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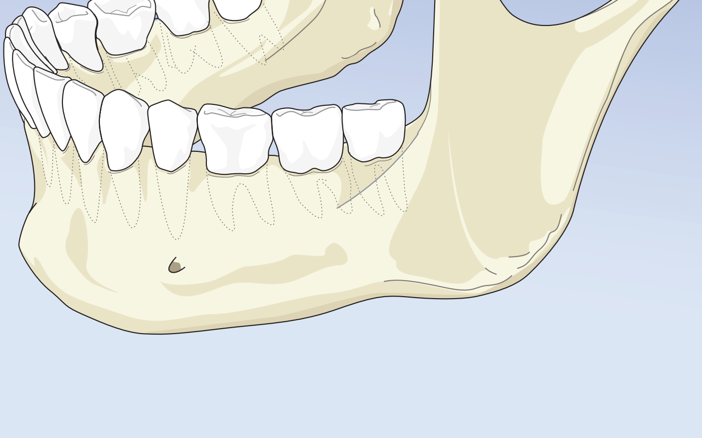
2 Mandibular fractures



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Authors Michael Ehrenfeld, Joachim Prein

2.1 Symphyseal and parasymphyseal fractures

1 Anatomy and definition

The symphysis of the mandible is defined as the region between the roots of the central incisors, and the parasymphysis as the region between the lateral roots of the canines and the central incisors. Together they can be referred to as the chin or mental region (**Fig 2.1-1**).

This region is characterized by very vascular bone whose blood supply comes from the lingual side of the chin via the attached lingual and sublingual muscles. In addition terminal branches of the lingual artery may enter the bone directly. Under masticatory load rotational forces may occasionally be observed in this particular region; this must be considered when internal fixation is performed.

Linear and oblique fractures are the characteristic injury in this region. Comminution or bone loss is relatively rare. Occasionally, there is an inferior butterfly fragment which, if large, may involve the insertion of the suprahyoid musculature, and usually is associated with high-energy trauma seen in high-speed injuries such as motor-vehicle accidents and gun shots.

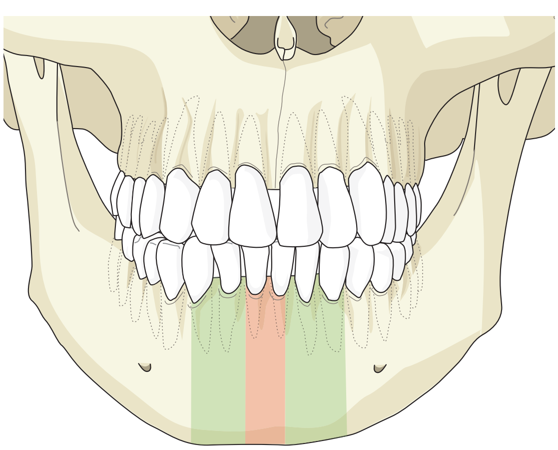


Fig 2.1-1 Anatomy of the symphysis (red) and parasymphysis (green).

2 Imaging

X-rays in two planes, such as an orthopantomogram (OPT) and a Clementschitsch view, are sufficient (**Fig 2.1-2 a–b**). A panorex view tends to blur the center (symphysis section), whereas a CT is the only image giving a clear picture of both

Fig 2.1-2a–b
a Orthopantomogram (OPT) of a midline fracture.
b X-ray according to Clementschitsch with subcondylar fracture on the left.

cortices (**Fig 2.1-3**). In cases where a CT scan of the head has to be taken because of additional injuries, axial scans are usually sufficient and can be used instead of plain films.

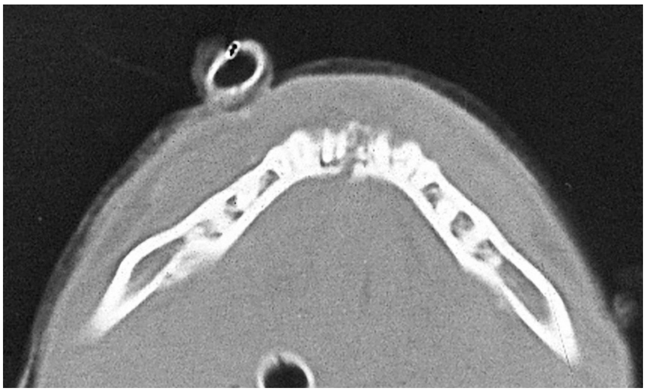


Fig 2.1-3 CT of a midline fracture.

3 Surgical approaches

Typically, a transoral approach is used, however, under special circumstances a transcutaneous approach should be considered.

The standard approach to the chin area is via a transoral vestibular approach. In dentate patients the incision line usually lies in the mobile gingiva at a distance of 8–10 mm to the junction between attached and mobile mucosa (**Fig 2.1-4**). In edentulous patients a crestal incision is preferred. Initially, a smaller incision from canine to canine is made. Some surgeons prefer to cut through the mucosa, underlying facial muscles and periosteum right to the bone, others prefer to mobilize the mucosa first and to incise muscles and periosteum on a different level (**Fig 2.1-5a–b**). From the central smaller incision the more lateral soft tissues can be elevated subperiostally to identify the mental nerves and mental foramina. Then the cut can be extended laterally without major risk of permanently damaging the mental nerve. The complete labial surface of the chin including the inferior mandibular border may be exposed via this approach. However, this approach does not permit visual control of the lingual cortex. Consequently, under some circumstances an external approach should be considered.

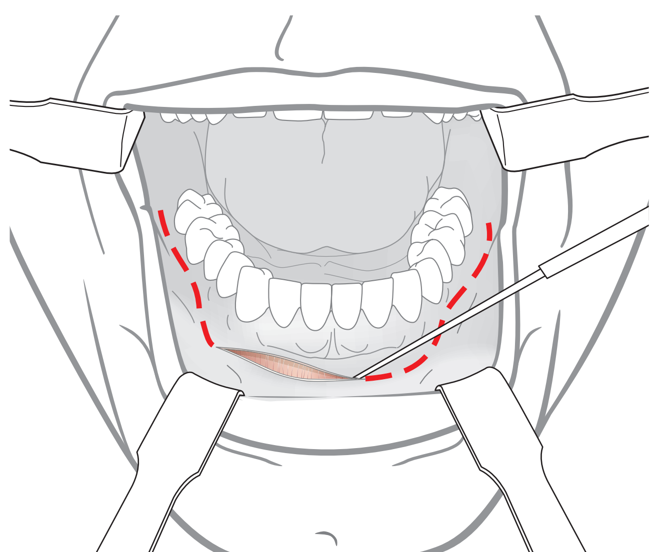


Fig 2.1-4 Incision line for a transoral vestibular approach (incision with an electric needle).

Transcutaneous approaches may also be considered in cases of preexisting lacerations in the chin area. From time to time they are indicated when significant comminution or bone loss is present. In rare cases they are performed secondary to a transoral approach, when the repositioning is difficult and the lingual aspect has to be visualized. A planned transcutaneous incision is performed in the submental area taking the relaxed skin tension lines into account. An isolated submental incision can also be made in a curved line directly posterior to the border of the mandible. Care must be taken not to extend it too laterally in order to avoid damage to the marginal branch of the facial nerve. In cases when a more extended submandibular approach is required an incision in the submandibular fold is recommended (**Fig 2.1-6**).

Transoral and transcutaneous approaches are always closed in layers with resorbable or nonresorbable suture material (skin and mucosa only) depending on the surgeon's preference. It is important to repair the transected mentalis muscle with meticulous suturing to avoid a drooping chin.

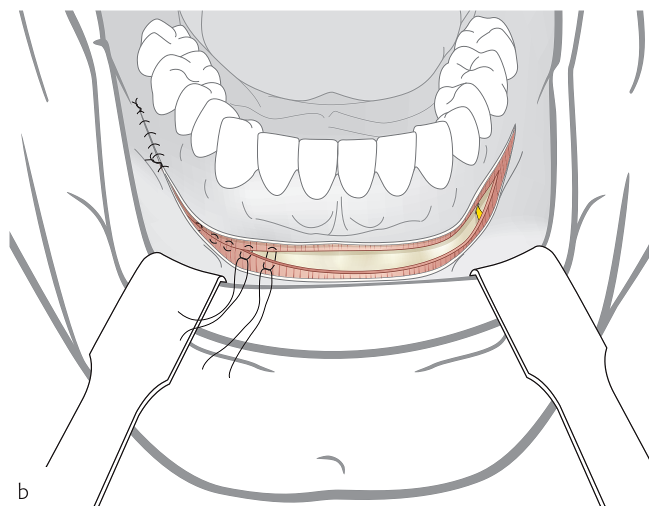


Fig 2.1-5a–b
a Stepwise incision through the mucosa first, followed by the incision through the muscles and the periosteum.
b Two-layer wound closure for muscle and mucosa.

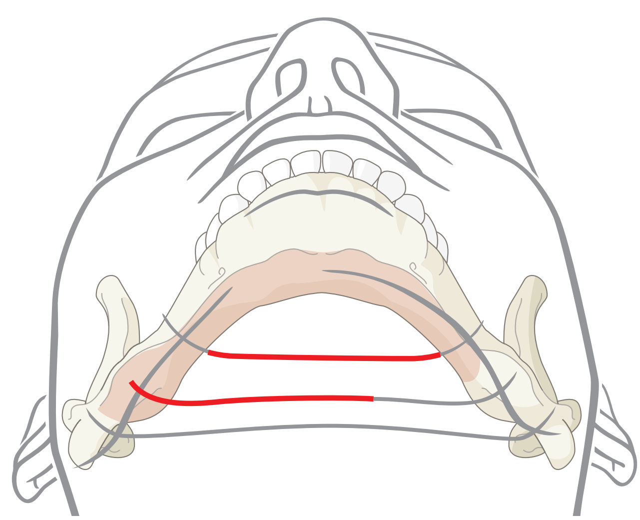


Fig 2.1-6 Incision lines for transcutaneous approaches following skin creases.

4 Osteosynthesis techniques

In healthy bone, fractures in the symphyseal and parasymphyseal region can be successfully treated with a variety of options. These include miniplate, compression plate, or lag screw osteosynthesis. Multifragmentary, defect, and infected fractures as well as fractures of an atrophic mandible should be treated with reconstruction plates according to the techniques described in chapter 2.4 (Fractures in bone of reduced quality). In nondisplaced and nonmobile fractures, nonsurgical therapy may occasionally be considered.

Before internal fixation with plates and screws is performed, mandibulomaxillary fixation (MMF) should be applied with arch bars or splints. IMF screws can also be used.

Fragment reduction in the chin area can be performed manually, with the help of reduction forceps, or with a positioning wire.

4.1 Plate osteosynthesis

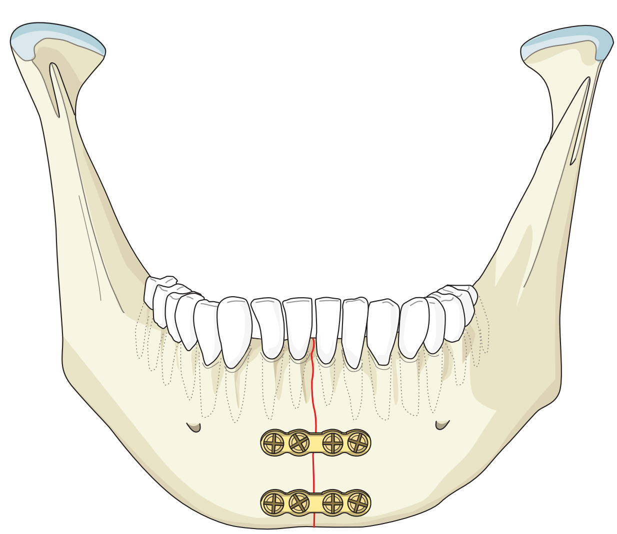
Miniplate osteosynthesis is probably the technique most frequently applied for these fractures worldwide. The standard technique involves the placement of two miniplates 2.0 or corresponding plates from the Matrix system with 4 or 5 holes. One plate is placed directly above the inferior border, the second plate is placed considerably higher in the central portion of the mandible underneath the tooth roots (**Fig 2.1-7a**). Both locking and nonlocking plates can be used.

One plate is bent and contoured to the bone surface first. This plate may be placed either at the upper or lower border.

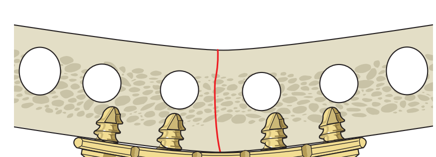
In bilateral subcondylar fractures in combination with a midline fracture, pressing on the angles and upper ramus bilaterally creates a gap in the labial cortex. The lingual cortex of the mandibular fracture is approximated and the width of the mandible is corrected.

The screw fixation for the superior plate is always monocortical to avoid damage to tooth roots (**Fig 2.1-7b**). For the inferior plate fixation both monocortical and bicortical screw placement is possible.

Miniscrews are inserted monocortically (without pretapping) in the self-tapping mode. If screws are inserted bicortically, pretapping reduces the torque. Without pretapping, there is a risk of fracture or sheering of screw heads when using miniscrews.



a



b

Fig 2.1-7a–b
a Standard technique in plate osteosynthesis of the chin involves two 4- or 5-hole miniplates 2.0.
b The screw fixation for the superior plate is always monocortical to avoid damage to tooth roots.

4.2 Compression plate osteosynthesis

Compression plates in the chin area can be placed in the center of the symphysis at a safe distance from the tooth roots. Biomechanically, one compression plate in the center (neutral zone) of the mandible is sufficient to neutralize all forces within a normal range. In this area a 4-hole compression plate is usually used, either a limited contact dynamic compression plate (LC-DCP) 2.4, a universal fracture plate 2.4, or a compression plate from the Matrix Mandible system. The use of a tension band splint or at least a bridal wire is strongly recommended to neutralize distraction forces at the superior border of the mandible (**Fig 2.1-8**).

Alternatively, if placement of a tension band splint is not possible or not acceptable, a compression plate osteosynthesis can be performed in a 2-plate technique. In a 2-plate compression osteosynthesis one miniplate is used as a tension band plate directly underneath the apices of the front teeth. The second plate is a compression plate which is placed close to the lower border of the mandible (**Fig 2.1-9**). After reduction the tension band plate is applied first, usually with monocortical screw placement. Then the compression plate is inserted.

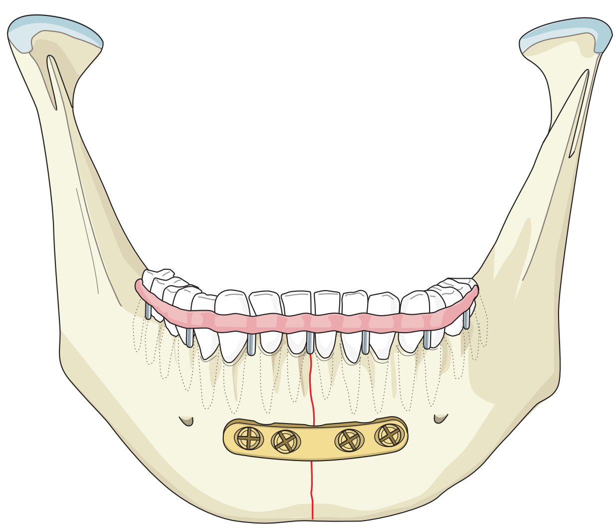


Fig 2.1-8 Compression plate osteosynthesis with an LC-DCP and a tension band splint.

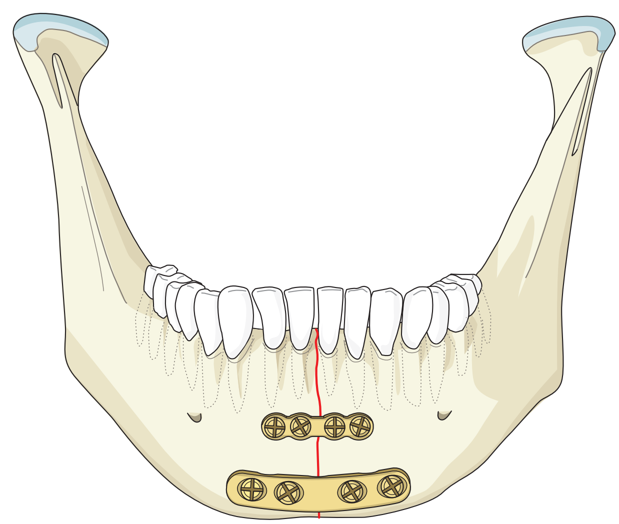


Fig 2.1-9 Compression plate osteosynthesis with an LC-DCP and a 4-hole miniplate as tension band.

A compression plate is primarily contoured to the bone surface, but must then be slightly overbent to avoid lingual gap formation during tightening of the screws. Only one screw on each side of the fracture line is placed in an eccentric manner to exert compression at the fracture surface. The compression screws are inserted eccentrically toward the outside of the plate holes with the help of a drill guide (**Fig 2.1-10a–b**). After screw placement, the compression screws are alternately tightened applying compression at the fragment interface. The remaining screws are inserted in a neutral fashion toward the inside of the plate holes, again with the help of a drill guide (**Fig 2.1-11a–b**).

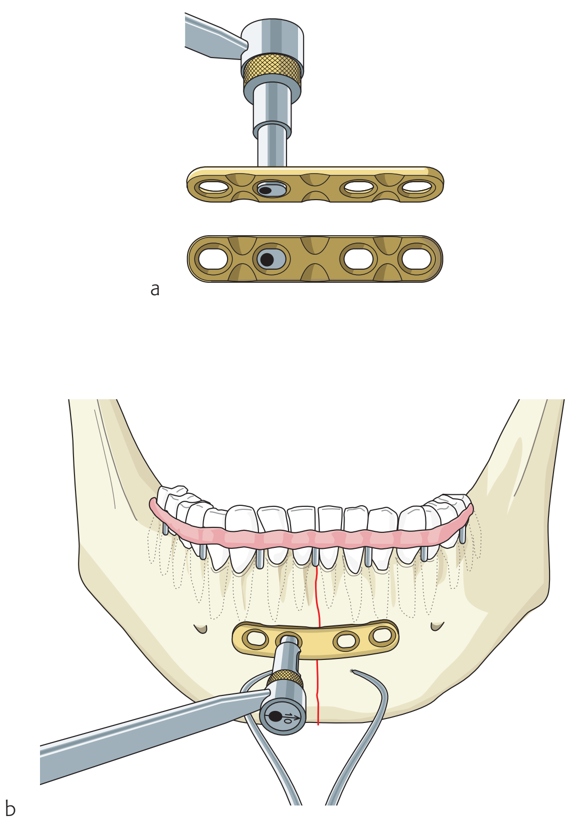


Fig 2.1-10a–b Eccentric screw placement into the oval-shaped plate hole of a DCP on either side of the fracture. The arrow on the drill guide is pointing towards the fracture line. The eccentric drill guide has a golden marker band. Alternative tightening of the screws leads to compression of the fracture.

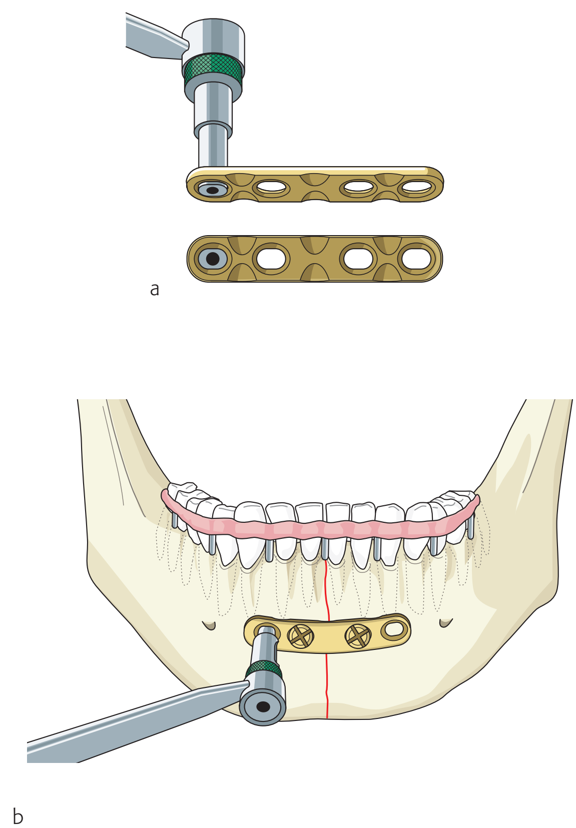


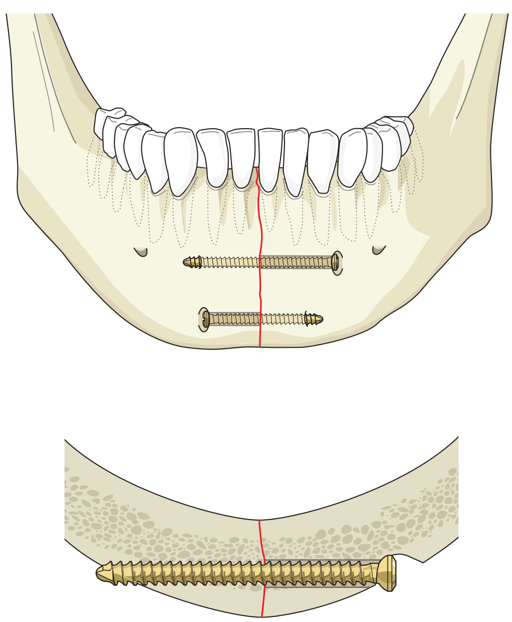
Fig 2.1-11a–b Neutral screw placement in the outer holes after tightening of the inner screws. The neutral drill guide has a green marker band.

4.3 Lag screw osteosynthesis

Lag screw osteosynthesis is another type of compression osteosynthesis. Typically two 2.4 mm lag screws are used to avoid torsion and for better stability, but one 2.4 mm lag screw in combination with a tension band splint can be sufficiently rigid.

If two lag screws are used, one screw is placed at the inferior border while the second screw is placed a few millimeters superior to the first screw at a safe distance from the tooth roots (**Fig 2.1-12a–b**).

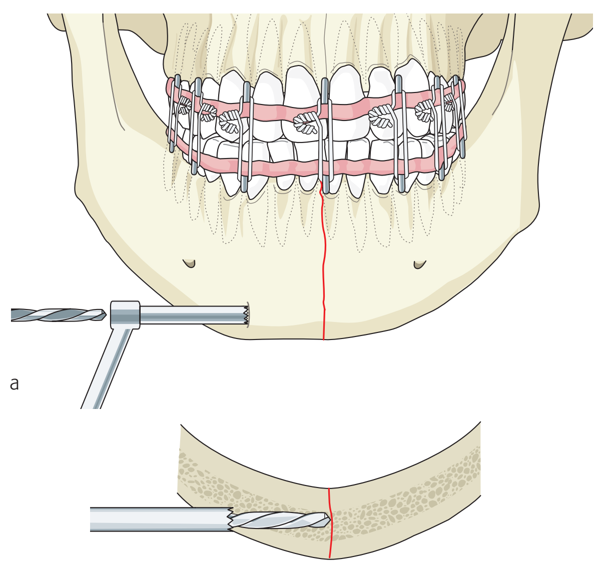
First the fragments are reduced. The gliding hole for the first screw is drilled using a 2.4 mm drill bit and a 2.4 mm drill guide for soft-tissue protection (**Fig 2.1-13a–b**). The gliding hole only penetrates the proximal fragment. It ends at the fracture surface, creating a canal in which the screw glides. After completion of the gliding canal, a second canal in the opposite fragment is drilled using a 1.8 mm drill bit and a 1.8 mm drill guide.



a

b

Fig 2.1-12a–b
a Position of two horizontal lag screws.
b With this technique the screw thread engages only the opposite fracture fragment in the far cortex.



a

b

Fig 2.1-13a–b The gliding hole is drilled to the same diameter as the outer thread diameter of the screw (2.4 mm) using a 2.4 mm drill guide.

A 1.8 mm drill guide is inserted into the gliding hole to determine the correct direction for drilling (**Fig 2.1-14a–b**). The depth is measured with a depth gauge, then the 1.8 mm canal is tapped (**Fig 2.1-15a–b**). The cortical bone on which the screw head is going to engage is countersunk to allow the screw head to snuggly fit onto the bone, thus avoiding microfractures within the cortical layer during tightening and reducing palpability (**Fig 2.1-16a–b**). Finally, the first screw is inserted and fully tightened. The second screw is inserted using the same technique. It can be placed in the same direction or from the opposite side. It does not matter which screw is inserted first but the second hole must be drilled only after the first screw is tightened.

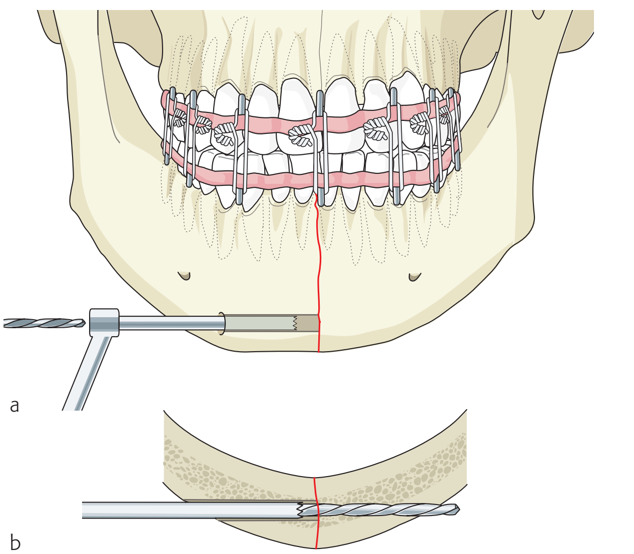


Fig 2.1-14a–b The traction hole is drilled to the same diameter as the core of the screw (1.8 mm) using a 1.8 mm drill guide.

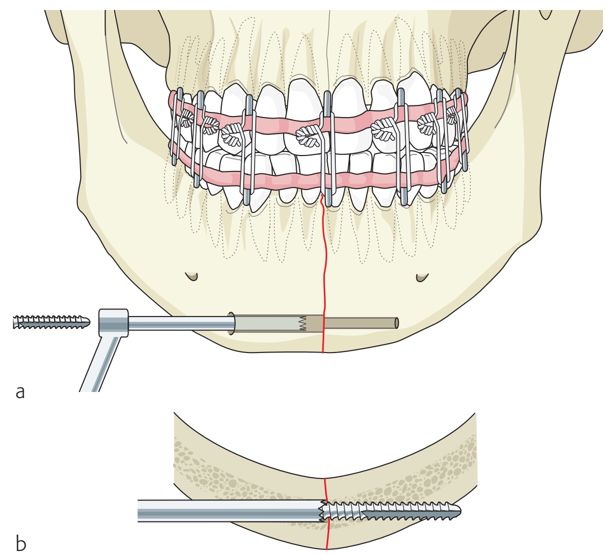


Fig 2.1-15a–b The traction hole is tapped.

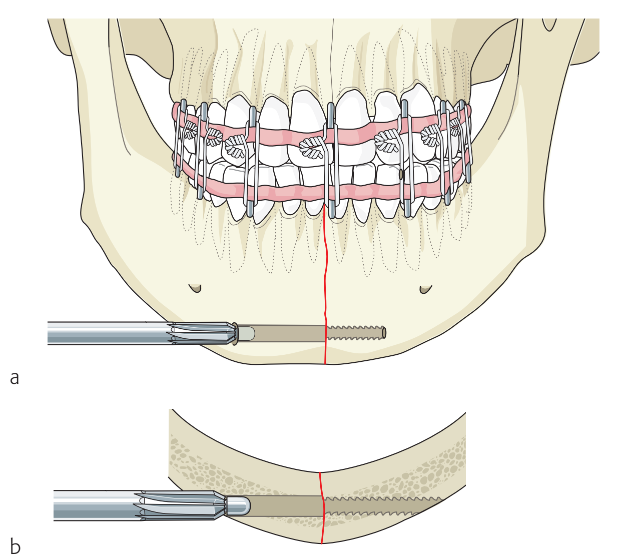


Fig 2.1-16a–b Countersinking for the screw head.

5 Perioperative and postoperative treatment

Miniplate osteosynthesis in the mandible is commonly addressed as being semirigid. The patients are allowed to fully function passively (unrestricted mouth-opening). They are not put into MMF, unless other injuries or special circumstances should require it. A soft diet for approximately 4 weeks postoperatively is recommended. In this period full masticatory function without any restrictions must be avoided. Compression plate osteosynthesis and lag screw osteosynthesis are functionally stable, and a soft diet is not necessary.

Perioperative antibiotics can be considered, but are not needed unless the fracture area shows primary signs of infection or contamination, eg, with foreign bodies.

It is strongly recommended to tape the soft tissues of the chin area for 2–3 days to avoid significant swelling that may lead to dehiscence and secondary soft-tissue healing (**Fig 2.1-17**). MMF for a few days can also be used to immobilize the soft tissues.

Fig 2.1-17 Tape dressing of the chin area is recommended for 2–3 days postoperatively.

6 Complications and pitfalls

Care must be taken to place the transoral incisions as described. A misplaced incision may lead to secondary soft-tissue healing and damage to the mental nerve.

Damaging the tooth roots must be avoided through proper screw placement. Especially in larger massive mandibles the outer contour of the alveolar sockets does not always indicate the anatomical location of the apices of the teeth. A preoperative OPT always shows the exact length of the teeth.

Symphyseal or parasymphyseal mandibular fractures in conjunction with bilateral displaced condylar fractures, particularly in combination with comminuted midface fractures, risk losing the transverse dimensions of the mandible with the result of posterior widening (flaring). In such cases it is essential to check the lingual side of the mandible after reduction and after osteosynthesis, if necessary through a transcutaneous incision.

These injuries are better fixed using longer heavy plates instead of miniplates, such as 10 to 12-hole reconstruction plates to control the width of the mandible through the angles, and lag screws may also be used. Miniplates may not be strong enough for challenging biomechanical scenarios.

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Authors Leon Assael, Brett Ueeck

2.2 Body and angle fractures of the mandible

1 Anatomy and definition

The lateral body of the mandible is defined as the portion distal to the canine (parasymphysis) but proximal to the third molar. The angle of the mandible includes the third molar region and the junction of body and ramus (**Fig 2.2-1**).

The anatomy of the mandible body and angle includes the well-defined buccal and lingual cortices, alveolar bone in the dental portion, a centrally or inferiorly located inferior alveolar canal, internally the mylohyoid ridge, and the external oblique ridge. The angle of the mandible is thinner inferiorly, with a concretion of the buccal and lingual cortex. An antegonial notch is noted anterior to the true angle of the mandible.

Muscles of the mandibular angle and body often define a fracture pattern and access incisions designed to dissect between them and elevate aponeuroses. Important muscle attachments are:

- Masseter muscle: lateral inferior border/angle attachment
- Medial pterygoid muscle: medial inferior border/angle attachment
- Temporalis muscle: coronoid process anterior border attachment
- Buccinator muscle: attachment on lateral border/external oblique ridge
- Superior pharyngeal constrictor: attachment at medial aspect of angle
- Mylohyoid muscle: attachment along the well-defined mylohyoid ridge

The lateral body of the mandible is characterized by the presence of two premolars and three molar teeth. The third molar, if still present, is often impacted, partially or fully submerged in soft tissue and bone.

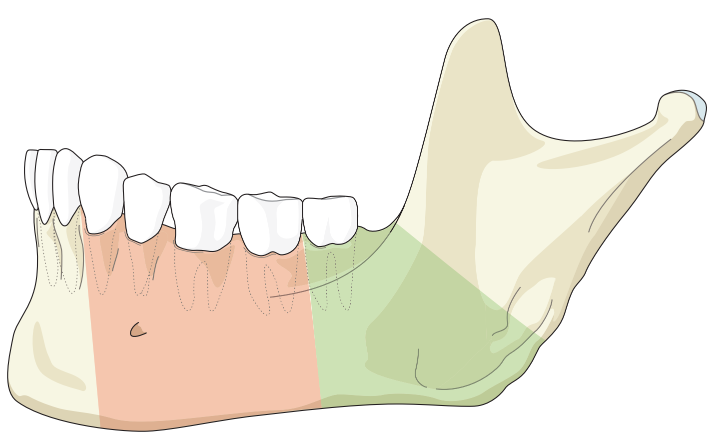

Fig 2.2-1 The lateral body of the mandible (red): distal to the canine but proximal to the third molar. Angle of the mandible (green): from the area between the third molar and the junction of the ascending ramus.

Somatosensory afferent peripheral nerves of the body and angle region are also factors to be considered in trauma and internal fixation of this region (**Fig 2.2-2**):

- Inferior alveolar nerve: contained in the inferior alveolar canal, exiting in the premolar region from the mental foramen after sending off incisive nerves to the symphysis. The mental nerve curves downward just before its exit to provide innervation of the lip, chin, and mandibular teeth.
- Lingual nerve: approximately 1–2 mm medial to the internal oblique ridge of the mandible at the angle, moving more medially into floor of the mouth and tongue. It relays sensation and taste (with the chorda tympani) to the anterior two thirds of the tongue. It is at risk during reduction and screw fixation of the superior border of the angle region.
- Long buccal nerve: sensation to the check and buccal vestibule. It crosses the anterior ramus above the angle, and is at risk during transoral incision at the angle.

Motor innervation to the region includes the motor division of the trigeminal nerve supplying the muscles of mastication, mylohyoid, and anterior belly of the digastric muscle. The facial nerve supplies the muscles of facial expression with the marginal and cervical branches in the submandibular triangle. Depressors of the lip and chin may suffer paresis if attention is not given to the marginal mandibular branch as it courses 0–10 mm beneath the antegonial notch of the angle.

2 Blood supply

While the blood supply and oxygenation to this region is generally excellent, it may be compromised due to trauma, access incisions, age, and disease. The arterial supply to the angle and body includes the periosteal plexus of vessels as well as the inferior alveolar artery. Edentulous and older patients rarely have a patent inferior alveolar artery due to arteriosclerosis and atrophy. In fracture situations this artery may often be damaged. When the periosteum is stripped, especially in multisegmented body fractures, fragments may become totally disconnected, and under this condition they can be compared with a free bone graft.

It is often challenging to close the mucosa in this region. All these factors predispose comminuted fractures to infection.

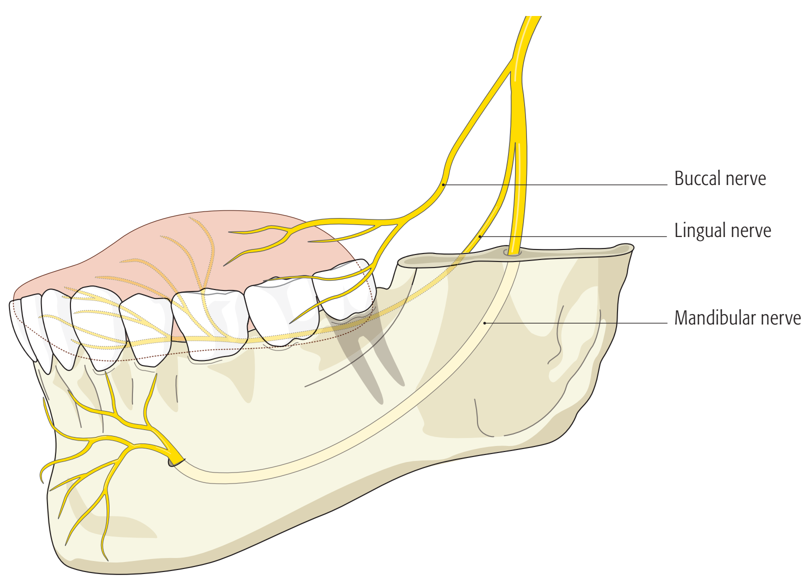

Fig 2.2-2 Somatosensory afferent peripheral nerves of the body and angle region.

3 Imaging

Two views are required, preferably at right angles, to effectively image fractures of the mandibular angle and body. The following are of value in imaging of fractures of the body and angle region:

- Orthopantomogram (OPT): the standard universal imaging method for evaluation of the mandible rarely fails to identify fractures of the angle and body. New computed OPT can offer streaming contrast and magnification potential.
- Posteroanterior view of the mandible: can identify fracture obliquity in the body and angle region.
- Lateral oblique view of the mandible: an alternative to OPT when one is not available.
- Occlusal view of the mandible: an intraoral film view where the buccal and lingual aspects of the cortex in the body and angle region may be delineated.
- Computed tomography (CT) of the mandible: axial, coronal, and sagittal views as well as 3-D reconstruction can be used to identify most fractures as well as completely delineate fracture anatomy. Rarely, CT may miss fractures due to volume averaging that are noted on OPT.

Rarely, a fracture may be missed by any x-ray technique. Fractures that are missed are nondisplaced. In this situation, the clinical signs are the only clues to identification.

4 Biomechanics

As noted in chapter 1.3.1 (Biomechanics of the craniomaxillofacial skeleton), after axial loading, the body and angle area constitute a tension zone at the superior border (dental arch), and a compression zone at the inferior border. The neutral zone lies in the center of the mandible and often corresponds to the region of the neurovascular canal. Biomechanically, the mandibular angle is a challenging region because anatomical changes from the body to ramus lead to a change of vectors during loading.

5 Fracture patterns

Fracture patterns in the mandibular body depend on the energy of the impact and vector. They may be direct or indirect fractures. They are mostly linear, sometimes with a basal wedge or oblique surface. Comminution is seen in high-energy trauma. Most fractures of the angle of the mandible occur in the location of the third molar and extend to the antegonial notch anterior to the true angle. They are often oblique, extending more anteriorly in the external oblique ridge than in the internal oblique ridge. A triangular comminution at the inferior aspect of the mandible is common.

6 Treatment planning

Access incisions and proposed methods of osteosynthesis are selected before surgery.

Managing impacted third molar

The third molar may be extracted or retained when associated with the fracture. Infected, fractured, or completely mobilized third molars should be removed either before or after reduction and stabilization, depending on the situation.

Managing inferior alveolar nerve

Preoperative neurosensory evaluation is indicated to determine whether neurotmesis might be a factor in treatment selection. Simultaneous microsurgical repair of this nerve is not commonly performed but may be considered as a treatment option.

7 Surgical approaches

Mandibulomaxillary fixation (MMF) is normally applied before surgical approach. Both transoral and transcervical approaches to the angle and body region have their utility.

For angle fractures, the standard transoral approach is a buccal vestibular incision medial to the buccal fat pad and lateral to the temporalis muscle separating buccinator fibers. If the third molar is not to be removed the incision may remain in the buccal vestibule. The incision is released into the buccal mucosa anteriorly, taking care to remain behind or above the mental nerve exit (**Fig 2.2-3**).

For fractures of the mandibular body, the transoral approach is via a vestibular incision beveled into mid root of the premolars to protect the exit of the mental nerve. Circumferential subperiosteal dissection around the mental nerve can be carried out to reveal the fracture and provide room for fixation. Marginal gingival incisions are also possible.

Transcervical access is via the submandibular standard approaches. Attention to Langer's lines of skin relaxation will permit an esthetic scar. Sharp dissection through subcutaneous tissue, platysma, superficial investing fascia, and periosteum is performed. The use of a nerve stimulator to assess and protect the marginal mandibular branch of the facial nerve may be useful. Ligation of the facial vein and/or artery is often indicated and may be helpful for protection of the facial nerve (**Fig 2.2-4a–b**).

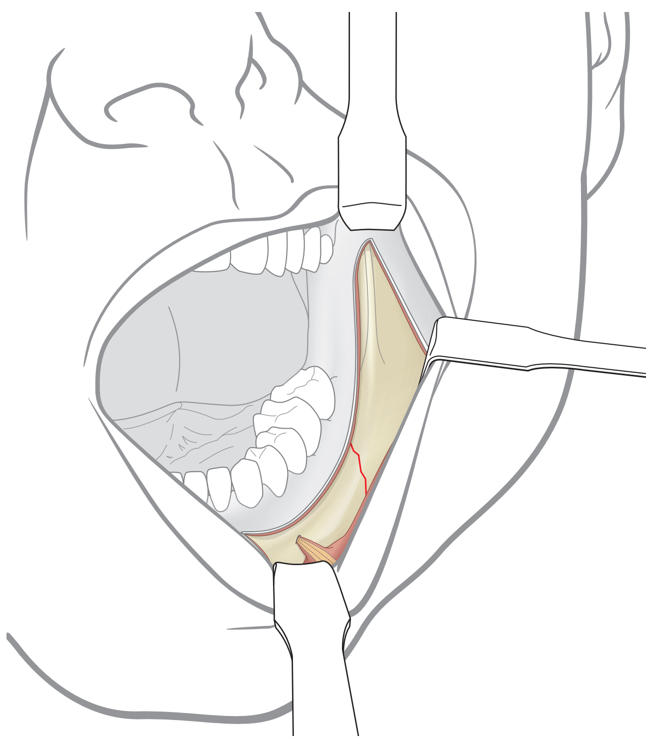

Fig 2.2-3 Transoral approach for angle fractures. The incision is released into the buccal mucosa.

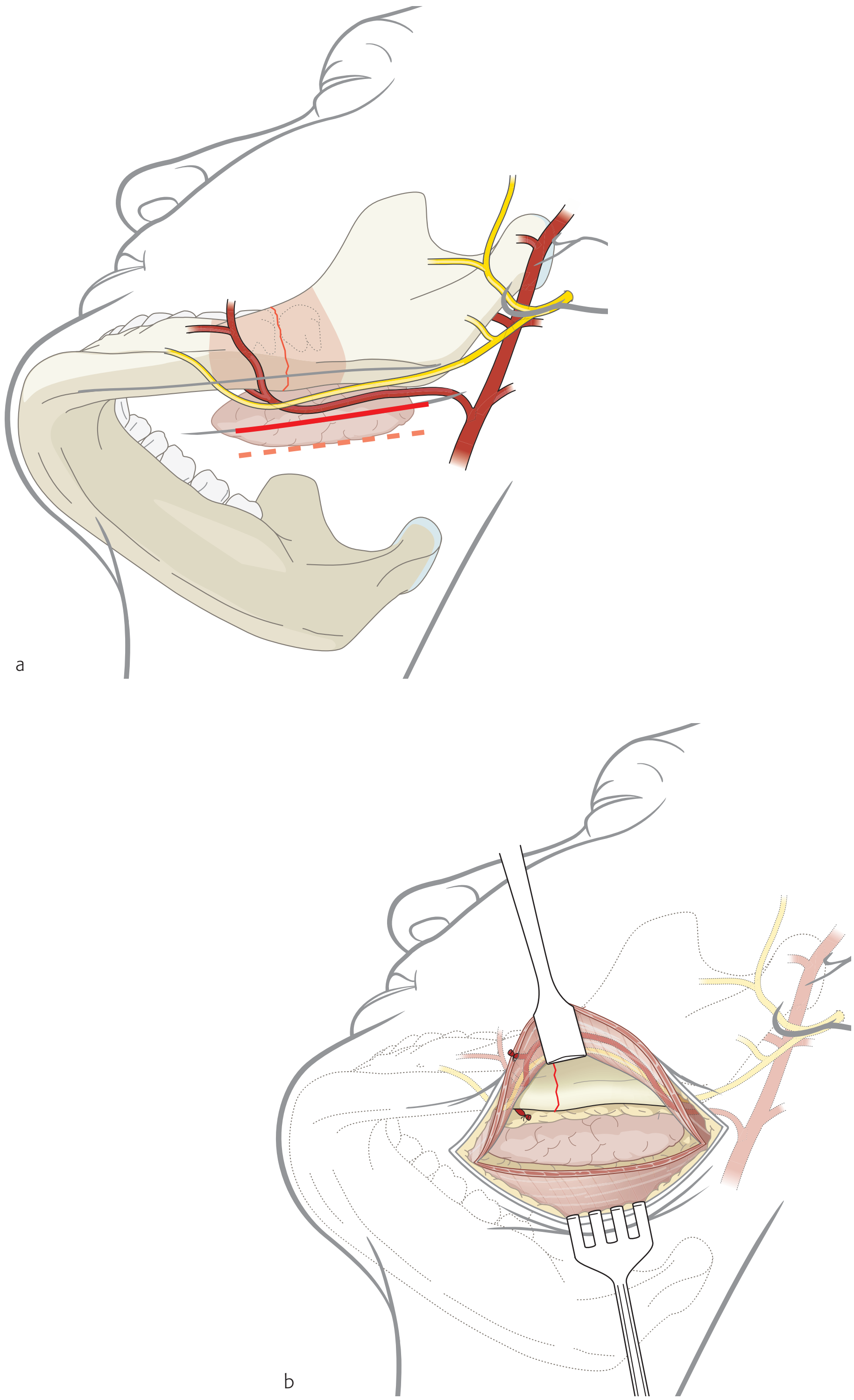

Fig 2.2-4a–b Transcervical access of the submandibular standard approach.

a Sharp dissection stepwise through skin (red line cranial), platysma, and superficial cervical fascia (dotted line caudal).

b Ligation of the facial vein and/or artery is often indicated. The bone surface is reached in a layer underneath the superior cervical fascia.

8 Osteosynthesis techniques

MMF is applied and reduction of fractures is obtained either manually or with the assistance of reduction forceps. If an arch bar is applied across a fracture in the dental segment, the diastema in the fracture site should be eliminated. This allows the arch bar to act as a tension band.

Depending on bone quality, quantity, and on special circumstances, such as comminution or bone loss, either a load-sharing or a load-bearing osteosynthesis is indicated. Load sharing can be achieved with miniplates 2.0, or corresponding plates from the Matrix Mandible system, compression plates, or lag screws.

Miniplate osteosynthesis in the lateral body is typically performed transorally with a single miniplate in the center of the mandible (neutral zone), and with screws engaging only the cortex next to the plate, ie, monocortical screw insertion (**Fig 2.2-5**). In the angle, a miniplate is typically placed in the region of the superior border (tension zone), either on the oblique ridge from a transoral approach (**Fig 2.2-6a–b**) or on

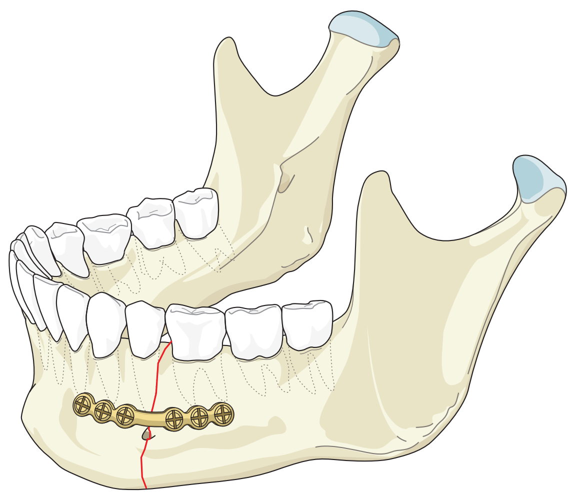

Fig 2.2-5 Transoral single miniplate fixation in the center of the mandible (neutral zone) with screws engaging only the cortex next to the plate.

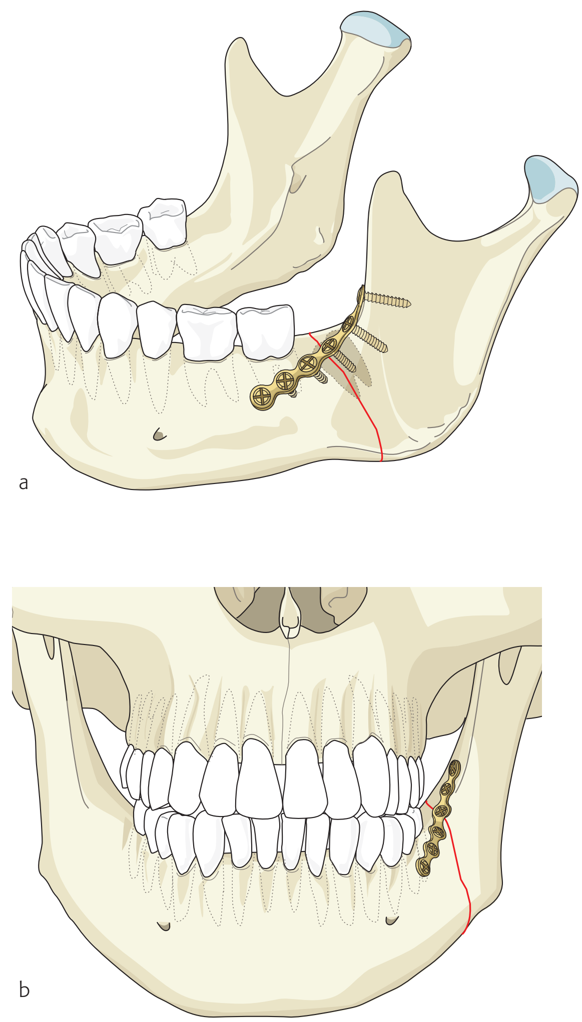

Fig 2.2-6a–b Miniplate fixation in the angle of the mandible on the oblique ridge.

the superior lateral surface of the mandible with the help of transbuccal instrumentation or an angulated screwdriver (**Fig 2.2-7a–b**). Care must be taken to avoid the roots of the teeth. Monocortical fixation permits safe placement. If a single miniplate is used it should be a 6-hole miniplate with three screws on either side of the fracture.

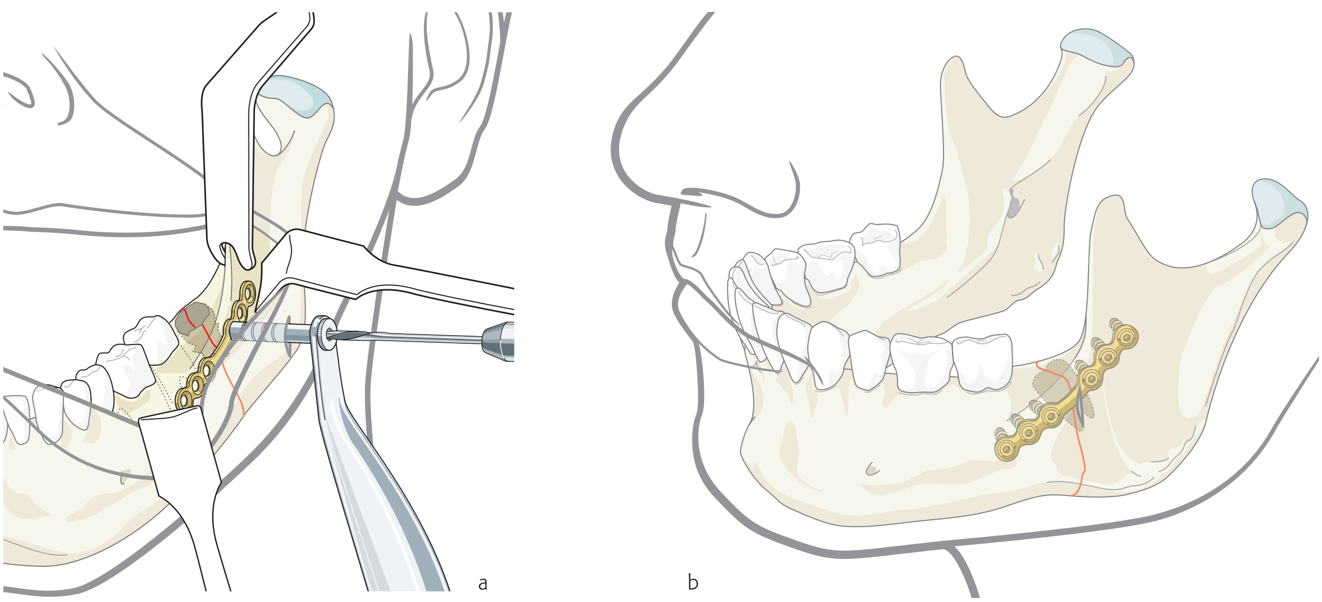

Fig 2.2-7a–b Miniplate fixation on the superior lateral surface of the mandible with the help of transbuccal instrumentation.

In case of reduced bone buttress, for instance after wisdom tooth removal, some surgeons prefer using two miniplates, one at the superior and one at the inferior border of the mandible, with a minimum of two screws on either side of the fracture (**Fig 2.2-8**, **Fig 2.2-9**). Miniplate fixation alone is generally adequate for well-buttressed fractures of the angle and body. A well-buttressed fracture has no comminution and there is adequate contact of good bone at the fracture site. Chewing may cause a reversal of forces resulting in an opening of the inferior border if only the superior border is stabilized with a tension band. Using a plate of sufficient stiffness will mitigate this effect.

If greater stability is required, a load-sharing compression plate osteosynthesis can be performed with either an LC-DCP 2.4, a universal fracture plate 2.4, or corresponding plate from the Matrix Mandible system. Compression plate osteosynthesis is performed at the inferior border of the

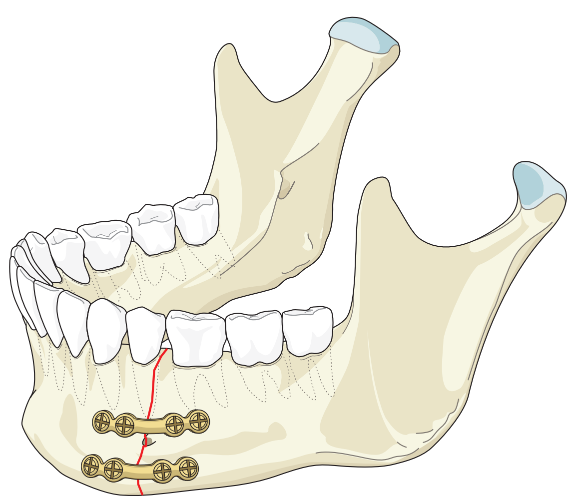

Fig 2.2-8 Double-plate fixation with miniplates for slightly dislocated mandibular lateral body fracture. Monocortical fixation of the superior plate avoids damage of tooth roots.

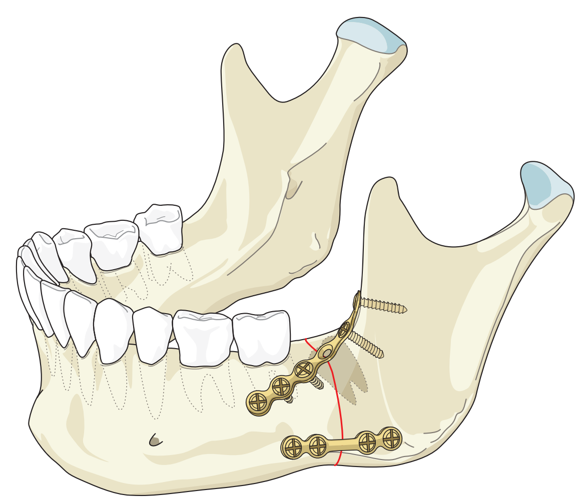

Fig 2.2-9 Miniplate fixation with two plates for a mandibular angle fracture.

mandible; screw fixation is bicortical. This type of osteosynthesis typically creates distracting forces at the superior border of the mandible and the lingual surface. To avoid superior gap formation, tension banding must be performed with either a tension band splint or a tension band plate before compression plating. A tension band splint can be applied using an arch bar, which can be reinforced with acrylic (**Fig 2.2-10**). A mandibulomaxillary wire fixation is not strong enough for tension banding. Alternatively, a tension band plate may be applied close to the superior border of the mandible (**Fig 2.2-11**). Placement of dynamic compression plates at the body and angle is usually possible with protection of the inferior alveolar nerve, but preoperative evaluation of the location of this nerve is useful.

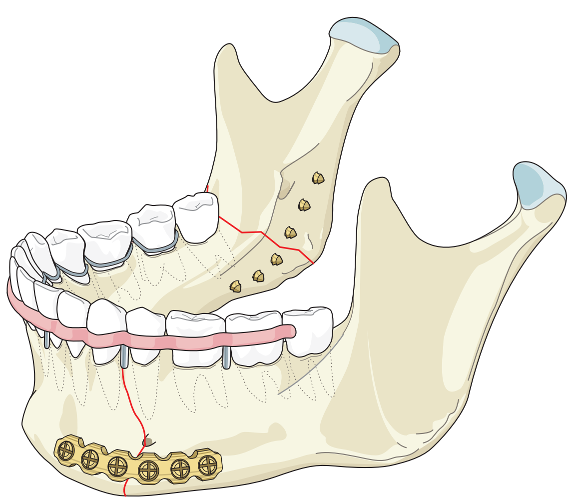

Fig 2.2-10 Tension banding performed with an arch bar reinforced with acrylic. In addition a universal fracture plate 2.4 is placed at the inferior border.

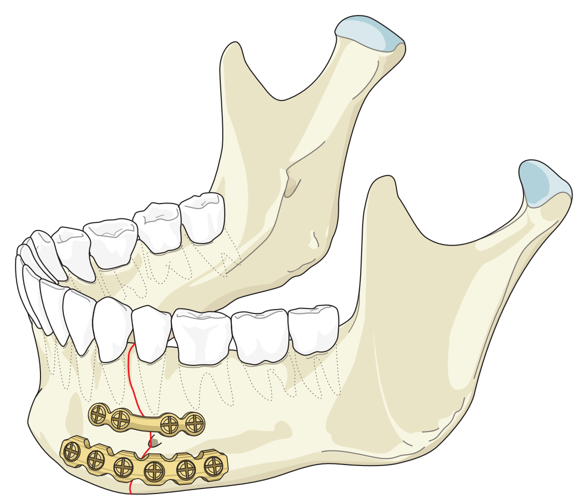

Fig 2.2-11 Double-plate fixation with a miniplate as a tension band above the mandibular nerve, and a universal fracture plate 2.4 at the lower border of the mandible. Protection of the inferior alveolar nerve has to be considered.

Lag screw fixation is another technique to perform load-sharing fixation. Typically lag screw fixation is indicated for fractures with oblique surfaces. To stabilize these, multiple lag screws (at least two) may be used in place of a stabilization plate. The principle for placement of these lag screws is to create compression across the sagittal portion of the fracture. At least two screws perpendicular to the fracture surface are required for 3-D stability and to neutralize rotational forces (**Fig 2.2-12a–b**).

Load-bearing osteosynthesis with either nonlocking or locking reconstruction technique is indicated for fractures with reduced bony buttress, such as comminuted, defect, or infected fractures; fractures of atrophic mandibles or treatment delayed fractures with nonunion (chapter 2.4, Fractures in bone with reduced quality). Combinations, for instance lag screw fixation with plate fixation, are possible (**Fig 2.2-13a–b**).

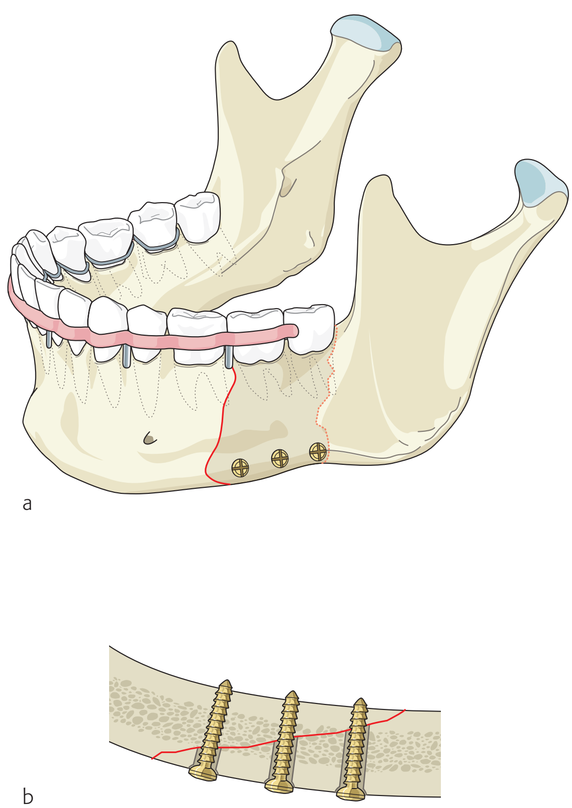

Fig 2.2-12a–b Oblique fracture stabilized with lag screw fixation. At least two screws perpendicular to the fracture surface are required for 3-D stability.

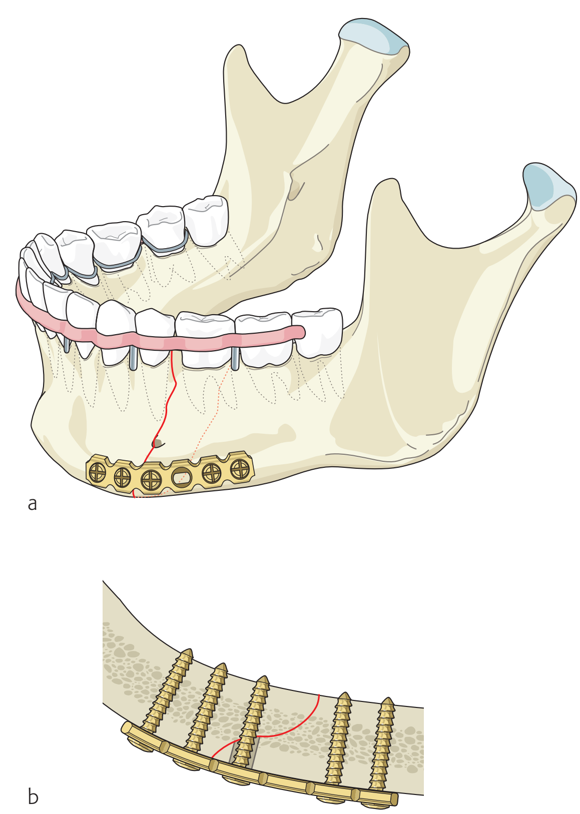

Fig 2.2-13a–b Load-bearing osteosynthesis in an oblique fracture of the lateral body. Regular plate fixation combined with lag screw technique for the oblique area.

9 Perioperative treatment

The use of perioperative antibiotics for open reduction of the body and angle fracture remains controversial. Antibiotics should be given to all patients with fractures when treatment is delayed. If antibiotics are to be used prophylactically, preoperative high-dose parenteral application is recommended with good anaerobic gram-positive coverage. Clindamycin, penicillins, or first-generation cephalosporins are most widely used. The emergence of methicillin-resistant staphylococcus aureus infection in the patient with maxillofacial trauma has altered the prophylactic regimen in some centers. They prefer broad-spectrum penicillin in combination with clavulanic acid. Use of drains in buccal and transcutaneous incisions is at the surgeon's discretion.

10 Postoperative treatment

All methods of stable internal fixation of fractures of the body and angle region should have the goal of early restoration of full function including diet, airway, and speech. However, fixation techniques present with varying degrees of stability. No MMF is indicated unless necessitated by additional fractures that have undergone nonsurgical treatment (eg, associated condylar fractures).

Single superior border plates for angle fractures provide sufficient stability where there is good buttressing of the fracture at the angle of the mandible. Factors that might compromise buttressing include removal of impacted third molar, oblique fracture lines, or comminution at the inferior border. If superior border plating is performed in these circumstances without an additional plate at the inferior border, a brief period of MMF may be necessary. A brief period of soft-tissue rest in occlusion using MMF may support soft-tissue healing.

11 Complications and pitfalls

During internal fixation, complete visualization of the fracture can be problematic in angle and body fractures. Failure to fully identify the fracture anatomy may result in inappropriate fixation. Opening of the inferior border during superior border plating must be anticipated and controlled, typically with a second plate. Flaring of the ramus due to poor adaptation on the lingual aspect of the mandible is also a severe risk. Screw placement into the mandibular canal can be avoided through careful planning.

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Authors Nils-Claudius Gellrich, Ralf Schoen

2.3 Condyle, ascending ramus, and coronoid process fractures

1 Anatomy and definition

Fractures of the mandibular condyle area are common and account for 9–45% of all mandibular fractures in adults and approximately for 50% of all mandibular fractures in children. Many classification systems describe condylar and subcondylar fractures; none is generally accepted and universally used. This presents a problem particularly when condyle fracture studies are compared. Today, simple classification systems are widely used. They address anatomical location of the fracture and distinguish between condylar head, subcondylar fractures (**Fig 2.3-1**), and pathological conditions such as dislocation of the condylar head. They also address angulation of the bones comprising the fracture segments and describe contact among the fragments.

In condylar head fractures the fracture line may run inside the capsule of the temporomandibular joint (TMJ), but frequently condylar head fractures have an extracapsular component. Some condylar head fractures divide the head sagitally, where a portion remains intact with the rest of the ramus. Subcondylar fractures are located below the condyle and can be classified into high (condylar neck) and low subcondylar fractures. Subcondylar fractures are located at the base of the condylar process at or below the level of the sigmoid notch.

Fractures below the sigmoid notch are fractures of the ascending mandibular ramus. Various patterns of displacement and dislocation of the proximal fragment are possible. Condylar and subcondylar fractures are usually closed fractures.

Coronoid process fractures are rare and may occur without involvement of the condylar process. Isolated fractures occur in combination with zygoma or zygomatic arch fractures, and marginal, submarginal, submuscular types have been described. Coronoid fractures may be a portion of a comminuted angle and ramus fracture.

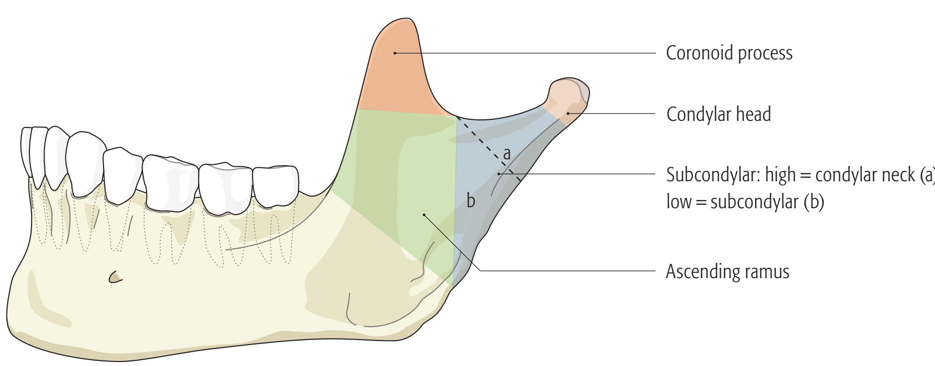

Fig 2.3-1 Fracture location can be anatomically distinguished.

2 Imaging

For treatment planning, the anatomical location, comminution of the fracture, degree of displacement, and dislocation are evaluated preoperatively. The minimum standard required is plain x-rays in two appropriate planes, for instance AP projections such as Towne's view, lateral oblique, and panoramic x-rays (OPTs). Fractures of the condylar head are often not seen on standard x-rays. Computed tomography (CT) or cone beam tomography in axial, sagittal, and coronal planes allow for a more detailed evaluation of the fracture components and are considered the gold standard of preoperative diagnostics (**Fig 2.3-2a–b**, **Fig 2.3-3**).

Fig 2.3-2a–b Computed tomography allows for a detailed evaluation of the fracture components.
a Coronal view.
b Axial view.

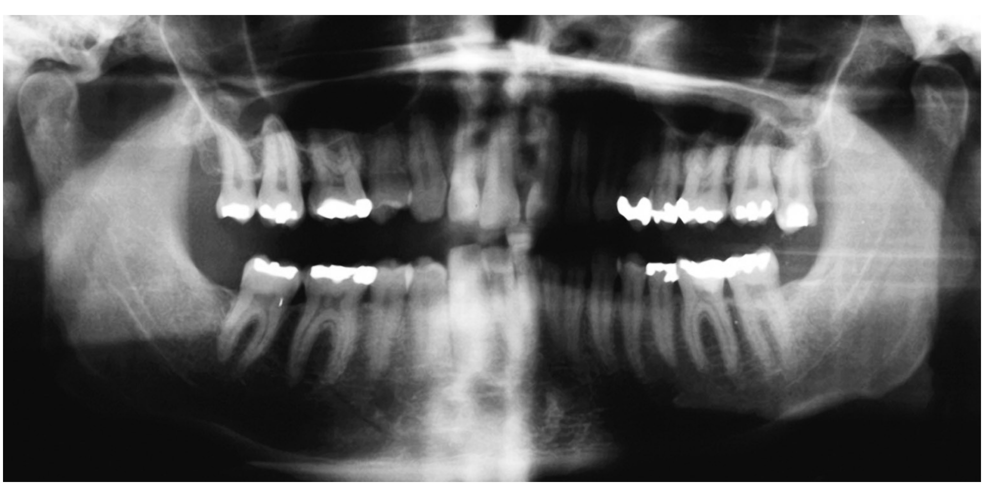

Fig 2.3-3 Plain x-rays, such as panoramic x-rays, are the minimum standard for preoperative evaluation.

In many centers condylar head fractures and fractures of the coronoid process are treated nonsurgically, although promising results have been reported for surgical treatment of condylar head fractures. Condylar neck, subcondylar fractures, and fractures of the ascending ramus may be treated nonsurgically or surgically by open reduction and fixation.

The decision for or against open reduction depends on the following factors:

- Condition of the patient (ie, cervical spine injury)
- Compliance of the patient
- Functional impairment (malocclusion, limited mouth opening)
- Concomitant fractures of the mandible (body and symphysis/parasymphysis, bilateral condyle) or midface (especially panfacial fractures)
- Dislocation of the condylar head
- Degree of displacement and bone contact at the fracture interface
- Status of dentition

3 Nonsurgical treatment

Nonsurgical management (also called conservative treatment or closed reduction) is still widely practiced. For the majority of pediatric fracture patterns, for undisplaced fractures, fractures without or with only minor functional disturbances, and condylar head fractures excellent long-term results can be obtained with nonsurgical treatment. Nonsurgical management may mean no treatment, observation, and mostly a period of soft diet. It may be indicated for patients with undisplaced or mildly displaced fractures of the condylar region with no significant functional impairment. Nonsurgical management can also include mandibulomaxillary fixation (MMF) for a short period of of time. This can be achieved with dental devices such as arch bars, wire loops, brackets, or bone-anchored devices (hooks, intermaxillary fixation (IMF) screws). For MMF elastics are widely used, typically for a short period of up to two weeks. This type of nonsurgical treatment is indicated for patients with functional problems, pain, disturbance of the occlusion, and displaced fractures.

MMF is most widely performed with arch bars but can also be performed with two stainless steel transmucosal minihooks fixed with one bone screw each or two IMF screws anchored in the anterior median aspect of the mandible and maxilla (**Fig 2.3-4**). Arch bars allow for MMF in a multicontact interdentation. MMF established with limited points of contact (eg, IMF screws) may create a fractional open bite.

IMF screws and single-point fixation devices have no flexibility.

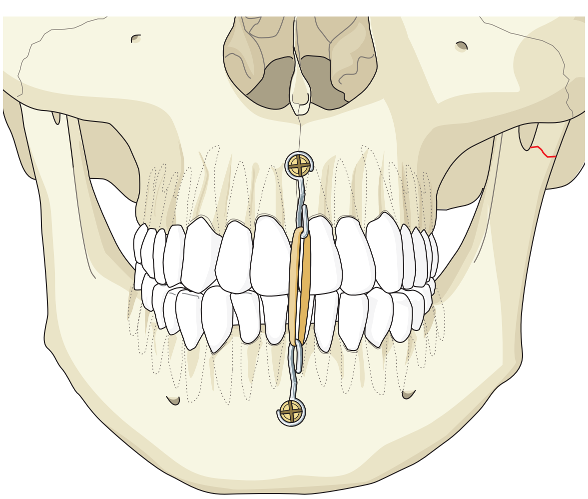

Fig 2.3-4 Mandibulomaxillary fixation (MMF) performed by two stainless steel transmucosal minihooks fixed with one bone screw each, anchored in the anterior median aspect of the mandible and maxilla.

Care has to be taken not to harm tooth roots. The fixation of bone-anchored devices is less time-consuming for the patient compared with applying arch bars, as mouth opening is not necessary. MMF may be difficult to perform if patients are partially or totally edentulous, present with preexisting bite deformities, or when they are noncompliant. In contrast to bone-anchored devices, MMF with arch bars allows for more flexibility with postoperative functional therapy with guiding elastics, especially if eccentric placement is indicated (**Fig 2.3-5**).

After nonsurgical treatment, temporomandibular joint (TMJ) function depends on regeneration of the condylar area and adaptation of the tissues. In children younger than 6–8 years, nonsurgical treatment is regarded to be the treatment of choice for most condylar head and subcondylar fractures due to the high regeneration potential of the growing condylar process. However, in severely dislocated subcondylar fractures restitutional remodeling is not always achieved and growth anomalies with facial asymmetry may occur.

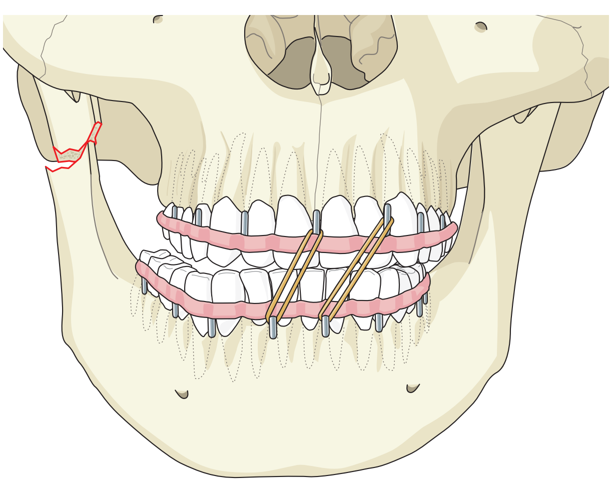

Fig 2.3-5 MMF with arch bars and guiding elastics allows for more flexibility during postoperative functional therapy, especially if eccentric placement is indicated to correct a mandible deviation.

4 Surgical treatment

The surgical treatment of displaced condylar fractures aims for anatomical reduction and restoration of the vertical height of the ascending mandibular ramus to reestablish preinjury occlusion and adequate TMJ function. Injuries in the TMJ area typically include soft-tissue involvement with rupture of the capsule and ligaments and displacement or rupture of the disc. These soft-tissue injuries are generally not surgically addressed, although exposure and anatomical reduction of the bones may allow for reposition of lacerated soft tissues in the TMJ area.

Superior functional results are reported following surgical treatment compared with nonsurgical treatment for fractures with dislocation of the condylar head and displaced fractures with functional impairment, such as malocclusion and open-bite deformity due to shortening of mandibular ramus height.

5 Surgical approaches

Open reduction can be performed by transcutaneous (**Fig 2.3-6a–b**) and transoral approaches. Endoscopically assisted approaches are also possible. Coronal approaches have also been used.

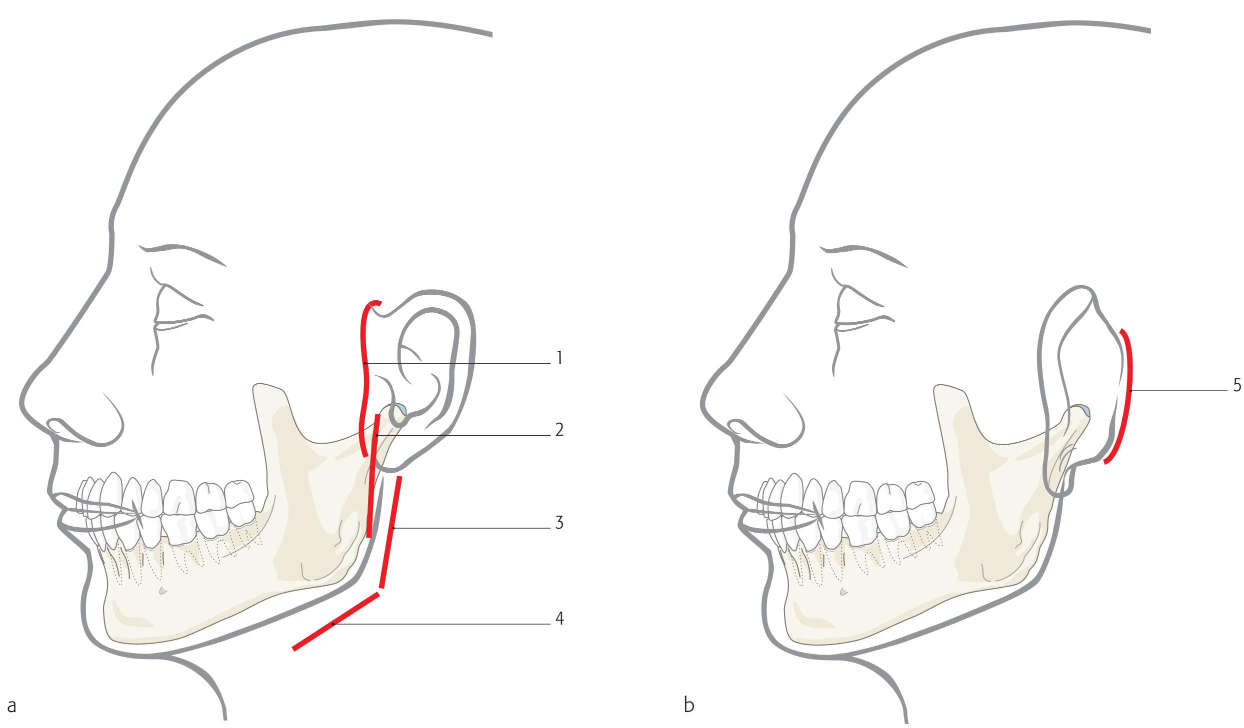

Fig 2.3-6a–b Different external approaches are possible:
1 Preauricular approach
2 Transparotid approach
3 Retromandibular approach
4 Submandibular approach
5 Retroauricular approach

6 Surgical techniques

Biomechanical conditions in the condylar area are demanding and due to the reduced dimensions, the bone can only buttress on a limited basis. Osteosynthesis today is typically performed with plates and screws. Recommended are two miniplates. One stronger plate, such as a universal fracture plate, can also be used. In cases where the anatomy only allows for placement of one miniplate, stronger mandible miniplates should be used. A minimum of two screws need to be anchored in the proximal condylar fragment to allow for rotational stability.

Lag screw fixation of condylar area fractures is not yet accepted as a routine method of treatment. For open reduction and internal fixation (ORIF) of condylar head fractures, it is mostly the only surgical option because typically there is not enough space for plate placement.

Intraoperative distraction of the TMJ area by downward pressure onto the posterior molars facilitates localization of the proximal fragment and anatomical reduction. A patient should therefore not be in MMF at the beginning of surgery, but after approach and fragment reduction. A wire can be inserted temporarily into the angle to pull the mandible inferiorly to distract the fracture.

Miniplates 2.0 or corresponding plates from the Matrix Mandible system should be securely anchored with two screws on each side of the fracture for osteosynthesis. For fixation of the miniplate in the strong cortical bone along the posterior border of the ascending mandibular ramus, bicortical screw fixation is recommended. As the subcondylar area is a mechanically demanding site, two miniplates allow for increased stability and safety (**Fig 2.3-7a–c**). Alternatively, anatomically shaped condylar plates can be used. When two plates can be used for osteosynthesis precise

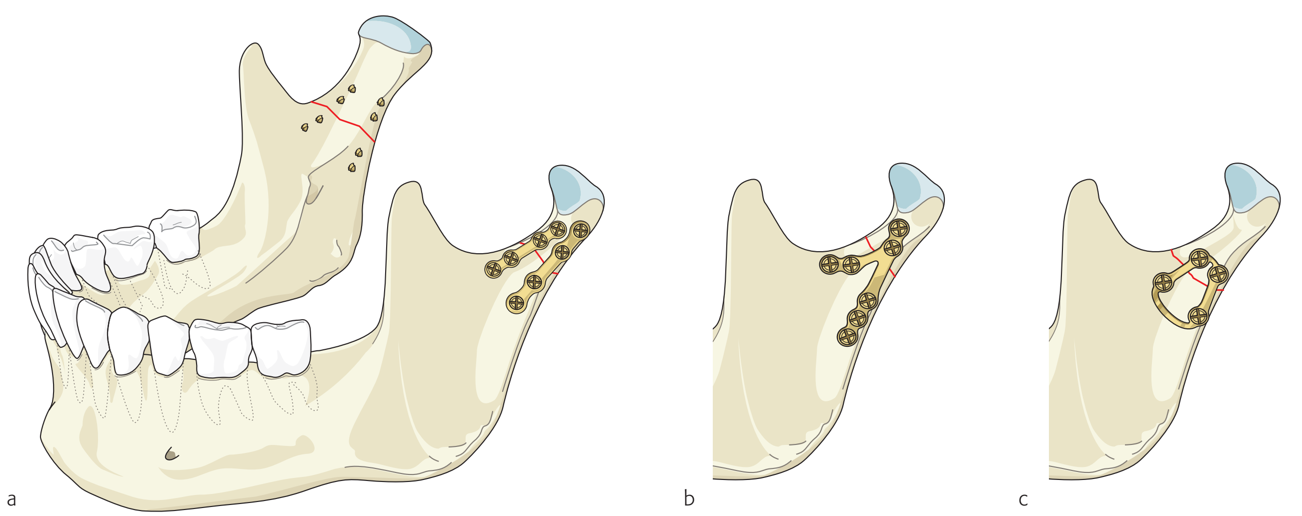

Fig 2.3-7a–c
a Two miniplates (2.0 and 1.5) should be securely anchored with two screws on each side of the fracture. As the high subcondylar area is a mechanically demanding site, two miniplates allow for increased stability and safety.
b–c Fixation with specific implants for the subcondylar region.

anatomical reduction is facilitated by a first plate inserted close to the sigmoid notch. The initial fixation with only two screws positions the fracture segments. This facilitates the precise placement of a second (ideally more rigid) plate along the posterior border, especially in severely displaced fractures. If the size of the mandible allows placement of a stronger plate, such as a universal fracture plate, this may be used for increased stability (**Fig 2.3-8a–b**).

Preferably a 4-hole noncompression miniplate 2.0 with space (tension band plate) is placed along the posterior border. Miniplates of the 2.0 or 1.5 system or corresponding plates from the Matrix system may be used in the sigmoid notch area (see **Fig 2.3-7a–c**). More rigid plates such as mandible plates 2.0, universal fracture plates, or corresponding plates from the Matrix Mandible system may be more difficult to apply in an endoscopically assisted approach. Precise bending of stronger plates under such conditions is not always possible and displacement or malalignment of the fracture may be caused when tightening the screws. For transoral osteosynthesis angulated drills and screwdrivers with a screw-holding device facilitate the insertion of the first screw together with the plate. Transbuccal insertion of the screws can be performed without an angulated screwdriver. Endoscopically assisted transoral approaches with angulated scopes allow precise control of anatomical reduction in areas of limited visibility.

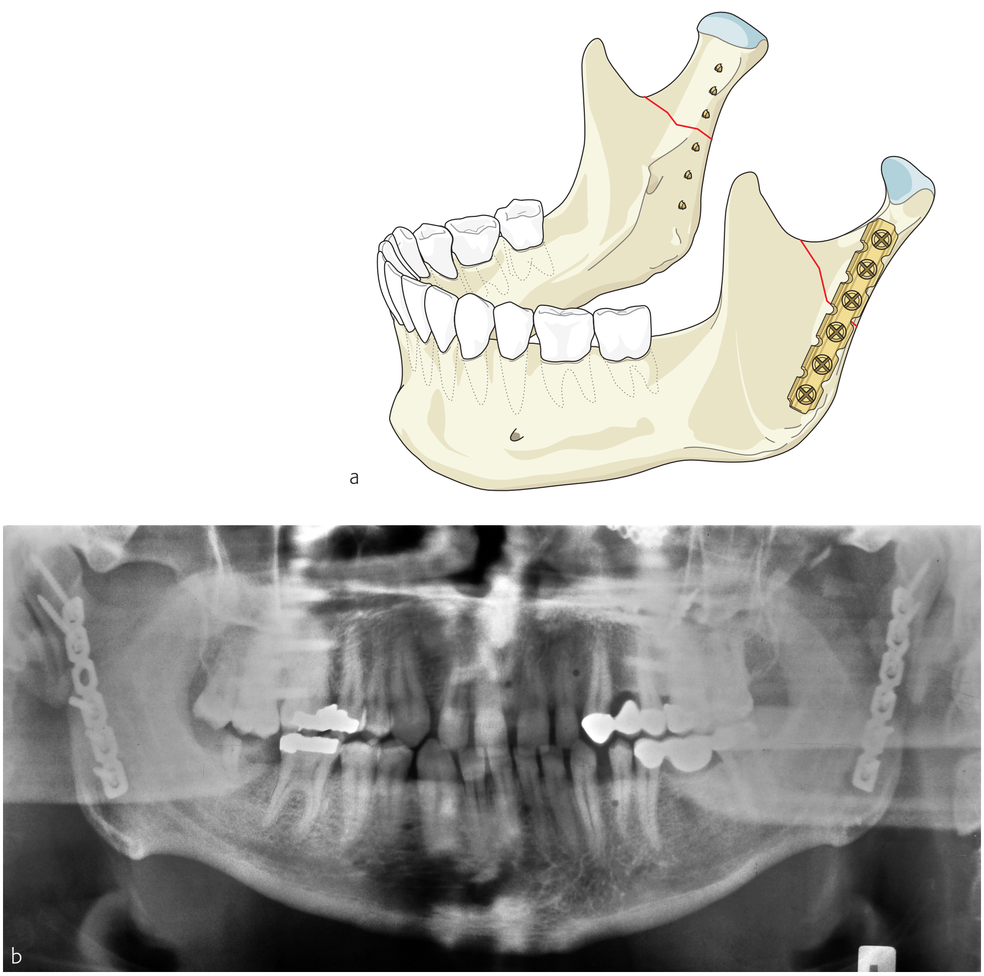

Fig 2.3-8a–b If the size of the mandible allows, a stronger plate (universal fracture plate) may be used for increased stability.

Fractures of the ascending ramus are treated according to the biomechanical requirements associated with the fracture type (**Fig 2.3-9**). Multifragmentary fractures are typically treated with a load-bearing osteosynthesis, if needed after simplification with miniplates.

Immediate postoperative function without MMF is achieved following anatomical reduction and adequate osteosynthesis of subcondylar fractures.

Some surgeons favor a short period of MMF with elastics to allow the soft tissue and joint to rest (up to 7 days). After that, guiding elastics, typically night-time elastics, are used. This treatment is purposely more conservative but results in far fewer problems, especially when midface fractures are present.

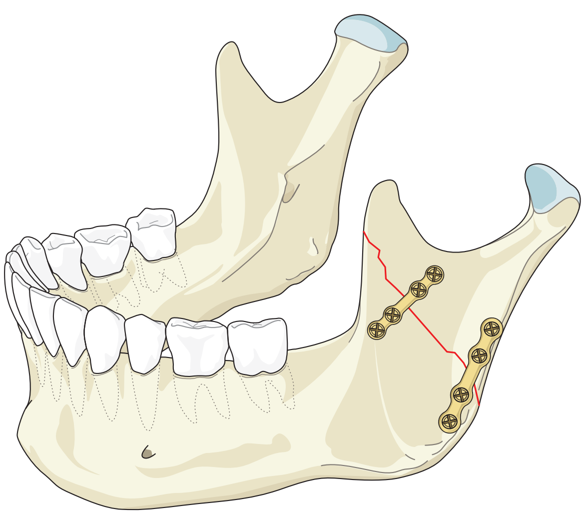

Fig 2.3-9 Fracture of the ascending ramus stabilized with a miniplate 2.0 posteriorly and a miniplate 1.5 placed anteriorly.

7 Postoperative treatment

Malocclusion and impaired TMJ function may occur in condylar area fractures even after treatment. To evaluate the treatment outcome and to correct any undesired results a close follow-up of the patients is mandatory, until return to almost full function.

Temporary functional problems or disturbances of the occlusion are typically treated with guiding elastics, both after open or nonsurgical management. To achieve adequate functional results with mouth opening of more than 40 mm, a prolonged functional therapy may be necessary. This will avoid deviation and bilateral protrusion, especially after nonsurgical management. Besides guiding elastics, functional therapy may involve physiotherapy or the use of orthodontic appliances. When functional treatment is offered, excellent results can also be achieved in nonsurgically treated severely displaced fractures. However, functional treatment with orthodontic appliances (ie, an activator) for rehabilitation is time-consuming and expensive, and may take up to 1 year. Therefore, it can only be performed in compliant patients and those who can afford such a treatment. If complications after surgical treatment lead to unsatisfying postoperative results, functional treatment can be performed to a certain extent.

8 Complications and pitfalls

Surgical complications, such as injury to the facial nerve (especially the temporal branch in preauricular incisions and the marginal branch in submandibular incisions) or visible scars, may occur when open reduction by transcutaneous approaches is performed. To minimize the risk of these complications, endoscopically assisted techniques using limited transoral incisions have been developed.

Surgical treatment of condylar fractures remains technically demanding. The fracture type influences the difficulty of reduction. In severely displaced and medially dislocated or overriding fractures, open reduction can be challenging and anatomical positioning of the condylar fragment may not always be possible. It is important to detect the condylar head position and zones of comminution in preoperative imaging to allow for adequate reduction with a specific approach or plate fixation, thus minimizing intraoperative surprises.

Due to intensive mechanical forces on the condylar process area failure of osteosynthesis due to fatigue fractures of the plates or loosening of screws occur in subcondylar fractures in 5–10% of cases (**Fig 2.3-10a–b**), especially when limited fixation with unstable plates has been used. To avoid micromovement at the fracture site, precise reduction and osteosynthesis with two plates are recommended.

Avascular necrosis of the condylar head, perhaps because of excessive soft-tissue stripping after surgical treatment, is rarely seen. To avoid this, it is recommended to always leave the lateral pterygoid muscle attached.

Following nonsurgical or surgical treatment impaired TMJ long-term function due to abnormally shaped condylar heads, shortened mandibular ramus height, or growth anomalies with facial asymmetry may occur. Limited TMJ mobility of the deranged condylar process may lead to functional dislocation of the contralateral condyle on jaw opening with chronic TMJ pain.

Soft-tissue complications, such as scar formation, internal derangement, pain, or functional disorders, may be seen after surgical and nonsurgical management.

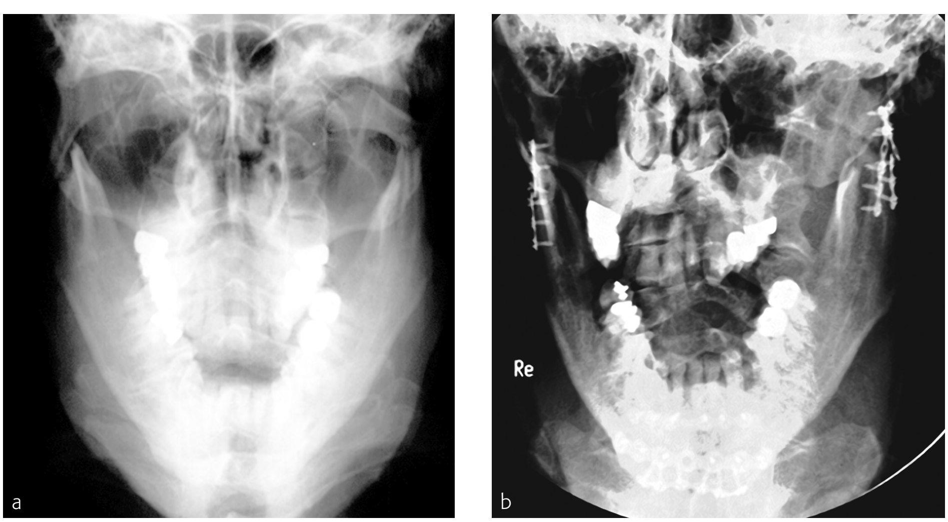

Fig 2.3-10a–b
a X-ray showing a bilateral condylar fracture.
b Failure of miniplate osteosynthesis with weaker midface plates in both subcondylar areas.

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Authors Brian Alpert, George M Kushner

2.4 Fractures in bone of reduced quality

1 Introduction

Bone of reduced quality (and quantity) may result from atrophy, infection, comminution, and defects. The common denominator in these fractures is the inability to effectively use any form of load sharing, since the bone is inadequate in quality and quantity.

Atrophic mandibular fractures

In these fractures the alveolar process and often much of the basilar bone has been lost. This is usually the result of long-term edentulism, although atrophy and edentulism are different conditions because edentulous does not necessarily mean atrophic. The remaining bone is markedly diminished in height and often width, and is frequently entirely cortical (and brittle) in nature. The highest degree of atrophy is seen typically in the lateral body of the mandible, an area without major muscle attachment. There is no effective endosteal blood supply. The nutrient vessel (inferior alveolar artery) is often outside of the bone.

Multifragmentary mandibular fractures

This type of fracture typically arises from high-speed or intense blunt trauma or missile wounds and results in fragmentation of the bone into multiple pieces. The fragments are often located in open wounds.

Defect mandibular fractures

These fractures are characterized by loss of bone substance at the fracture site creating a gap of variable size with loss of bone buttressing. This loss of substance may be secondary to loss of a tooth, avulsion of a comminuted fragment, sequestration, or following an osteotomy for tooth removal. A pathologic entity such as a cyst or metastases, may also result in a defect.

Infected mandibular fractures

When open mandibular fractures are untreated and if treatment is delayed, infection of the fracture site and/or surrounding soft tissues is inevitable. Initially, the infection process is characterized by purulent drainage; diffuse bone involvement with sequestration occurs later.

All these fractures in bone with reduced quality are often additionally complicated by being both open and displaced. They are some of the more difficult fractures to manage and historically were subject to a high complication rate.

2 Imaging

Imaging in two planes is mandatory to assess the fractures. Panoramic x-rays are usually necessary to define these fractures. Although they are often inadequate for diagnosis when used alone, they are still necessary to give the "big picture." Axial and coronal CT scans properly define the individual fractures with respect to comminution, splaying, condylar inclination, and so on. They are also useful to judge symmetry.

3 Surgical approaches

Fractures in bone of reduced quality are generally approached transfacially and require wide exposure to visualize and complete a stable fixation. Although transoral approaches may sometimes be used, exposure may be suboptimal and compromise the ultimate open reduction and internal fixation (ORIF). Transoral approaches may sever the inferior alveolar nerve and artery as they may be in soft tissue on the surface of the mandible. In addition, long reconstruction plates required for load-bearing fixation are difficult to place transorally. In such cases, the surgeon must be prepared to supplement the exposure with a transcutaneous approach.

4 Osteosynthesis techniques

Rigid internal fixation (RIF) has been more effective in these complex injuries than in all other types of mandibular fractures in both improving outcomes and shortening the course of treatment. In the past, closed techniques with cumbersome mandibulomaxillary fixation (MMF) and/or external fixators often requiring prolonged periods of immobilization of the jaws were the rule for these fractures. Nonunion, malunion, sequestration, and trismus often resulted.

Contemporary RIF in the form of load-bearing osteosynthesis is the treatment indicated as is free autogenous particulate marrow bone grafting in areas of bone defect or diminished healing capacity. Modern locking reconstruction plates anchored by at least three screws on either side of the fracture or defect allow for undisturbed healing. If wound complications occur, the internal fixator stabilizes the segments during further debridement, grafting, etc, with the patient continuing to function.

5 Treatment

5.1 Atrophic mandibular fractures

Over the years, a variety of treatments have been used in the management of atrophic mandibular fractures.

"Skillful neglect" means taking away the dentures from the patient and imposing a soft diet for nondisplaced fractures. Closed reduction with dentures or splints stabilized with suspension and circummandibular wires have been used for both monomaxillary and mandibulomaxillary fixation. These appliances are cumbersome, painful, and subject to infection. Outcomes are not predictable.

External fixators have been used with varying degrees of success. Both transoral and transcutaneous ORIF with wires, both with and without MMF, were used with limited success, as was ORIF with titanium or stainless steel mesh and screws. K-wires, both intramedullary and at the inferior border, had their advocates. ORIF stabilized with wire and split ribs for support and for osteogenesis has also been recommended. With the advent of plates and screws, many surgeons attempted fixation with miniplates both from transoral and transcutaneous approaches.

Experience has shown two things: first, elderly infirm patients do not tolerate MMF well. They suffer a great deal and may even die. Second, in the management of these fractures, one should do what one knows will work, not what one hopes will work. In this sense the most effective treatment is a definitive initial surgical procedure. Today, this means a well-anchored reconstruction plate with autogenous particulate marrow bone grafting if necessary.

Since the atrophic mandible has diminished vascularity, no load-sharing capacity, and is often brittle, the internal fixation device in the form of a reconstruction plate or locking reconstruction plate with bicortical screw placement must carry the functional load (**Fig 2.4-1**). The angle and symphysis typically provide the screw sites because this is where

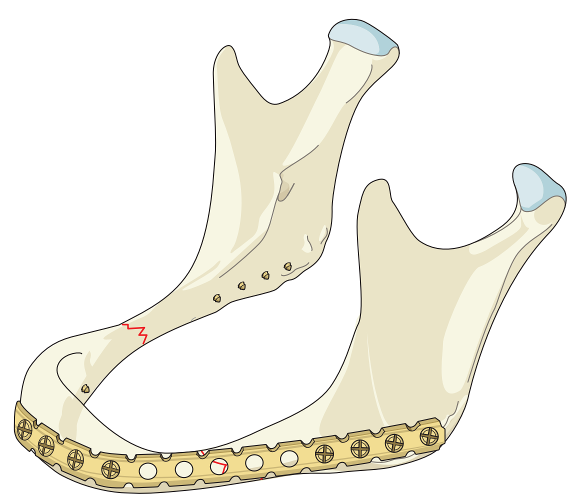


Fig 2.4-1 A reconstruction plate (locking or nonlocking) with bicortical screw placement (mostly only possible in chin and angle region) must bear the functional load in an atrophic mandible.

the bone is of better quality and often of higher quantity. Unnecessary periosteal stripping should be avoided. Bone grafts can be placed primarily or secondarily. Bone can be cancellous, harvested from the iliac crest, or the tibia. No form of MMF is used.

The functional forces on the atrophic mandible should not be underestimated. Wishboning, deformation of the bone during function, will rapidly cause fatigue failure of miniplates (**Fig 2.4-2a–b**). Reconstruction plates or locking reconstruction plates with bicortically anchored screws are indicated.

Fractured atrophic mandibles may be approached transorally with difficulty by an experienced team, but the most predictable approach is through a submandibular transcutaneous incision. Anesthesia techniques should use muscle relaxants to improve reduction after the facial nerve branches have been isolated and protected. Miniplates may be useful to provide temporary stabilization. Then, a load-bearing reconstruction plate is applied. This fixation may be larger in height and circumference than the bone at the fracture site. Particular bone graft is packed around the defect.

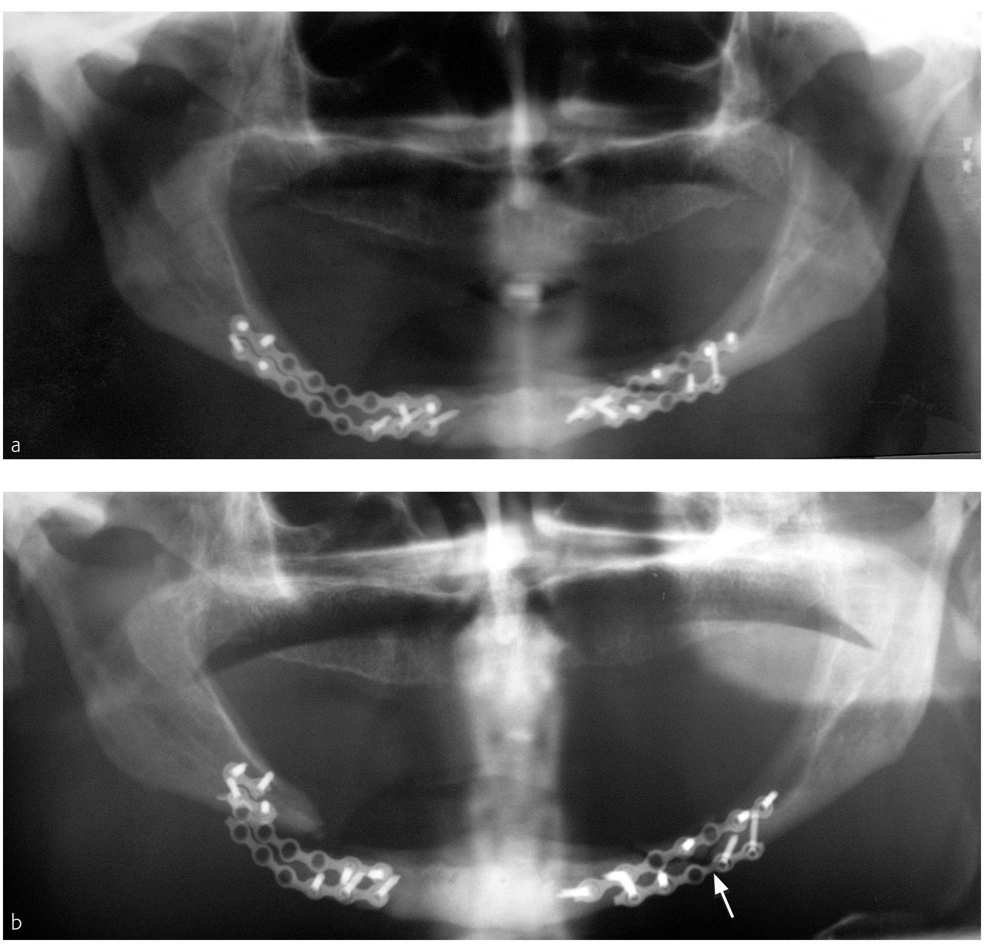
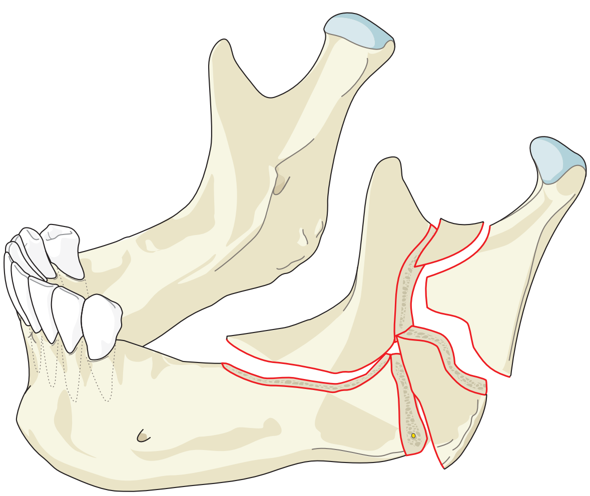


Fig 2.4-2a–b
a Miniplate fixation of bilateral fractures in an atrophic mandible.
b Failure of miniplate fixation (plate fractures on both sides).

5.2 Multifragmentary mandibular fractures

Multifragmentary fractures of the mandible are generally the result of a significant impact on a localized area causing a shattering of the bone. Most are open fractures that are difficult to treat and have a higher complication rate. Traditional treatment consisted of closed techniques that were designed to avoid devitalizing bone fragments, which often led to infection and sequestration. This was accomplished with MMF, splints, and external fixators. ORIF was believed to be contraindicated.

Contemporary management involves rigidly fixing the teeth in proper occlusion with arch bars, wires, and acrylic. After reduction, the fragments are prelocalized with miniplates, typically with monocortically placed screws, and/or lag screws to position the fracture segments. Lingual periosteal attachments are preserved. The entire area of comminution is then spanned with a reconstruction plate, fixed with bicortically anchored screws which completes a load-bearing osteosynthesis. At least three screws are placed on either side of the area of comminution (**Figs 2.4-3a–c**, **2.4-4a–b**, **2.4-5a–b**). Additional screws may be used to lag or fix the smaller fragments to the plate. Small tooth-bearing fragments should always be aligned with an arch bar. Care must be taken to avoid too much periosteal stripping, which may result in devascularization and necrosis. Bone defects may be primarily grafted as necessary, as long as appropriate soft-tissue closure around the bone graft is feasible. Obviously, the preferred approach is transcutaneous with exposure wide enough to thoroughly appreciate alignment and adequately stabilize the fragments. After load-bearing fixation, MMF is released and the patient allowed limited function.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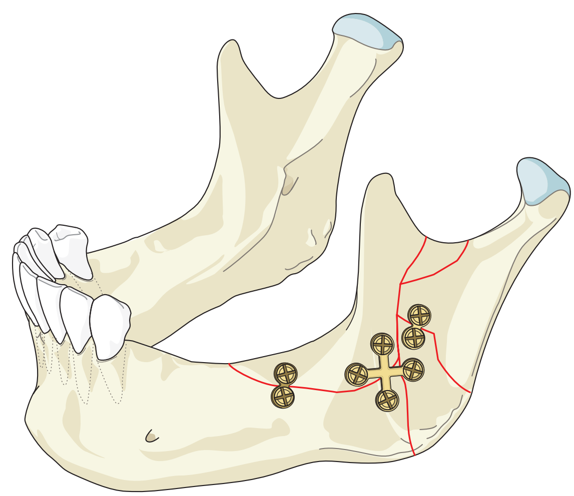
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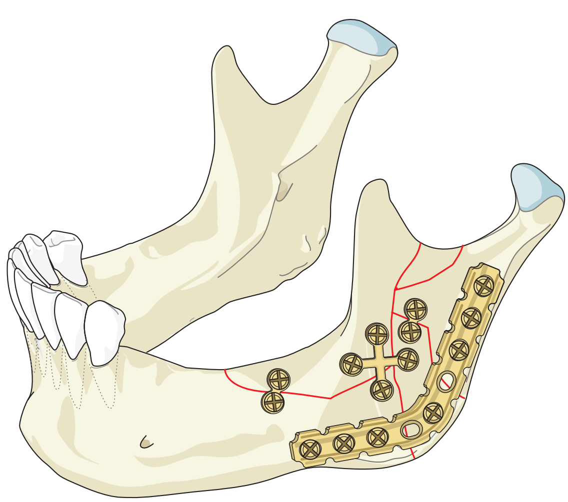
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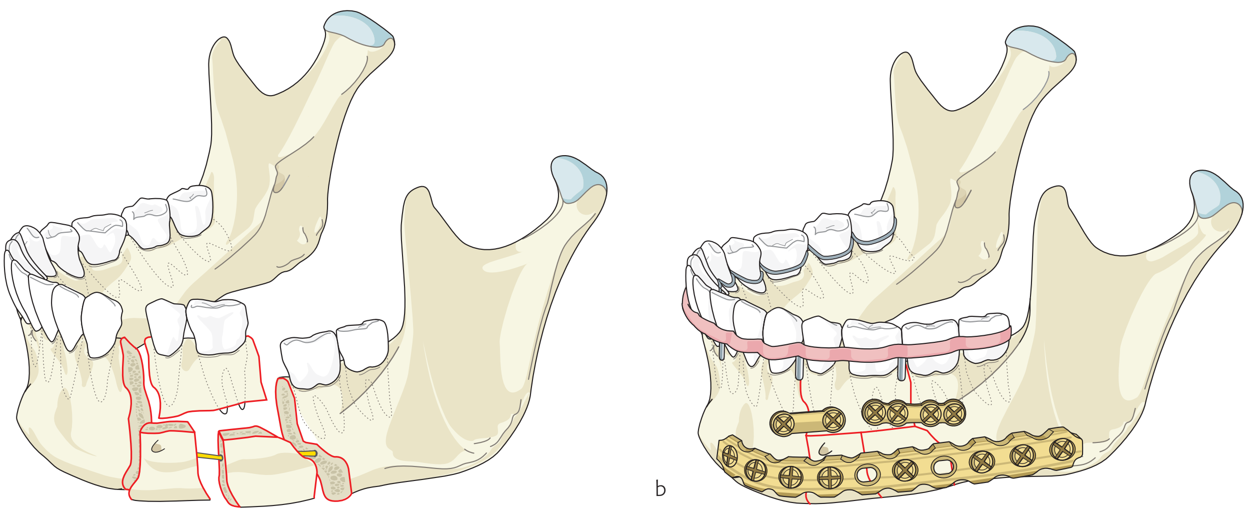
Fig 2.4-3a–c
a Comminuted fracture of mandibular angle and ramus area.
b Primary adaptation of the fragments with miniplates and monocortically placed screws.
c Subsequent stabilization of the comminuted area with a reconstruction plate 2.4 and bicortical screw placement.

This form of treatment has dramatically shortened the course of healing and improved outcomes in these complex fractures. Rigidly fixed fragments, though devitalized by periosteal stripping, usually do not sequester. Maintaining function minimizes the trismus from scarring and the disuse atrophy seen after prolonged periods of MMF. These fractures are not suitable for splints, wires, or miniplates. Open reduction and internal fixation without load-bearing osteosynthesis, such as miniplate fixation, is unpredictable and often leads to infection and sequestration.

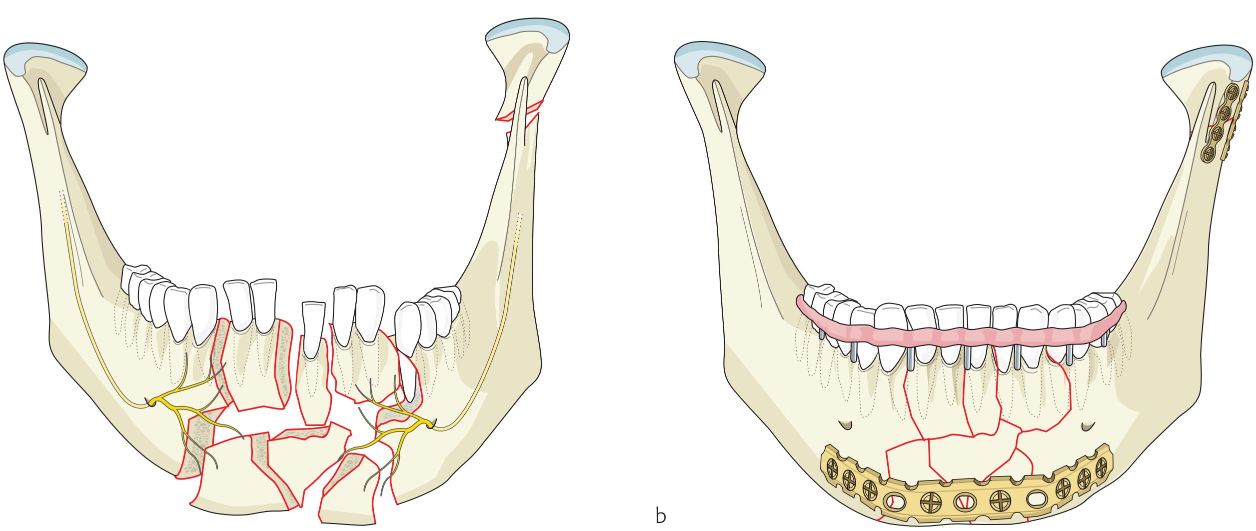


a b

Fig 2.4-4a–b

a Multifragmentary fracture of the left side of the mandibular body. The nerve remained intact.

b Fracture stabilization with two miniplates as tension band (monocortical screw placement) and one reconstruction plate to bridge and stabilize the comminuted area. Tooth-bearing fragments should be aligned with an arch bar.



a b

Fig 2.4-5a–b

a Comminuted fracture in the chin area with considerable dislocation of the various fragments, including a subcondylar fracture on the left.

b Adaptation and stabilization of the tooth-bearing fragments with an arch bar. Bridging and stabilization of the comminuted area with a reconstruction plate and at least three screws in the nonfractured body area. Superior small fragments are aligned through the arch bar. Sufficiently large fragments are fixed to the plate as well. Subcondylar fracture fixation with two miniplates.

5.3 Defect mandibular fractures

Defect fractures result from loss of bony substance due to disease, injury, debridement, or infection. In such cases bone contact at the fracture site is often inadequate for union to take place.

As with other complex mandibular fractures, load-bearing osteosynthesis is placed following MMF in the correct occlusal relationship. Transfacial access is traditional, yet transoral approaches for defect fractures anterior to the first molar may be effectively used for both the RIF and grafting. A reconstruction plate or locking reconstruction plate is anchored bicortically with three screws on either side, well away from the fracture and defect (**Fig 2.4-6a–c**).

Smaller defects with an intact and viable soft-tissue envelope are typically grafted with free nonvascularized bone, as long as the condition of the soft tissue allows tension-free and complete wound closure. Should the soft-tissue quality not allow primary bone grafting, secondary bone grafts are an option. Temporary exposure of a reconstruction plate is not a problem.

In larger bone defects and in defects associated with poor soft-tissue status as well as in combined bone and soft-tissue defects, such as in gunshot injuries, microvascular bone and soft-tissue transplantation is preferred.

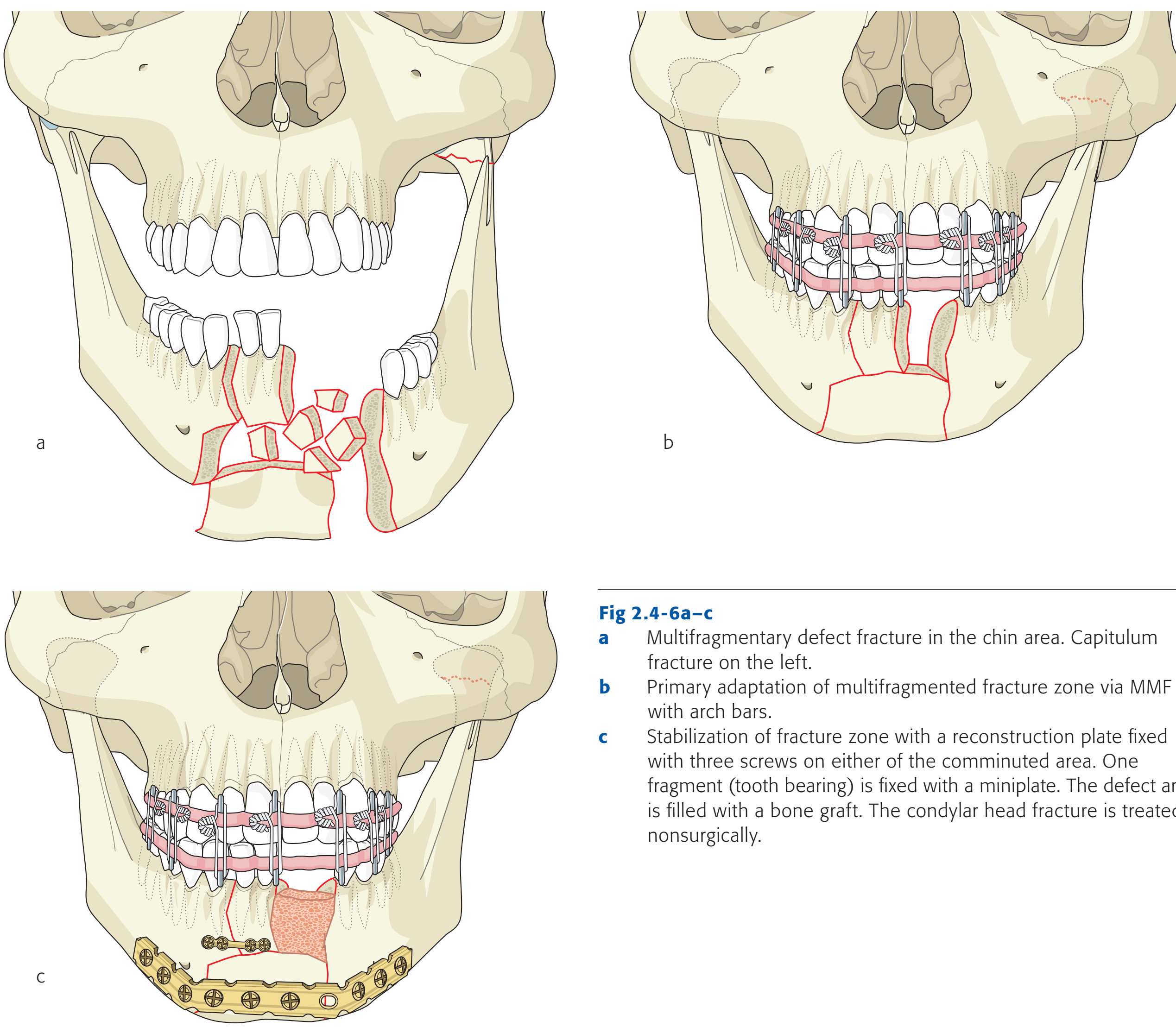


Fig 2.4-6a–c

a Multifragmentary defect fracture in the chin area. Capitulum fracture on the left.

b Primary adaptation of multifragmented fracture zone via MMF with arch bars.

c Stabilization of fracture zone with a reconstruction plate fixed with three screws on either of the comminuted area. One fragment (tooth bearing) is fixed with a miniplate. The defect area is filled with a bone graft. The condylar head fracture is treated nonsurgically.

5.4 Infected mandibular fractures

Historically, all open mandibular fractures were considered potentially infected if not treated within 24 hours. Indeed, open fractures were managed with closed techniques in the form of MMF appliances, splints, and external fixators. All teeth were removed from fracture sites and internal fixation was believed to be contraindicated. If the fracture became infected, drainage and sequestrectomy were performed while the occlusion was controlled with MMF.

As treatment evolved, antibiotics were added to the treatment protocol but with little benefit. Debridement was initiated only after radiographic evidence of sequestrum formation and time to union was calculated from the time drainage ceased. If a bone graft was needed, this was done 3–6 months following cessation of the drainage.

Modern therapy is based on the AO principle that the infected fracture is best managed by rigidly immobilizing the fragments. This allows the body's defenses to eliminate the infection and permit healing.

Protocol calls for incision and drainage of the acute infection, antibiotics, and removal of involved nonpreservable teeth. If the process becomes chronic, MMF is performed, the fracture is adequately exposed and debrided, and load-bearing osteosynthesis is placed (**Fig 2.4-7a–b**).

Either transoral access for fractures in the chin area or transcutaneous access may be used. Load-bearing fixation is performed with a reconstruction plate or locking reconstruction plate anchored bicortically with three or four screws placed on either side, well away from the infected fracture site.

Aluminum bending templates greatly facilitate plate bending which must be precise for reconstruction plates to prevent the bone from being adapted to an improperly contoured plate. Bending of the locking reconstruction plate need not be as precise since it is a true internal fixator that does not depend on the plate-to-bone interface for stability. One must be cognizant of the anatomy of the area when placing screws. Avoid tooth roots and the inferior alveolar neurovascular bundle. The complications of treatment should not add to

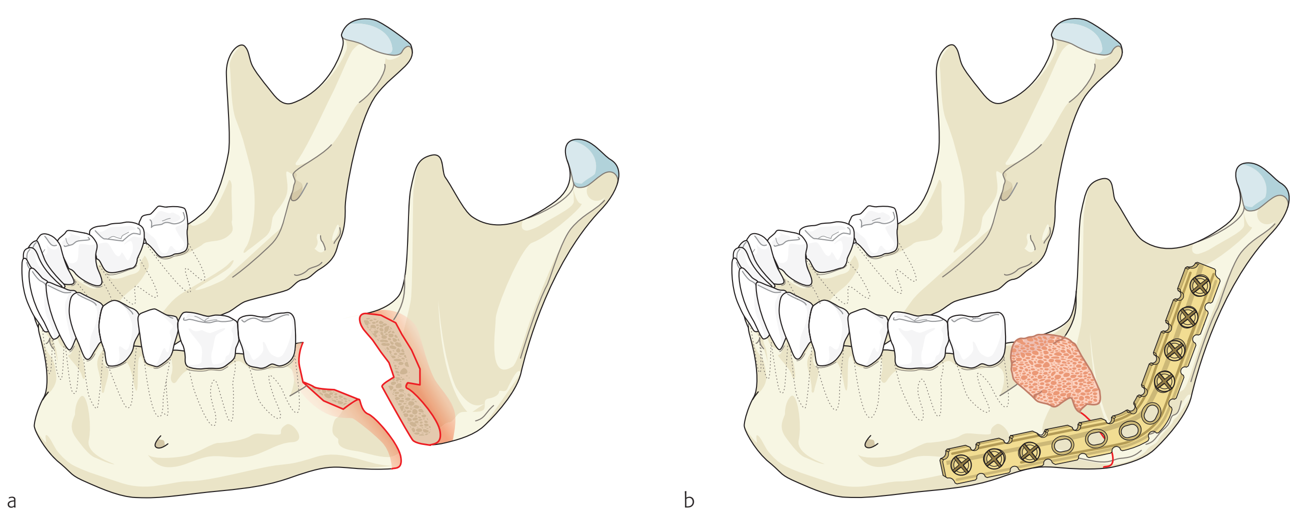


Fig 2.4-7a–b
a An acutely infected fracture of the mandibular angle.
b Bridging of the infected area with a reconstruction plate. At least three screws are placed on either side and well away from the infected zone. If the soft tissue allows, a cancellous bone graft is placed into the defect zone.

the complications of the injury. If soft tissue allows, primary autogenous particulate marrow bone graft may be placed in the resulting bone defect. MMF is released and the patient is allowed to function.

This contemporary infected fracture protocol has dramatically shortened the course of treatment for these patients. If successful, which it is most of the time, healing and union rapidly occur. When it is not, with continued drainage, loss of the graft and further sequestration, the internal fixator allows mandibular function and provides a platform for further debridement and secondary grafting. This concept has been used with success and only minor complication rates have been experienced.

6 Perioperative treatment

Culture-specific antibiotic regimen is indicated preoperatively and extending postoperatively. Used long term, it will only delay rather than prevent the emergence of a postoperative infection.

If the wound is wet or potentially infected, it should be drained. This is seldom necessary but is preferred by some surgeons (by vacuum or simply a dependent drain).

7 Complications and pitfalls

These complex fractures are subject to complications such as nonunion, malunion, infection, sequestration, loss of teeth, and neurosensory deficits. Modern treatment with load-bearing osteosynthesis has minimized many of these. Complications from load-bearing osteosynthesis are generally related to inadequate reduction and/or fixation which are operator errors in judgement or technique. Proper reduction is facilitated by adequate imaging and exposure. Application of adequate fixation is often governed by the understanding that it is rare to have too much fixation but all too common to have too little.

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