usually recommended with this type of membrane. Implant placement is usually delayed for a period of 6–9 months, and the barrier is removed during second-stage surgery.

Surgical recommendations

As in smaller defects, the cortical plate is perforated to promote migration of osteogenic cells from the residual bone. Before cutting the nonresorbable barrier, it is convenient to use a piece of sterile paper as a stent which can be adapted to the defect, simulating

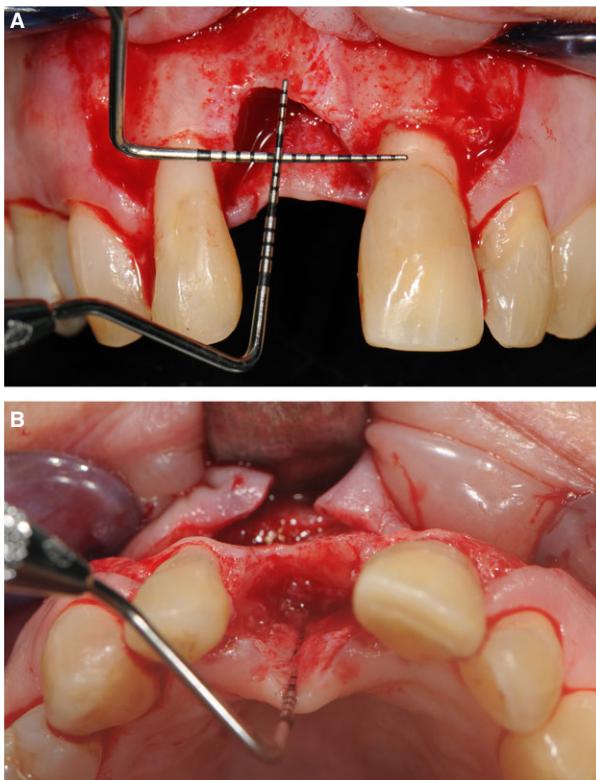


Fig. 23. (A, B) Guided bone regeneration with a nonresorbable membrane is indicated in irregular, complex defects, especially with a vertical component, where it would be difficult to adapt a block graft.

the final area and shape of the barrier required. Once the final shape of the barrier has been defined, the nonresorbable membrane can be trimmed until the proper shape is achieved (Fig. 24A,B). Nonresorbable barriers need to be immobilized with titanium pins or microscrews. Titanium screws can also be used to support the membrane in the central part, thus achieving a 'tent effect' (Fig. 25). The membrane is usually partially fixed before filling the defect with the graft. The defect is then filled with autogenous particulate bone or with a mixture of autogenous bone and an osteoconductive biomaterial (73). Definitive fixation of the membrane is then achieved. Particular care should be taken to assure a minimal distance of 1.5 mm between the membrane edges and roots of the adjacent teeth because the gingival sulcus could represent a source of contamination during healing (Fig. 26). The membrane should be in tension and if a titanium mesh is used, the sharp edges should be eliminated to reduce the risk of soft-tissue dehiscences during healing.

Tension-free, primary closure of the flap is mandatory and periosteal releasing incisions are necessary in order to mobilize the flap. In the maxilla, the releasing procedure is limited to the buccal side of

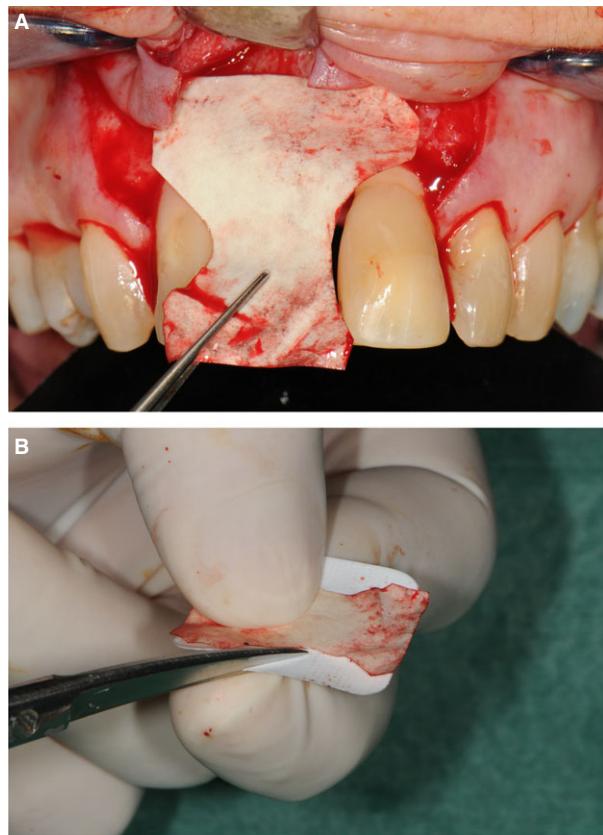


Fig. 24. To facilitate adaptation of the membrane, a sterile paper stent is first adapted to the defect (A). The nonresorbable membrane will then be trimmed, based on the stent (B).



Fig. 25. A screw is used to provide mechanical support to the expanded-polytetrafluoroethylene membrane.

the flap because palatal tissues cannot be released. In the mandible, and in particular in the posterior area, passivation of the lingual flap helps to achieve tension-free coverage of the augmented area. A combination of single and horizontal mattress sutures is used to assure closure of the flaps (Fig. 27A,B). During the healing phase, the treated area should be protected from pressure, and temporary fixed prostheses, such as Maryland bridges, are usually preferred. If the membrane does not become exposed,



Fig. 26. The space underneath the membrane is then filled with a mixture of autogenous particulate bone and an osteoconductive biomaterial, and the membrane is finally secured with titanium pins.

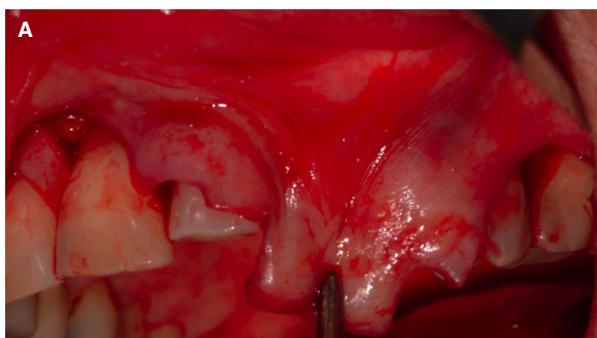


Fig. 27. (A, B) A tension-free suture assuring a primary intention closure of the flap is mandatory when a nonresorbable barrier is utilized.

its removal is usually performed after a 6- to 9-month healing period, and implants are placed at this time. Removal of the membrane should be performed carefully to avoid damaging the underlying regenerated bone (Figs 28A,B and 29A,B).

Benefits and limitations

Guided bone regeneration using nonresorbable barriers represents an effective surgical technique and should be considered as the preferred technique in irregular defects with a vertical component (class 4). However, a higher rate of complications (between 10% and 20%) has been reported, even by experienced surgeons. This technique requires advanced

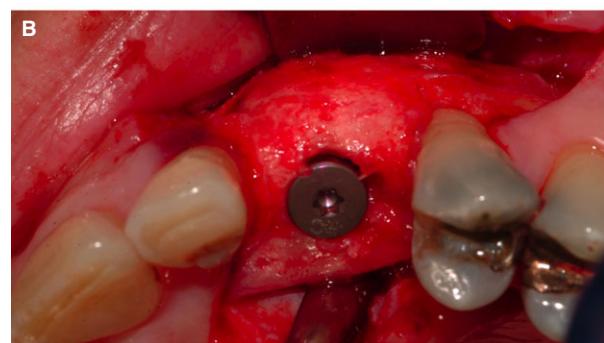
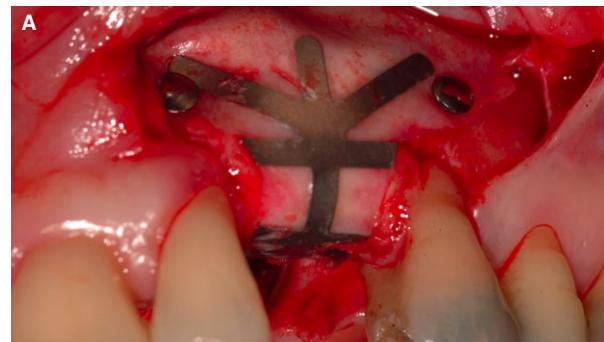


Fig. 28. Delicate removal of the membrane after a period of healing of 9 months (A). An adequate volume of bone for implant placement has been regenerated (B).



Fig. 29. Clinical (A) and radiographic (B) aspects of the treated area after delivery of the implant-supported crown. (Augmentation and implant surgery, Dr Paolo Casentini; prosthetic rehabilitation Dr Martin Thürthenthaler.)

surgical skills because it is technically demanding and therefore should only be performed by adequately trained and experienced surgeons. As nonresorbable

barriers are usually used in conjunction with a significant amount of autogenous bone, the need to harvest this bone increases the total complexity of the procedure and postoperative morbidity. As longer surgical times can be expected, intravenous sedation in association with local anesthesia is often recommended. The use of guided bone regeneration is very well supported by the literature as far as the treatment of partially edentulous patients is concerned. On the contrary, the use of vertical guided bone regeneration in fully edentulous patients is supported by very limited literature.

Crest splitting and expansion techniques

Splitting techniques represent an alternative to guided bone regeneration in ridges with a moderate horizontal atrophy (class 2, according to the classification presented here) and can be carried out in conjunction with implant placement. Compared with guided bone regeneration, the indications for these are limited because the presence of a layer of cancellous bone between the two cortical plates is vital and, for this reason, the technique is rarely applied in the mandible. Buccal inclination of the crest is a contraindication for these techniques as splitting usually increases the buccal inclination of implants simultaneously inserted. The techniques are operator-sensitive and require a level of training and experience. For these reasons, the technique has had a limited uptake compared with guided bone regeneration. Nonetheless, if the technique is applied correctly, in carefully selected cases, it is possible to achieve adequate correction of the atrophic ridge (3, 31, 72).

Indications

These procedures are indicated in class 2 cases with moderate, horizontal maxillary alveolar atrophy, and

where the cancellous component of bone and its elasticity allow expansion (Fig. 30A,B). On the contrary, sparse scientific data are available on expansion techniques applied to the mandible.

Surgical recommendations

In expansion techniques, minimal elevation of the flap is recommended, in order to reduce the risk of resorption of the split buccal bone. If a sagittal osteotomy technique is performed, it is recommended to undertake a mid-crestal bone cut utilizing the least invasive technique, such as piezosurgery or a thin cutting disc. Mesial and distal releasing bone cuts are carried out with the same instruments. The sagittal split is then performed using chisels, expansion screws or special expansion devices (Fig. 31A,B). Excessive buccal inclination of implants should be avoided. For this purpose, during implant site preparation, the bur should be kept in contact with the palatal wall of the sagittal osteotomy and excessive contact with the buccal wall should be avoided. As expansion techniques usually create a conical cavity in the bone, the use of conical implants is recommended (Fig. 32A,B).

Benefits and limitations

Theoretically, the benefit of expansion techniques, compared with guided bone regeneration, is seen in the low morbidity in the postoperative period, if a minimal size of flap is elevated, as well as in a reduced cost, as membranes and bone substitutes are not usually used. On the other hand, the limitations of this technique should be mentioned: (i) the indications are limited as a result of the local anatomy (e.g. the need for a layer of cancellous bone between the cortical plates, excessive buccal inclination of implants in the case of a buccally tilted crest and this technique is rarely applicable in the mandible); (ii)

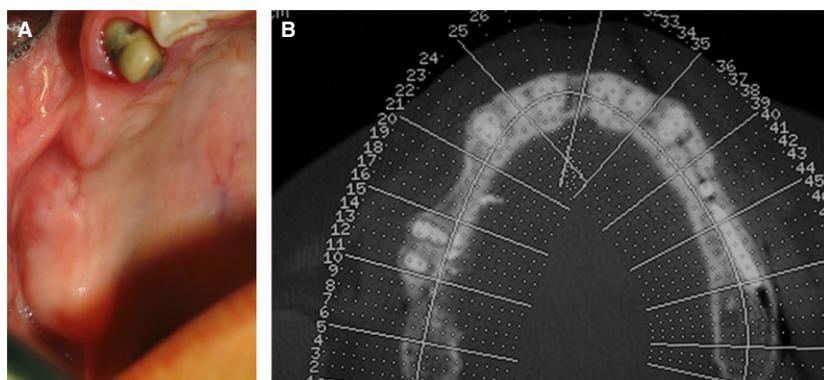


Fig. 30. A moderate, horizontal alveolar atrophy is present in the posterior area of the maxilla (A). Computerized tomography indicates separation of the two cortical layers by a layer of cancellous bone (B).

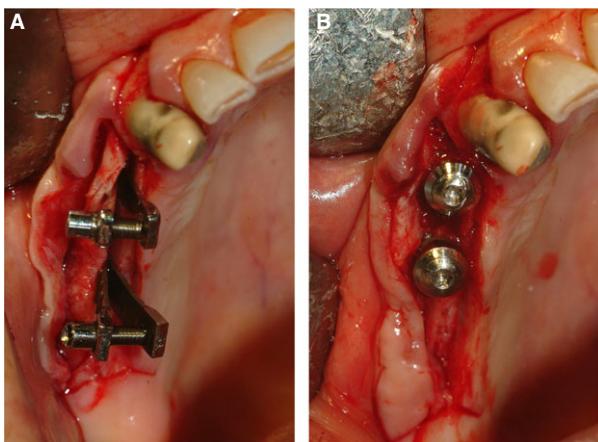


Fig. 31. A thin, mid-crestal osteotomy is performed with piezosurgical instruments. Expansion devices are inserted into the osteotomy site and gradually activated (A). After expansion, implant sites are prepared and implants are inserted (B). (Implant and augmentation surgery, Dr Paolo Casentini.)

the risk of fracture/unpredictable resorption of the buccal cortical layer; and (iii) it is an operator-sensitive technique requiring advanced surgical skills.

Autogenous bone block grafts

The best, scientifically documented, technique for correction of a significant horizontal and/or vertical alveolar bone defect is the use of autogenous bone blocks (2, 27, 56, 64). The biologic behavior of transplanted autogenous bone blocks is well known and combines osteoclastic degradation and osteoblastic substitution, which lead to healing and integration of the graft. During the integration process, the space between the graft and the recipient site is primarily filled with newly formed woven cancellous bone. Then, new bone tissue grows inside the graft, by the formation of so-called 'cutting cones', which represent tunnels connecting the native bone and the graft. The cutting cones, which are filled with concentric layers of lamellar bone, form the basis for formation of osteons or Harvesian systems (8). During integration, the grafted bone is usually completely replaced with osteons. Although complete bone remodeling of the graft may take several years, from a clinical point of view, after 4–6 months of healing, sufficient integration and revascularization of the graft has occurred and it is possible to place implants (Fig. 33A–C).

Indications

Bone grafting is a very predictable technique in the treatment of class 3 (advanced horizontal atrophy) and class 4 (advanced horizontal atrophy with a

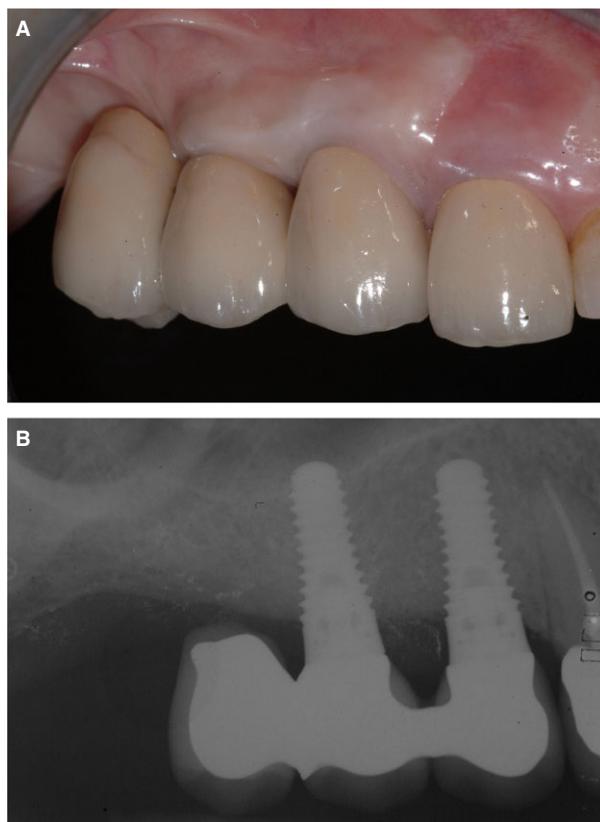


Fig. 32. Clinical (A) and radiographic (B) appearance of the treated area after rehabilitation. (Prosthetic rehabilitation, Dr Paolo Casentini.)

vertical component) situations. The only situation when a block graft is not ideal is when a defect has an irregular shape and size. In this situation, as previously stated, guided bone regeneration with a particulate graft and a nonresorbable barrier might be preferred. Bone grafting is also the best documented technique for the treatment of advanced atrophy in a completely edentulous arch.

Surgical recommendations

Every bone-augmentation procedure should be based on the prosthetically guided regeneration concept (Fig. 34A,B). After flap elevation, the dimensions of the recipient site are measured to allow a block of adequate width, height and length to be harvested and to facilitate surgical modeling of the graft before fixation (Fig. 35). Cortical perforations are carried out in the recipient site to facilitate migration of osteogenic cells and accelerate revascularization. The graft is harvested from the donor site with the mandibular ramus being the site preferred for grafts of limited dimensions (one to three missing teeth) because dense bone blocks of the desired dimensions can be readily harvested. Osteotomies in the donor site are carried out using piezosurgical instruments. The bone

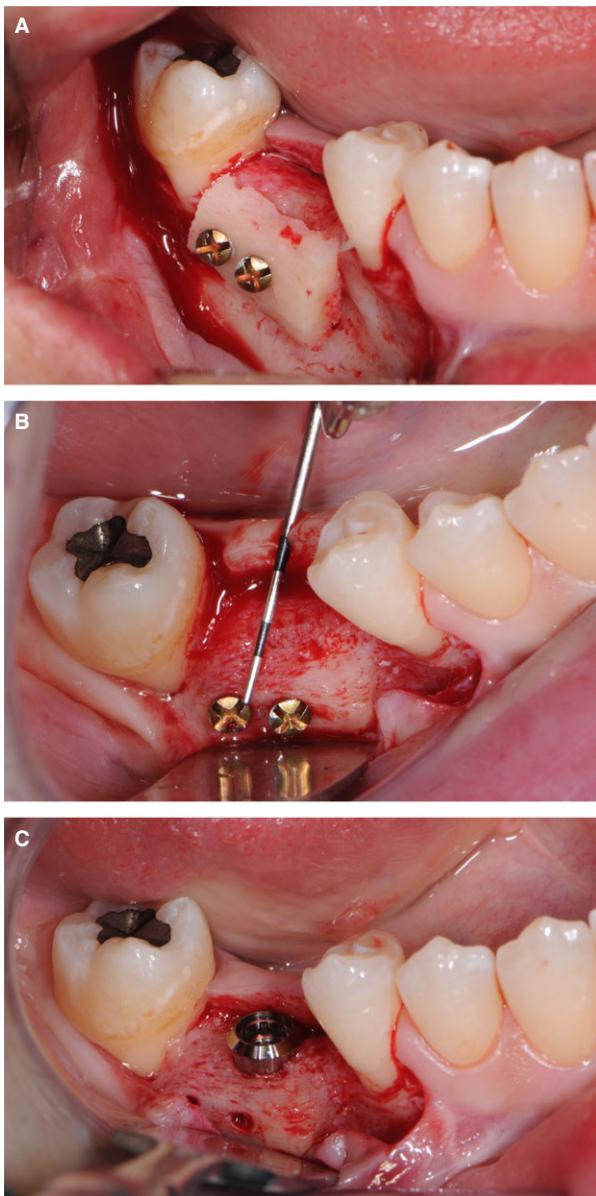


Fig. 33. Autogenous graft integration (A): after a period of 6 months, the graft has the same appearance as the surrounding native bone (B). Fixation screws can be removed and one implant is placed (C). (Augmentation surgery, Dr Paolo Casentini.)

block is then detached by rotation of a chisel inserted in the osteotomy lines (Fig. 36). Before removing the block, a small amount of particulate bone can also be harvested from the same area with a chisel or a bone scraper. Autogenous bone chips will be used to fill small gaps between the block and the recipient site. The graft is then trimmed with burs or with piezoelectric instruments with copious irrigation with sterile, refrigerated saline, and its adaptation to the recipient site is verified. As a general rule, precise adaptation and intimate contact with the native site should

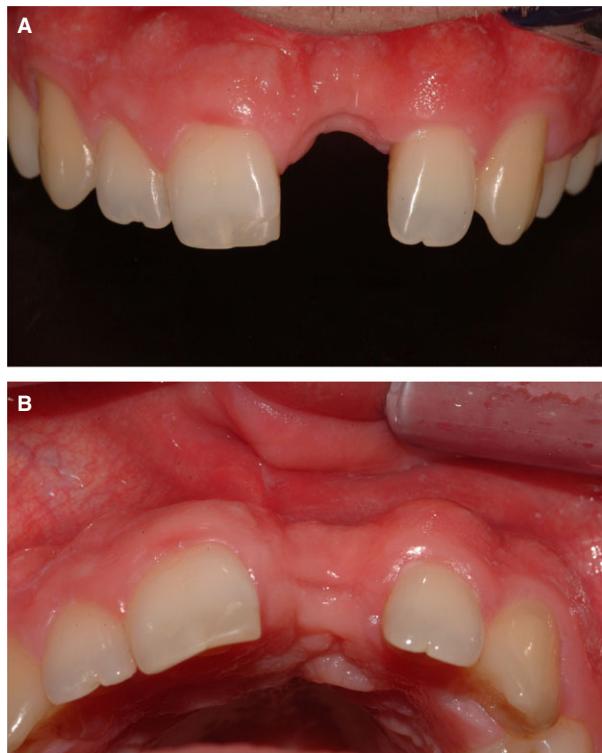


Fig. 34. (A, B) The missing left central incisor is associated with a class 3 horizontal defect where the residual bone volume does not allow implant placement in a correct, prosthetically driven position.

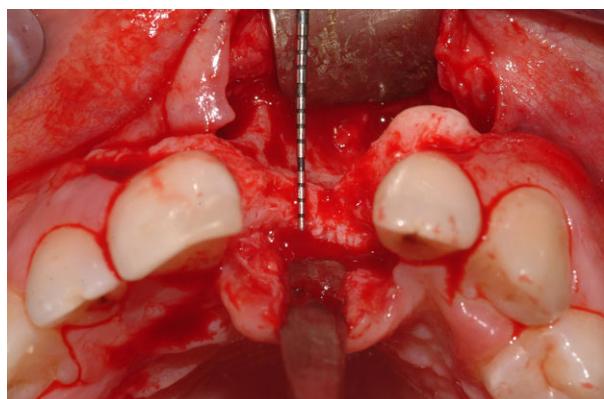


Fig. 35. After flap elevation the recipient site is measured in order to establish bone block dimensions.

facilitate migration of osteogenic cells and guarantee rapid integration of the graft. Once the best position of the graft has been defined, the perforation for the fixation screw is performed with specific drills. During this step, the bone block is immobilized with a hemostatic clamp or with specific instruments, such as the Luniatschek graft holder. Perforation should be widened more in the block and conversely it should be precise in the recipient site, allowing gentle compression of the graft by the fixation screw. Fixation screws with a 1.5-mm-diameter of varying length



Fig. 36. An autogenous bone block is harvested from the mandibular ramus. From the same area, small particles of bone can be harvested with a bone scraper. In this specific case, the buccal exostosis on the upper left lateral incisor was also used as a source of particulate bone.

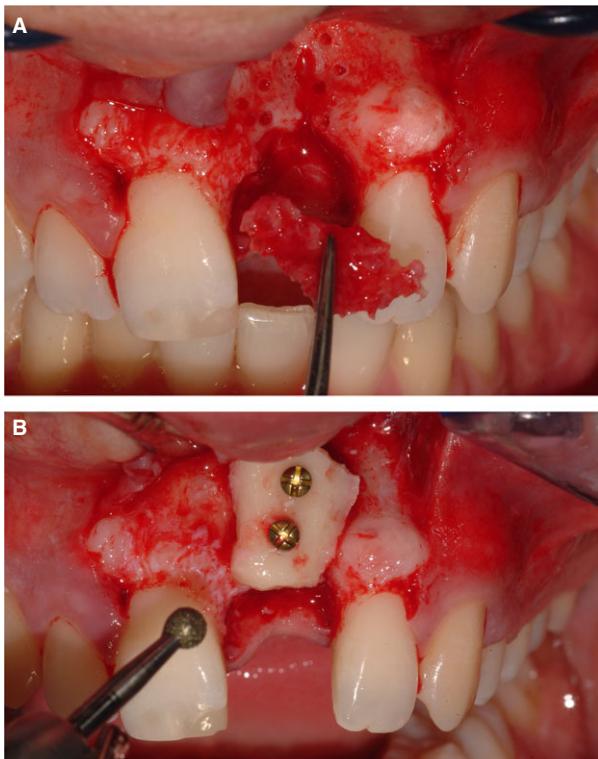


Fig. 37. Small gaps between the recipient site and the graft can be filled with particulate autogenous bone; in this case, part of the bone chips were placed before block fixation (A). The block was then secured with two osteosynthesis screws, and sharp edges were rounded with a 3-mm-diameter diamond bur (B).

(according to surgical needs and graft thickness) are considered ideal for bone block fixation. The number of screws may vary significantly according to the clinical situation, with the general rule being to apply the minimum number of screws required to immobilize the graft confidently. If a significant gap is present between the graft and the native bone, this should be filled with autogenous particulate bone (Fig. 37A). This is to guarantee good contact between the graft and the recipient site and to avoid connective tissue ingrowth in between, which may be detrimental to the graft integration process. Sharp edges of the graft should be eliminated in order to avoid flap perforation and dehiscence during healing (Fig. 37B). The graft can be covered with a thin layer of bone substitute with a low resorption rate, such as deproteinized bovine bone mineral (37, 62, 78) (Fig. 38A). The bone substitute should not be placed between the graft and the recipient site, as it could interfere with graft integration. Any gaps between the graft and the recipient site should be filled with autogenous particulate bone. The grafted area is then covered with a resorbable collagen membrane (Fig. 38B). The use of membranes and bone substitutes in association with bone graft seems to prevent the potential, partial, bone

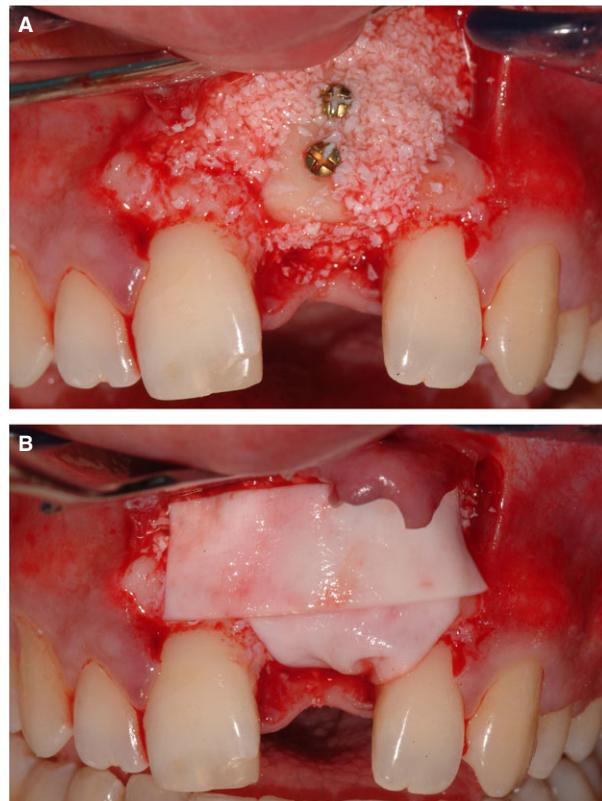


Fig. 38. The graft is covered and surrounded by deproteinized bovine bone mineral (A) and then protected with two layers of a collagen (resorbable) membrane (B).

resorption of the graft during healing (38, 63, 79). In cases of larger defects, in which intra-oral sites are unable to provide enough bone volume, extra-oral sites, such as the calvarium and the pericranial periosteum (pericranium) can be used to protect and prevent resorption of the graft (24). Tension-free, primary wound closure is essential, as in all augmentation techniques (Fig. 39).

Implants, in areas grafted with bone blocks, are usually placed after a healing period of 4–6 months depending on the quality of the grafted bone. If the donor site is the iliac crest, a shorter period (4 months) may be sufficient, as the iliac crest, because of its structure of predominantly cancellous bone, will undergo faster integration. In case of blocks harvested from the mandibular ramus, the chin or the calvarium, a longer healing time (6 months) is suggested (Figs 39–42). However, excessively long healing times might lead to excessive graft resorption as a result of the absence of mechanical stimuli leading to disuse atrophy.

Bone density in an area grafted with a bone block (with the exception of iliac bone) is usually high; for this reason, implant site preparation should be delicate and drills with a good cutting capacity should be used. The implant should be placed gently and any excessive pressure fit or insertion torques should be avoided. The latter might damage the bone graft, as the remodeling phase is still active, reduce its vascularization or eventually detach the graft from the recipient site. For the same reason, wide-diameter implants are usually not recommended after augmentation with bone blocks and, in many cases, reduced-diameter implants placed in a precise, prosthetically driven position are preferred. In complex three-dimensional defects, when traditional adaptation of the graft to the recipient site cannot be readily achieved, it is possible to use block grafts such as biological membranes to build up bony walls and to fill



Fig. 39. A tension-free primary intention wound closure is achieved after interrupting the periosteal layer.



Fig. 40. Re-entry after 6 months shows good integration of the graft and the absence of resorption.

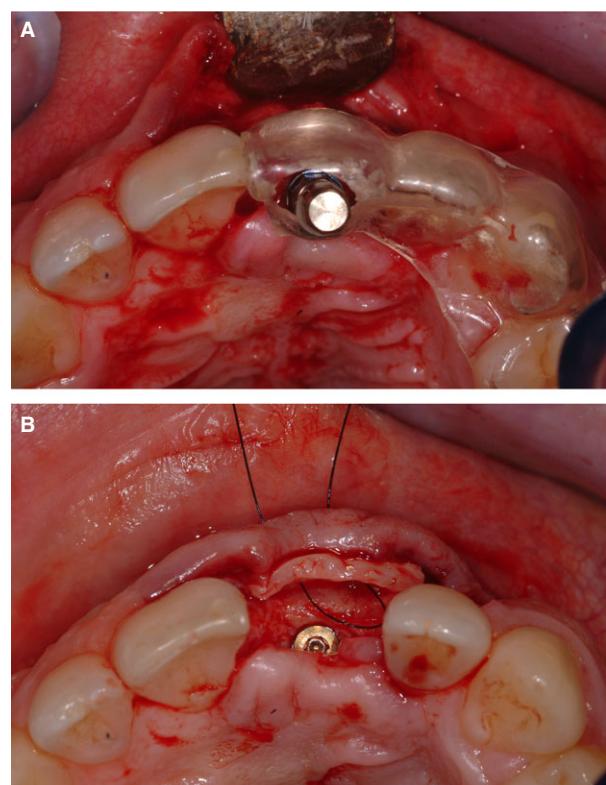


Fig. 41. An implant is placed in the previously augmented area, following the guidance of a surgical stent (A). A connective tissue graft was sutured to the internal part of the buccal flap to improve the shape of the edentulous crest to facilitate soft-tissue conditioning (B).

the residual space with particulate autogenous bone. With this approach, it has been demonstrated that, in spite of large parts of bone block not being in contact with the recipient site, bone regeneration still occurs (55) (Figs 43–45).

Benefits and limitations

Bone reconstruction using autogenous blocks is a very well-documented technique that has a lower

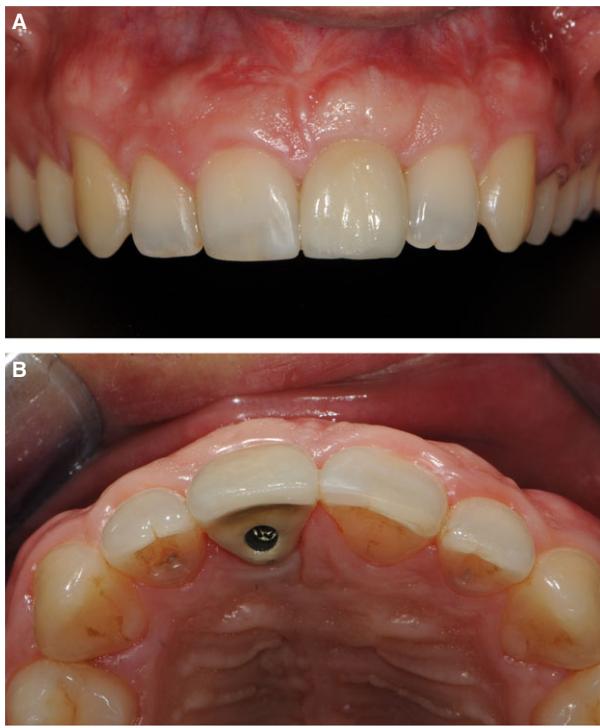


Fig. 42. Clinical appearance of the treated area after rehabilitation. Note the 'pleasant' symmetry between the treated site and the contralateral central incisor, in both buccal (A) and occlusal (B) views. (Augmentation and implant surgery, Dr Paolo Casentini; prosthetic rehabilitation, Dr Massimiliano Balsamo.)

complication rate compared with guided bone regeneration with nonresorbable barriers (23, 27). It is applicable in a wide range of clinical situations, allowing the simultaneous treatment of horizontal and

vertical alveolar defects, ranging from single tooth spaces to edentulous arches. When extra-oral donor sites are used, a practically limitless amount of bone is available to treat advanced atrophies and complex, three-dimensional defects (Figs 46–50). Like all bone-augmentation procedures, the use of bone blocks is an operator-sensitive surgical technique. In particular, harvesting techniques from extra-oral donor sites require specific training in maxillofacial surgery and knowledge of anatomy. On the other hand, harvesting of significant amounts of bone from extra-oral sites increases a patient's morbidity and requires general anesthesia or deep sedation. These aspects need to be discussed with the patient who must read and sign a detailed, informed consent form in which the indications, advantages, disadvantages, potentials and limits, as well as alternatives, must be thoroughly described.

Le Fort I osteotomy with interpositional bone grafts

The use of Le Fort I osteotomy was originally conceived in orthognathic surgery for the correction of class III skeletal malocclusion because it allows movement of the entire maxillary arch in the anterior-posterior, vertical and transverse planes until a class I occlusion is achieved (sometimes in association with sagittal osteotomies of the mandible). In the case of severe atrophy of the edentulous maxilla (class VI according to the Cawood & Howell classification) (19), the residual ridge may present not only insufficient

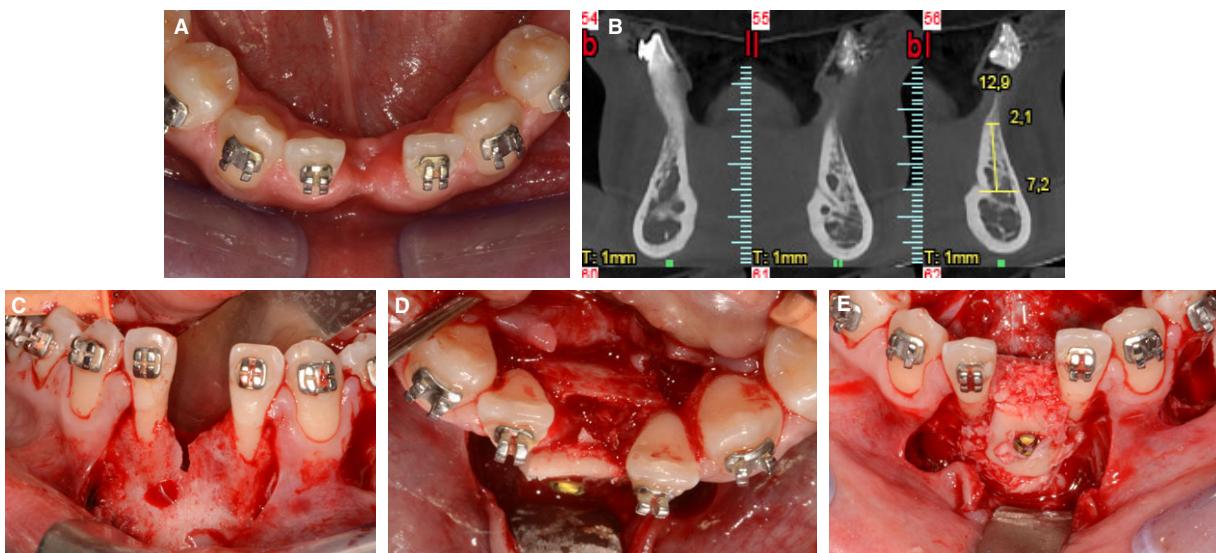


Fig. 43. A previous implant failure left an atrophic knife-edge edentulous crest with a trespassing defect (A, B). The missing buccal and lingual bony walls were re-created with two block grafts harvested from the mandibular ramus and the empty space was filled with autogenous particulate bone (C–E).

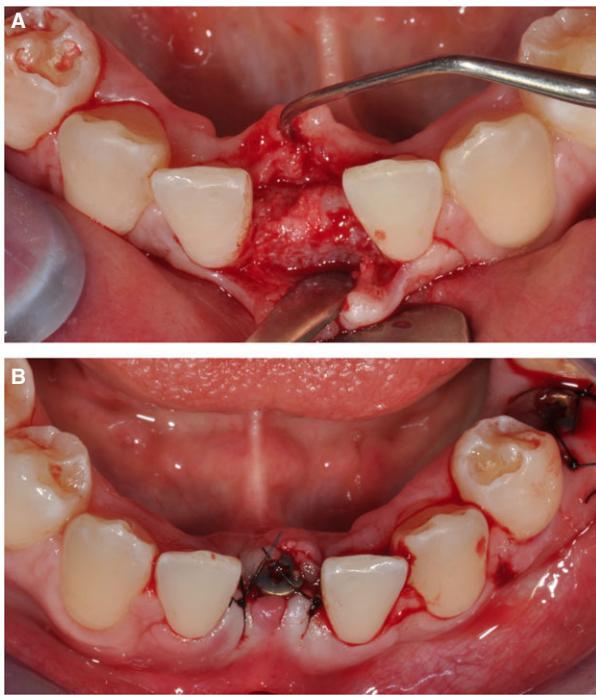


Fig. 44. After a period of healing of 6 months the graft was perfectly integrated (A) and an implant could be placed (B).

bone volume to host implants but also an unfavorable vertical, transverse and sagittal interarch relationship as a result of the tridimensional resorption pattern of long-standing edentulism. Finally, maxillary sinus pneumatization may further reduce the bone volume available for safe and reliable implant placement. In such a situation, even autogenous onlay bone grafts, in association with bilateral sinus grafting procedures (27, 34), may be insufficient/inadequate as a reconstructive procedure. Onlay grafts may create adequate volume for implant placement but they may be insufficient in recreating the correct intermaxillary relationship, thus jeopardizing the final outcome both

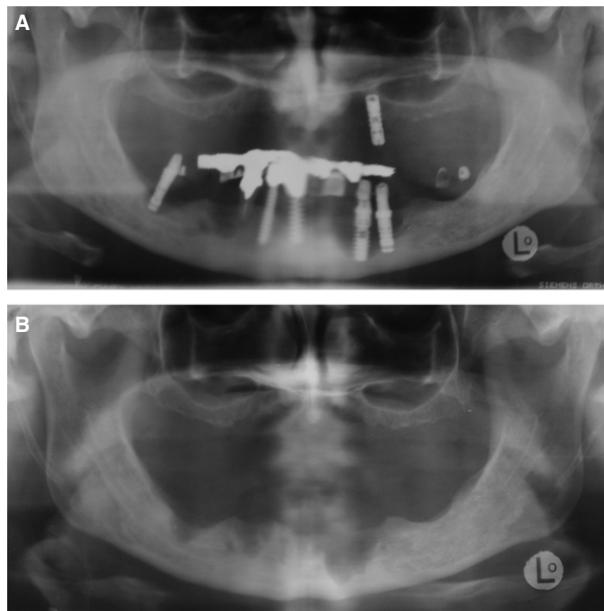


Fig. 46. Failure of a previous, severely inadequate implant-supported rehabilitation followed by chronic peri-implant infection, loss of integration of the majority of implants (initially 12 in the maxilla and 10 in the mandible) and an extreme degree of bone loss in both jaws (A). After the removal of all residual implants and a 3-month healing phase, a severe bone deficit involving both the maxilla and the mandible was present, thus rendering implant placement impossible, as demonstrated by the computerized tomography scans (B).

from an esthetic and a functional viewpoint. In such a situation, Le Fort I osteotomy along with autogenous interpositional bone grafts allow forward and downward repositioning of the maxilla, thereby simultaneously correcting intermaxillary vertical, anterior-posterior and transverse discrepancies. At the same time, the interpositional bone grafts (inlay nasal and maxillary sinus grafts) allow enough bone-volume augmentation to embed implants of adequate dimensions (25, 50, 58, 65, 76, 80).



Fig. 45. Clinical and radiographic appearance of the treated area after the final prosthetic rehabilitation demonstrated good integration of the crown (A) and the implant (B) in the surrounding tissues. (Bone augmentation and implant surgery, Dr Matteo Chiapasco; prosthetic rehabilitation, Dr Paolo Casentini.)

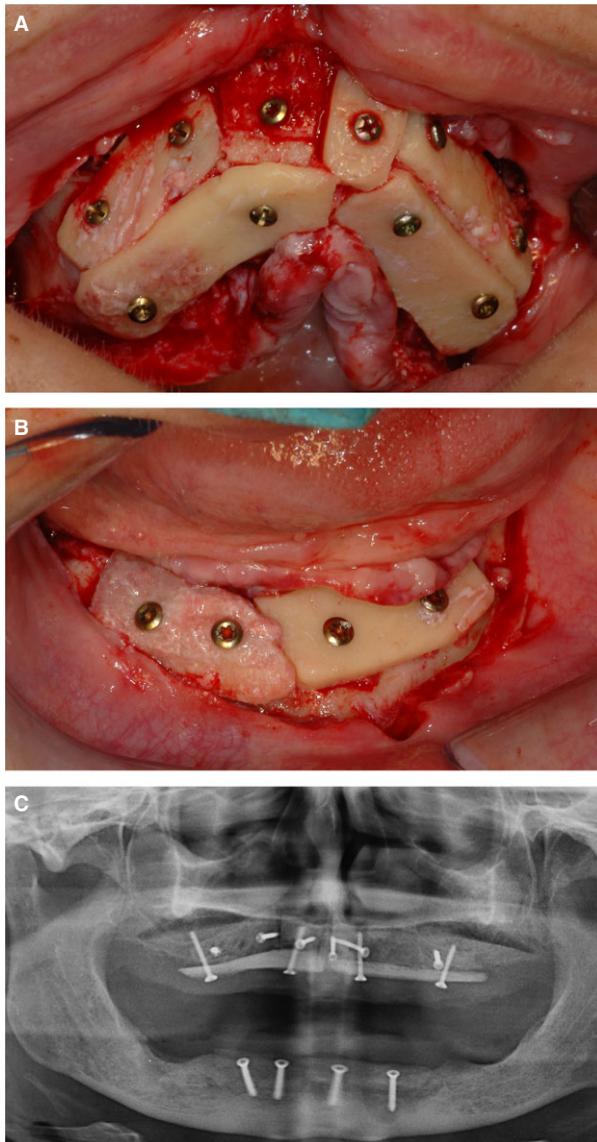


Fig. 47. A three-dimensional bone reconstruction was performed with bone blocks harvested from both the calvarium and the iliac crest and stabilized with titanium screws (A, C). At the same time, sinus floor elevation and grafting was performed on both maxillary sinuses (B).

Indications

Le Fort I osteotomies with interpositional autogenous bone grafts are indicated in cases of severe atrophy of the edentulous maxilla (class 4: advanced horizontal atrophy with a vertical component), such that the maxilla appears retruded compared with the mandible (Fig. 51A–C). In this situation, even with ‘thick’ onlay grafts, it is impossible to restore adequate sagittal intermaxillary relationships (Class I intermaxillary relationship). Grafting alone could lead to a situation where there is sufficient bone volume to place implants but not in a prosthetically driven position.

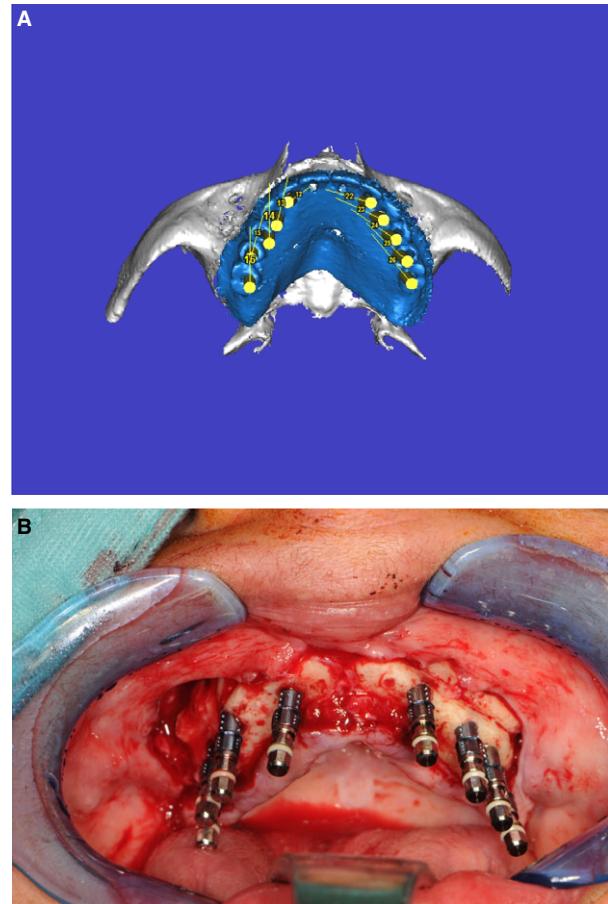


Fig. 48. After a 6-month healing period, planning software was used to aid implant placement (A). Eight reduced-diameter implants were placed in the maxilla and five were placed in the mandible (B), utilizing a computer-guided surgical procedure by means of a bone-supported guide.

Severe horizontal alveolar atrophy is often associated with severe vertical resorption with such an increased intermaxillary distance to render a prosthetic restoration supported by implants difficult to accomplish. Le Fort I osteotomy with interpositional bone grafts, taken from the iliac crest, may allow simultaneous correction of the horizontal and vertical intermaxillary relationships as well as allow the increase in bone volume to enable implant placement in a prosthetically driven position.

Surgical recommendations

Every bone-augmentation procedure should be based on accurate, prosthetically driven treatment planning (Fig. 52). The patient is always treated under general anesthesia with nasotracheal intubation. The procedure starts with harvesting of a bicortical bone block from the anterior iliac crest which is used in the reconstruction of the anterior and posterior maxilla. Surgical access is then closed in layers after adequate

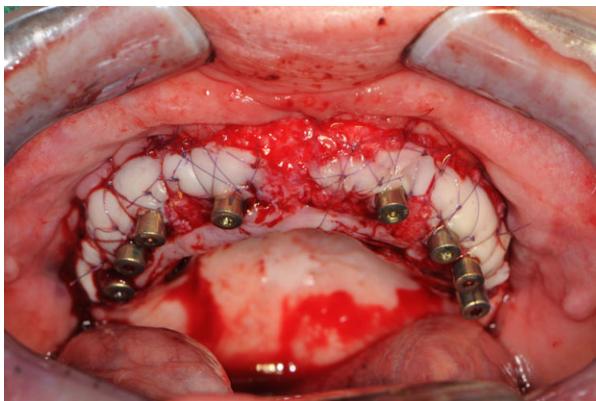


Fig. 49. After 3 months of further healing, a vestibuloplasty with mucosal grafts taken from the palate was performed to improve the quality of peri-implant soft tissues. After another 2-month healing period, abutments were connected and provisional prosthetic rehabilitation was started.

hemostasis and positioning of a vacuum drain. A midcrestal incision from the molar area on one side to the molar area on the opposite side is outlined and a full-thickness flap is elevated until the whole maxilla is exposed. The nasal floor and the lower margin of the nasal walls are identified and a subperiosteal dissection of the nasal mucosa is performed. The posterior part of the maxilla on both sides is exposed until the pterygoid-maxillary sutures are identified. Then a 'classical' Le Fort I osteotomy is performed using oscillating saws or piezoelectric instruments and fine chisels. Bone cuts include the anterolateral wall of the maxilla, the medial sinus walls, the nasal septum and the maxillary-pterygoid sutures. Whenever possible, the sinus mucosa is left intact, although this is not mandatory and not performed by many surgeons. The maxilla is then mobilized and brought downward and forward; the degree of these movements is dictated by the surgical template previously created on study casts (Fig. 53A,B). The autogenous bone block,



Fig. 50. (A, B) After 6 months the final prosthesis was delivered. Despite the significant bone reconstruction, the definitive rehabilitation required the use of a certain amount of pink porcelain to re-establish correct esthetics and function. (Bone augmentation, Dr Matteo Chiapasco; implant surgery, Dr Matteo Chiapasco & Dr Paolo Casentini; peri-implant soft-tissue management, Dr Matteo Chiapasco & Dr Paolo Casentini; prosthetic rehabilitation, Dr Paolo Casentini.)

taken from the anterior ilium, is then cut into pieces and shaped to fit into the anterior and lateral parts of the down-fractured nasal floor and maxillary sinuses. Two blocks are used – one on each side – as interpositional grafts for the reconstruction of the posterior maxilla, and one block is used in the anterior maxilla.

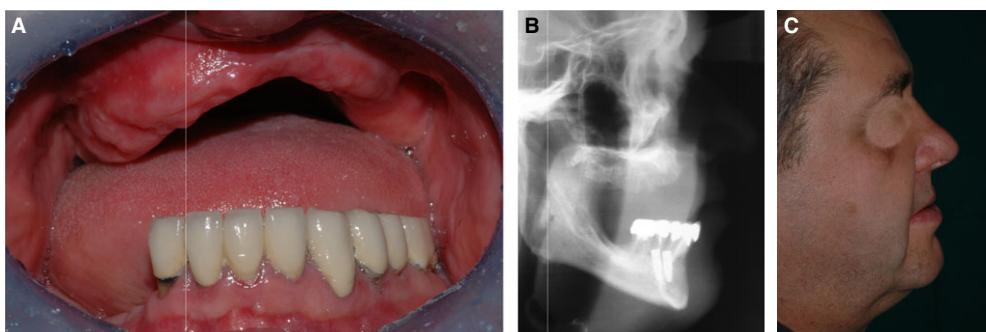


Fig. 51. (A–C) Extremely atrophic edentulous maxilla (class 4) with maxillary retrusion as a result of severe horizontal atrophy along with vertical resorption. Even after bony reconstruction, the maxilla would still be too retruded to allow an adequate, prosthetically driven prosthetic restoration, indicating the need for a Le Fort I osteotomy.



Fig. 52. Impressions are taken and plaster casts are mounted on an articulator. The severe retrusion of the edentulous maxilla is clearly visible. The ideal position of the dental arch in the edentulous area is simulated with a wax-up and, on the basis of this, a surgical template is constructed. With this information, advancement and lowering of the maxilla is simulated until the maxilla is in contact with the template, simulating its final position after surgery.

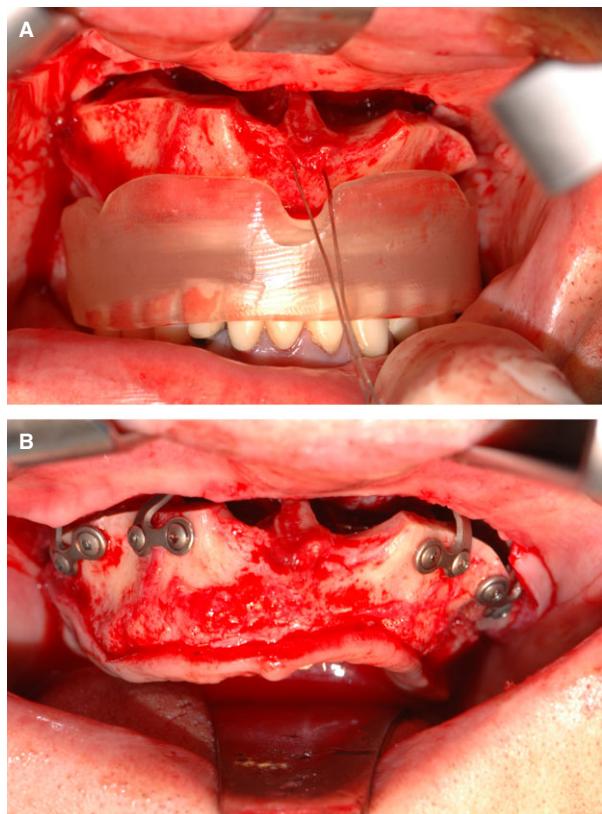


Fig. 53. Following a midcrestal incision involving the maxillary mucosa from the molar area of one side to the opposite side, a full-thickness mucoperiosteal flap is raised and osteotomies along Le Fort I lines are performed. The maxilla is down-fractured and advanced according to the prosthetic plan using the surgical template (A). The maxilla is then fixed in the new position and interpositional bone grafts are placed and tension-free, primary wound closure is carried out (B).

The down-fractured maxilla and bone blocks are stabilized using titanium plates and screws and all remaining spaces between the down-fractured maxilla and the bone blocks are filled with particulate iliac bone. Periosteal releasing incisions of the flap are performed to obtain tension-free primary wound closure (Fig. 54A,B). Implants are usually placed after a 6-month healing period, using the surgical template and following the principle of prosthodontically driven implant placement (Fig. 55). If screws and plates used to stabilize the mobilized maxilla interfere with the placement of implants, they should be removed (Fig. 56A–C).

Benefits and limitations

Le Fort I osteotomies, in association with interpositional autogenous bone grafts, are well-documented techniques (20, 25, 54, 58, 65, 71, 76, 80), although the number of cases treated and available literature are by far less than those related to autogenous bone grafts followed by implant placement. This technique allows correction of severe intermaxillary discrepancy

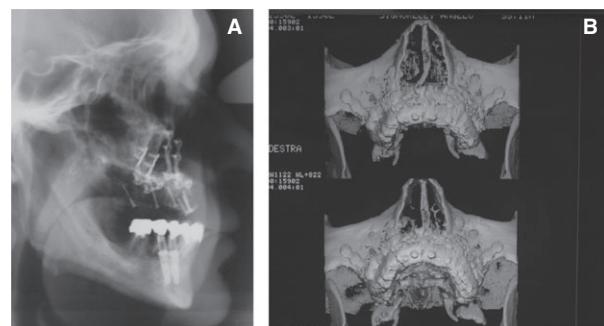


Fig. 54. (A, B) Postoperative radiographs clearly show the bone gain obtained and the correction of the horizontal retrusion of the maxilla, recreating a class 1 intermaxillary relationship.



Fig. 55. Six months after the reconstruction, implants are placed in the reconstructed maxilla using the surgical template.

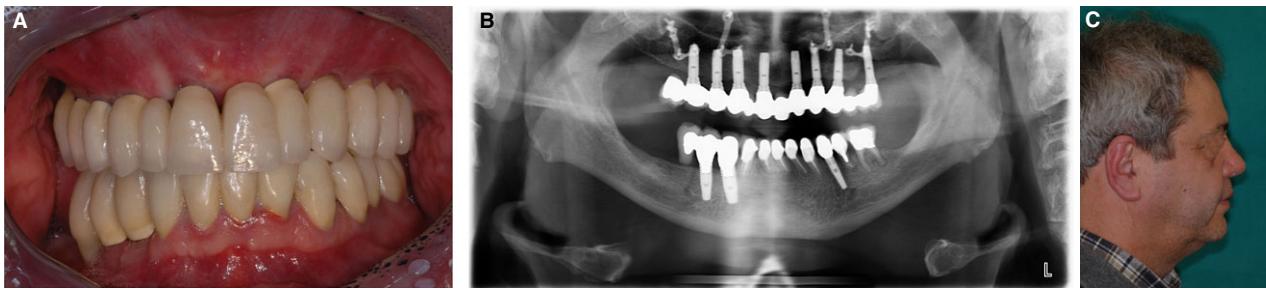


Fig. 56. Clinical (A) and radiographic (B) appearance of the treated area, after the definitive prosthetic rehabilitation, demonstrates an excellent result from a prosthetic and functional point of view as well as a major improvement in the facial profile of the patient (C). (Bone augmentation and implant surgery, Dr Matteo Chiapasco.)

associated with extremely atrophic edentulous maxillae with re-creation of adequate bone volume to allow placement of implants in an ideal position from esthetic and functional points of view. Maxillary advancement and lowering allows also significant improvement of facial and peri-oral soft-tissue support, with a general 'rejuvenation' of the facial appearance. The main drawbacks of this technique, compared with the others discussed previously, are: (i) more severe postoperative morbidity, mainly temporary gait/ambulation problems as a result of harvesting bone from the anterior ilium; (ii) longer surgical times and need for general anesthesia; and (iii) necessity of expertise in orthognathic surgery. Therefore, this technique should be limited to extremely atrophic edentulous maxillae in which bone grafts alone are insufficient in allowing adequate correction of the bone defect and the unfavorable intermaxillary relationships.

Conclusions

In the last 30 years, osseointegrated implants have transformed the possibilities of prosthetic rehabilitation of partially and completely edentulous patients with very encouraging long-term results. However, the initial 'pioneering' concept of implant-borne prostheses, using the residual available alveolar bone as a 'pure anchorage' to support prosthetic restorations, often led to less than ideal results from a functional and, in particular, esthetic point of view. Over the years, the concept of 'prosthetically driven' implant dentistry has gained credibility and is now considered the gold standard in such treatments. This concept is particularly important in situations in which the residual bone, as a result of atrophy, sequelae of periodontal disease, trauma, etc. is reduced in volume in the horizontal and/or vertical dimension.

Regarding horizontal alveolar defects, although reduced-diameter implants are available and may

allow acceptable prosthetic results, the present trend is to re-create, where possible, ideal conditions in terms of bone volume and surrounding soft-tissue quality (presence of adequate amounts of keratinized mucosa). The approach of prosthetically guided regeneration, presented in this article, allows for the reconstruction of lost alveolar and soft-tissue contours as well as implant placement in positions to permit prosthetic restorations that are optimal from a functional and esthetic viewpoint.

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