Author Richard H Haug

1.4.3 Design and function of implants

1 Introduction

High-quality implants and instruments are essential for successful internal fixation and reconstruction. Implants must come with defined and reliable mechanical and biological properties. They must be biocompatible, non-toxic, and corrosion resistant. Meticulous quality control during the production process is required. Implants and instruments require in most countries official certification of their safety and effectiveness based on legislative compliance regulations such as the European Medical Device Directive (93/42/EEC) or the Code of Federal Regulations (21 CFR 860) in the United States of America.

The gold standard material for craniofacial implants is titanium and its alloys, however, for some applications biodegradable implants may be considered. In the past, stainless steel and vitallium implants were used (**Table 1.4.3-1**). Most instruments are made from stainless steel, but instruments made of non-ferrous materials are also available for use within open magnetic resonance imaging.

Implant material	Specification	Composition
Commercially pure titanium	Grade 1	Ti (99%), N (0.03%), C (0.08–0.10%), H (0.015–0.0125%), O (.18%), Fe (.20%)
	Grade 2	Ti (99%), N (0.03%), C (0.08–0.10%), H (0.0125%), O (.25%), Fe (.30%)
	Grade 3	Ti (99%), N (0.05%), C (0.08–0.10%), H (0.0125%), O (.35%), Fe (.30%)
	Grade 4	Ti (99%), N (0.05%), C (0.08–0.10%), H (0.0125%), O (.40%), Fe (.50%)
Stainless steel alloy	316 L	Fe (approximately 65%), Cr (17–19%), Ni (13–15%), Mo (2.25–3.0%), N (0.1%), C (0.03%), Mn (2%), P (0.025%), Si (0.75%), Cu (0.50%)
Cobalt-chromium alloy	Vitallium	Co (58–65%), Cr (27–30%), Mo (6.0%), C (0.4%), Mn (1.0%), Si (1.0%), Fe (5.7%)
Titanium aluminum niobium alloy	TAN	Ti (approximately 87%), Al (5.5–6.5%), Nb (6.5–7.5%), N (maximum 0.05%), C (maximum 0.8%), H (maximum 0.009%), O (maximum 0.20%), Fe (maximum 0.25%), Tn(maximum 0.5%),
Titanium molybdenum alloy	Ti-15Mo	Ti (approximately 85%), Mo (14–16%), N (maximum 0.05%), C (maximum 0.10%), H (maximum 0.015%), O (maximum 0.20%), Fe (maximum 0.10%)
Poly L-lactic acid (PLLA) and Poly D, L-lactic acid (PDLA) combination		70% PLLA/30% PDLA
Poly (L-lactide-co-glycolide)		85% L-lactide/15% Glycolide

Table 1.4.3-1 Plate and screw materials (examples).

2 Implants

2.1 Screws

The basis for current rigid internal fixation is the interaction between screws, plates, and bone. To understand this interaction, the surgeon must first understand the screw, its components, and intended functions. To simplify the description of the screw components, the glossary of screw terminology should be reviewed (**Table 1.4.3-2**) along with a schematic representation of a typical screw (**Fig 1.4.3-1**). The first basic component of the screw is the core. This is generally the same diameter as the drill required to create the receptacle site within the bone that receives the screw. The outer diameter is the thread width. The threads engage the bone and provide resistance to pullout forces. It is this outer thread diameter that is the name-determinant of the particular screw or screw/plate system (for instance, 1.0 mm, 1.3 mm, 1.5 mm, 2.0 mm and so on) in conventional systems.

Head	The superior portion or cap of the screw that is attached to the core. It contains a recess for the screw driver.
Core	The center substantive portion of the screw to which the head and threads are attached.
Thread	That portion of the screw attached to the core that engages the bone. Thread diameter describes the width of the screw measured from the edge of the thread on one side to the other side. The outer thread diameter is associated with the description of the screw or plate system (eg, 1.0, 1.3, 1.5) in conventional systems, not in the Matrix systems.
Pitch	The distance between threads.
Flutes	The channels cut through the outer threads and into the core of the tip of a screw intended to collect bone debris.
Self-tapping	A screw that has been designed to be used without tapping. This requires at least two flutes at the tip of the screw that extend superiorly for at least two threads.
Self-drilling	A screw that has been designed to be used without drilling and tapping. This is a screw that is tapered to a point and possesses at least two flutes at the tip of the screw that extend superiorly for at least three threads.
Cruciform head	A screw head that has a flat cross-like recess with centered dimple that fits intimately with the corresponding screwdriver.
PlusDrive head	Optimized cruciform drive • Easy to pick up the screws • Improved retention in comparison to the conventional cruciform drive • Easy to re-engage the screwdriver in situ
Matrix head	Optimized PlusDrive
Emergency screw	When the threads in bone have stripped, or the hole was driven too large, then the next largest outer thread diameter screw is called an emergency screw in clinical terminology. A more accurate term would be a salvage screw.

Table 1.4.3-2 Glossary of terms for screws.

The Matrix plating systems for the craniomaxillofacial skeleton have a different denomination according to the areas of application (midface, mandible, orthognatic) and the plate sizes.

The head of the screw engages the plate or bone to maintain stability, and is also used by the screwdriver to insert the screw. The different types of screw heads correspond to the varying screwdriver types. For Synthes titanium screws, these are cruciform, PlusDrive, or Matrix. The distance between the threads is the pitch.

Intermaxillary fixation (IMF) screws have two holes underneath the head in a 90 degree angle to each other.

RapidSorb screws are made of 85% L-lactide/15% glycolide. They are available as 1.5, 2.0, and 2.5 mm (emergency screw) with a cruciform recess head. For insertion of resorbable screws, drilling and tapping is mandatory. As an alternative to screws, resorbable tags with a diameter of 1.5 mm are available. After drilling, a tag is pressed through the plate into the drilled hole thus fixing the plate to the bone (**Table 1.4.3-3a–c**).

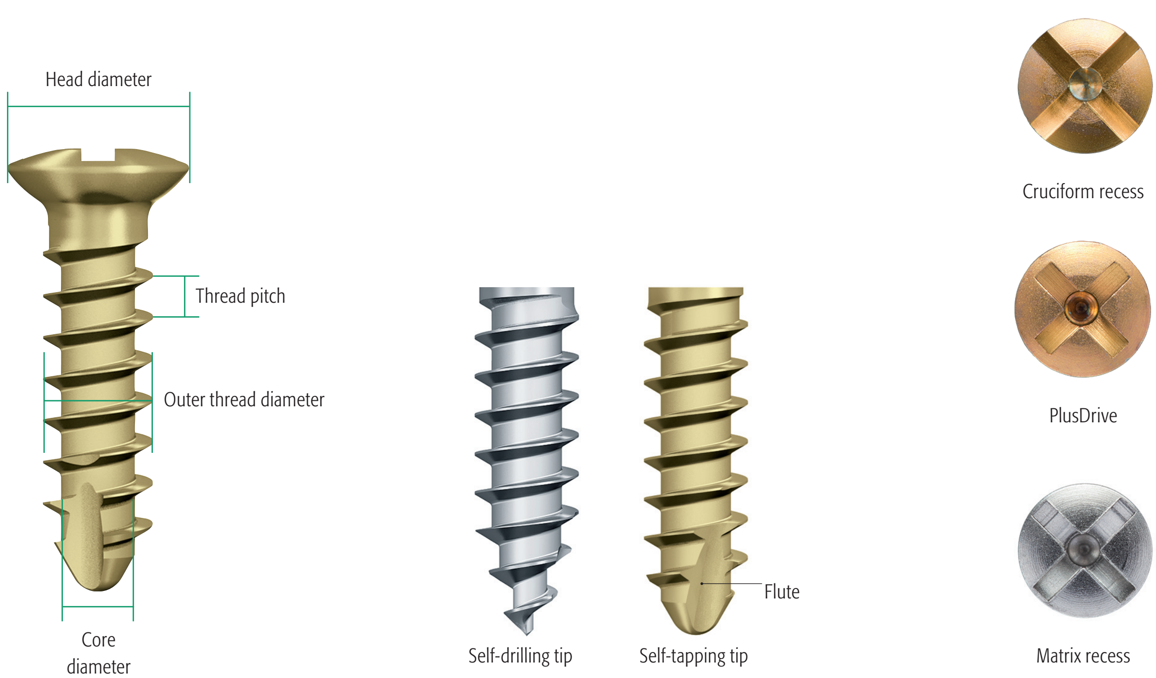


Fig 1.4.3-1 Craniomaxillofacial screws are fully threaded. Self-drilling or self-tapping screws are available.

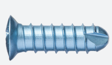
		Screw (midface)	Thread (mm)	Core (mm)	Pitch (mm)	Head ø (mm)	Length (mm)*	Drive
Compact system		1.0 mm, self-tapping or self-drilling (1.2 mm Emergency)	1.0 (1.2)	0.7 (0.9)	0.25 (0.25)	1.6 1.6	Self-tapping: 2, 3, 4, 5, 6, 7, 8 Self-drilling: 2, 3 Emergency: 2, 3, 4, 5, 6, 7, 8	Cruciform and PlusDrive. (Self-drilling screws with PlusDrive only)
Compact system		1.3 mm, self-tapping or self-drilling (1.7 mm Emergency)	1.3 (1.7)	0.9 (1.1)	0.5 (0.6)	2.4 1.4	Self-tapping: 3, 4, 5, 6, 8 Self-drilling: 4, 5, 6 Emergency: 3, 4, 5, 6, 8	Cruciform and PlusDrive. (Self-drilling screws with PlusDrive only)
Compact system		1.5 mm, self-tapping or self-drilling (2.0 mm Emergency)	1.5 (2.0)	1.1 (1.4)	0.5 (0.6)	3.0 3.0	Self-tapping: 4, 6, 8, 10, 12, 14,18 Self-drilling: 4, 6, 8 Emergency: 6, 8, 10, 12	Cruciform and PlusDrive. (Self-drilling screws with PlusDrive only)
Compact system		2.0 mm, self-tapping or self-drilling (2.4 mm Emergency)	2.0 (2.4)	1.4 (1.7)	0.6 1.0	3.5 3.5	Self-tapping: 4, 6, 8, 10, 12, 14, 16, 18 Self-drilling: 4, 6, 8 Emergency: 6, 8, 10, 12:	Cruciform and PlusDrive. (Self-drilling screws with PlusDrive only)
Matrix system		MatrixMIDFACE, self-tapping or self-drilling MatrixMIDFACE, emergency	1.5 1.8	1.2 1.5	0.6 0.6	2.6 2.6	Self-tapping: 3, 4, 5, 6, 8, 10, 12 Self-drilling: 3, 4, 5, 6, 8 Emergency: 3, 4, 5, 6, 8, 10, 12	Matrix
Matrix system		MatrixOrthognatic screw, self-drilling MatrixOrthognatic screw, self-tapping Emergency screw	1.85 1.85 2.1 2.1	1.5 1.5 1.7 1.7	0.6 0.6 1.0 0.6 1.0	2.6 2.6 3.0 2.6 3.0	4, 5, 6, 8 4, 5, 6, 8 10, 12, 14, 16, 18 4, 5, 6, 8 10, 12, 14, 16, 18	Matrix
Resorbable screws		Rapid resorbable screw 1.5 mm	1.5	1.15	0.6	2.5	3, 4, 5, 6, 8	Cruciform
Resorbable screws		Rapid resorbable screw 2.0 mm Rapid resorbable screw 2.5 mm (emergency)	2.0 2.5	1.6 2.0	0.75 0.75	3.2 3.2	4, 6, 8 4, 6, 8	Cruciform

Table 1.4.3-3a Craniofacial screws: midface (Compact and Matrix systems).
* Underlined numbers indicate the length of the screws shown in this table.

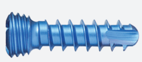
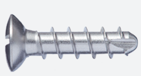
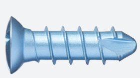
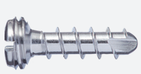
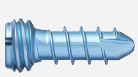
		Screw (mandible)	Thread (mm)	Core (mm)	Pitch (mm)	Head ø (mm)	Length (mm)*	Drive
Compact system		Cortex screw 2.0 mm, self-tapping or self-drilling	2.0	1.35	0.75 (4–6 mm length) 1.0 (8–18 mm length)	3.5	Self-drilling and self-tapping: 4, 6, 8 Self-tapping only: 10, 12, 14, 16, 18	PlusDrive (TAN) and Cruciform (TiCp)
		Emergency screw 2.4 mm	2.4	1.7	1.0	3.5	Emergency: 6, 8, 10, 12	PlusDrive and Cruciform
		2.4 mm TM Trauma, self-tapping	2.4	1.7	1	4.0	6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40	Cruciform
		Emergency screw 2.7 mm, self-tapping	2.7	1.9	1	4.0	Emergency: 8, 10, 12, 14, 16, 18	
		LOCK 2.0 mm, (locking), self-tapping or self-drilling	2.0	1.35	0.75	3.3	Self-tapping: 5, 6, 8, 10, 12, 14, 16, 18 Self-drilling: 5, 6, 8	PlusDrive
		UniLOCK screw 2.4 mm, self-tapping	2.4	1.7	1	4.0	8, 10, 12, 14, 16, 18, 20, 22	Cruciform
		UniLOCK screw 2.7 mm, self-tapping	2.7	1.7	1	4.0	8, 10, 12, 14, 16, 18	
		UniLOCK screw 3.0 mm, self-tapping	3.0	2.4	1	4.0	8, 10, 12, 14, 16, 18	
Matrix system		2.0 mm, self-tapping	2.0	1.4	1	3.5	5, 6, 8, 10, 12, 14, 16, 18	Matrix
		2.4 mm, self-tapping	2.4	1.8	1	3.5	5, 6, 8, 10, 12, 14, 16, 18	Matrix
		2.7 mm, self-tapping (emergency)	2.7	2.1	1	3.5	5, 6, 8, 10, 12, 14, 16, 18	
		2.0 mm locking, self-tapping	2.0	1.4	1	3.3	5, 6, 8, 10, 12, 14, 16, 18	Matrix
		2.4 mm locking, self-tapping	2.4	1.8	1	3.3	8, 10, 12, 14, 16, 18	Matrix
		2.9 mm locking, self-tapping	2.9	2.3	1	3.3	8, 10, 12, 14, 16, 18	Matrix

Table 1.4.3-3b Mandible screws (Compact and Matrix systems).
* Underlined numbers indicate the length of the screws shown in this table.

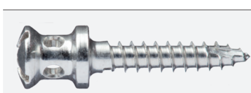
Screw (IMF)		Thread (mm)	Core (mm)	Pitch (mm)	Head ø (mm)	Length (mm)*	Drive
	IMF screw	2.0	1.35	0.75	4.0	8, 12	Cruciform

Table 1.4.3-3c Screw for intermaxillary fixation (IMF).
* Underlined number indicates the length of the screws shown in this table.

2.2 Function of screws

The purpose of screws is to stabilize bone, to secure a bone to a plate or a plate toward bone, to compress bone, or to fix special appliances such as distractors. Stabilization of bone can be accomplished by screws only (positional or compression technique) or by securing the bone to a plate. Compression can be accomplished via the lag screw principle or by the spherical gliding principle with a dynamic compression plate. While the concept of compression is currently controversial regarding its necessity for bone healing, compression does help to increase the stability of the reduction.

2.3 Types of screws

The nomenclature for screws (and the entire plate/screw system) in conventional systems follows the measurement of the outer thread diameter and the screw type. The outer thread diameter is measured in millimeters. Thus, 2.4 refers to a 2.4 mm outer thread diameter.
Two basic types of metal screws are in clinical use, conventional screws with a single thread and locking head screws. All Matrix Midface screws have an identical diameter of 1.5 mm and emergency screws of 1.8 mm. However, Matrix Mandible screws come in different outer thread diameters (2.0, 2.4, 2.7 emergency, and 2.9 mm) and can be used with all Matrix Mandible plates.

Three subtypes of conventional screws exist. The first screw generation needed pretapping with a tap of corresponding size. Today only biodegradable screws need pretapping to avoid shearing-off of screw heads during insertion. A self-tapping screw eliminates the need for preparing the bone with a tap. This inevitably saves steps in the procedure and therefore time. The tapping procedure removes select amounts of bone and creates an intimate receptacle for the screw. The flutes at the end of the self-tapping screw act as a tap and collect bone debris as the screw is advanced. A self-drilling and self-tapping screw eliminates the need for a drill, thus saving time by eliminating steps. The tapered edge of this type of screw acts as a drill, but is only used in limited circumstances based on the bone quality.

Locking head screws are screws with two threads, one to anchor the screw in the bone and a second thread to lock the screw to the plate. For locking head screws, the pitch along the core must be proportional in ratio to the pitch along the head (**Fig 1.4.3-2**). This permits engagement of both the bone and the plate. A disproportional pitch would not permit engagement of the plate.

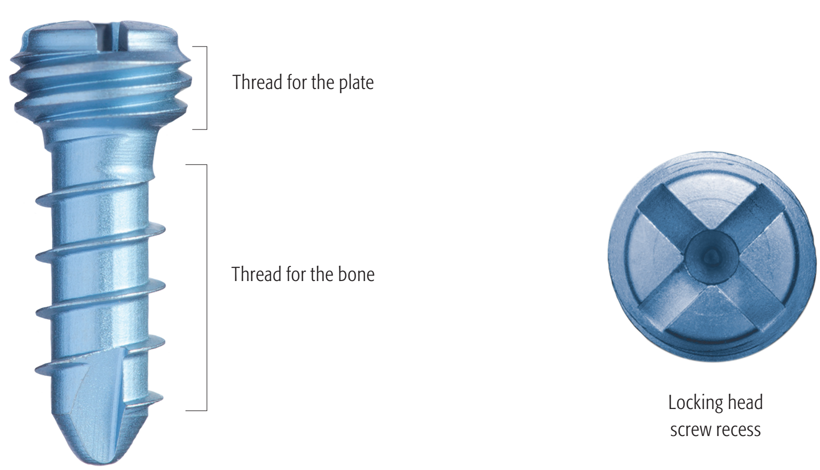


Fig 1.4.3-2 Locking head screw.

Locking head screws are a considerable advancement in plate/screw technology. Whereas conventional screws act by pressing the plate to the bone, locking head screws are locked into the plate (**Fig 1.4.3-3a–b**). Locking plate-screw combinations thus become a form of internal "external fixator." They do not depend upon the integrity of the outer table of bone to keep the plate/screw/bone interface intact and stable. They are particularly advantageous in bone of reduced quality. Moreover, because the screw is locked to both the plate and bone, relative movements between the plate, screw, and bone will not occur. This reduces fretting (movement between plate, screw, and adjacent or overlying tissues) and ultimately, fretting corrosion as well as screw loosening.

2.4 Technique and instruments for screw insertion

While the placement of screws might at first seem relatively simplistic, there are certain caveats that assure greater stability, better healing, and less breakage of the screw. The drill corresponding to the screw to be inserted is the same diameter as the core of the screw (**Fig. 1.4.3-4**). The drill should be used with the appropriate power tool described in the sections to follow. It should be stabilized adjacent to the bone or plate with the corresponding drill guide. This permits concentricity of the receptacle hole and screw during placement. Without such, there is a greater chance of the screw head shearing off the screw core. The drill guide and bone should be cooled while drilling to assure that the bone remains at a temperature of less than 47°C. This minimizes bone damage and necrosis.

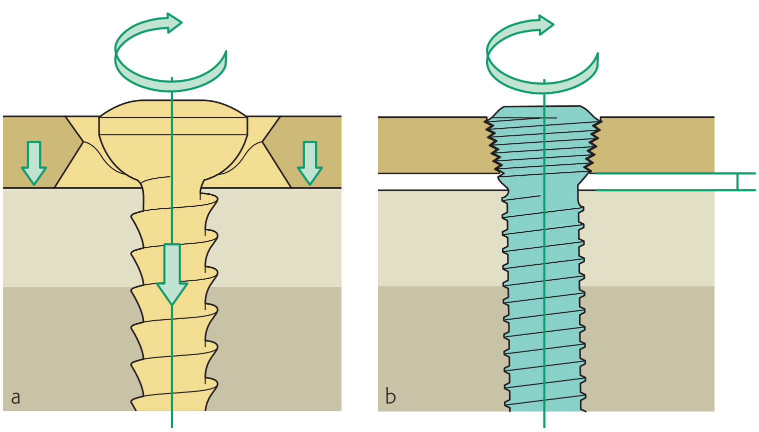


Fig 1.4.3-3a–b
a Conventional screw pressing the plate against the bone.
b Locking head screw stabilizing the plate without direct bone/plate contact.

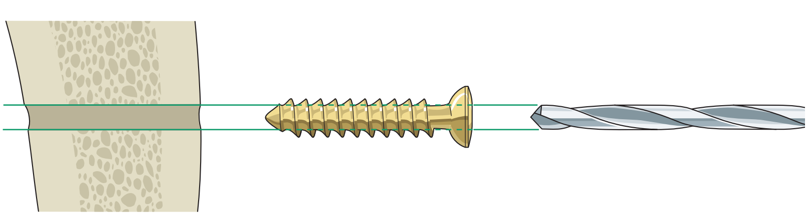


Fig 1.4.3-4 The drill bit diameters correspond with the core diameter of the corresponding screws.

The drill should be removed from the bone while it is still rotating. If the drill is allowed to stop rotating while in bone, it may become lodged in the bone and break. Once the drill is removed, for bicortical screw fixation, a depth gauge is used to measure the length for the screw to be placed. Finally, the screw is placed.

When securing plates with screws, the plate is first secured to the bone with the appropriate clamp. A drill guide is placed within the plate hole to maintain concentricity (neutral screw) or eccentricity (compression screw). For placement of locking head screws special drill guides that are screwed into the plate hole before drilling are recommended.

3 Plates

Since the initial application of rigid fixation to the mandible, numerous plate designs, differing in size, shape, dimension, and purpose have been developed and introduced for use in craniomaxillofacial fixation. Since the initial application four decades ago, continuous modifications of materials and design were made to improve implants, and therefore, patient care. Developments this past decade include the design of plates specific to particular anatomical regions, locking technology, and mesh, to name just a few.

3.1 Function of plates

The basic functions of a plate are to stabilize bone and/or bridge a void or gap, temporarily or permanently. Stabilization of bone can be performed by the most diverse forms and types of plates and by using different techniques (**Table 1.4.3-4**).

According to plate design, plates can be classified into adaptation plates, compression plates, and locking plates.

Adaptation plate	A 1.0 to 2.0 mm plate or Matrix plate with a chain-link design that permits linking of bone segments.
Dynamic compression plate (DCP)	A plate using the gliding-hole principle to compress the fragments.
Locking plate	A plate with a threaded hole. This plate is engaged by and therefore locked to the screw creating one stable unit.
Limited-contact dynamic compression plate (LC-DCP)	A compression plate with channels removed from the underside to permit less bone surface contact and more soft tissue ingrowth.
Reconstruction plate	A wide plate with a higher profile and therefore strong enough to provide the effects of buttressing.
Universal fracture plate	A plate with a chain-link design. While it looks like a reconstruction plate it is not as wide or as thick and therefore not as strong. It is a form of stabilization plate.
Plate profile	The height of the plate as measured from the undersurface (the portion which contacts bone) and the outer surface.
Intersection bar	The connection between two holes of a plate.
Strut plate	A plate composed of two plates linked together with interconnecting bars.

Table 1.4.3-4 Glossary of terms for plates.

Adaptation plates have round plate holes. Screws are typically placed into the center of each hole (**Fig 1.4.3-5**).

Compression plates have specifically designed oval-shaped plate holes with an oblique inner surface, that allow eccentrically placed screws to glide down the oblique inner surface of the hole to finally be centered within the plate hole (**Fig 1.4.3-6**). During this process the screw, which is firmly anchored into one fragment, takes the underlying bone with it. This facilitates a defined movement of the fragment toward the fracture line. If this procedure is performed on both sides of a fracture ultimately the two fragments are compressed, and the procedure is described as a compression osteosynthesis (**Figs 1.4.3-7a–f**, **1.4.3-8a–c**).

Fig 1.4.3-5 Section of an adaptation plate, titanium, thickness: 0.8 mm.

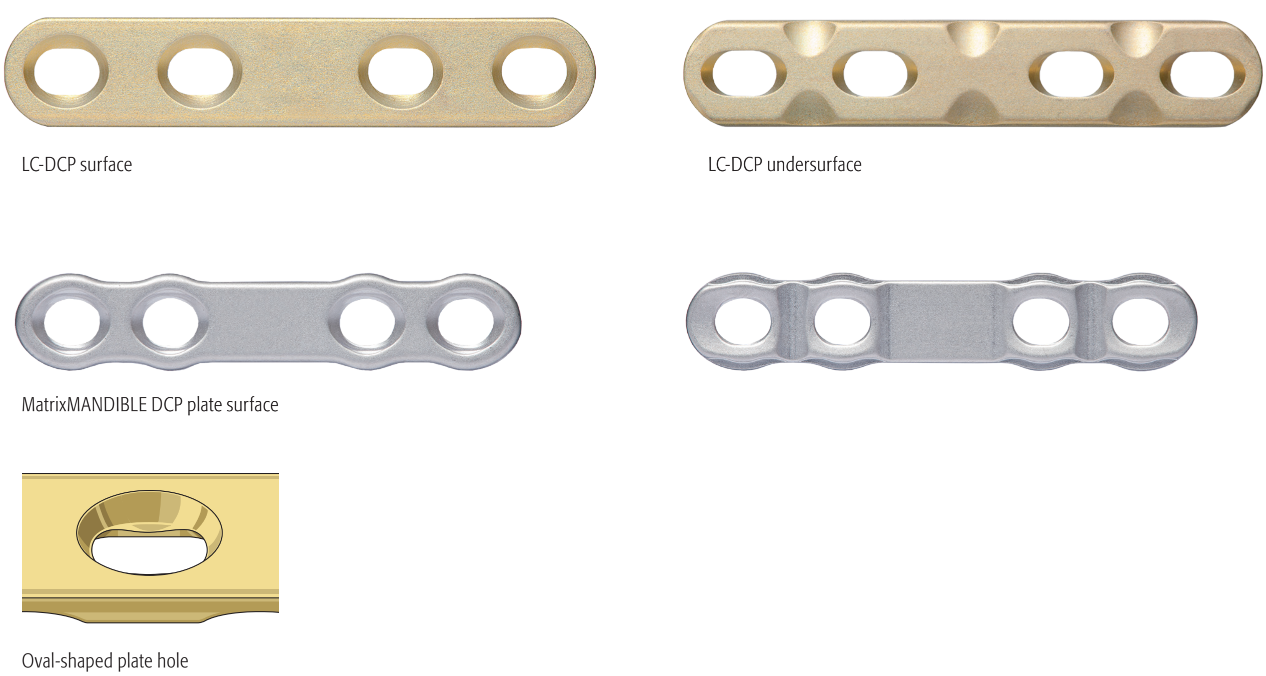


Fig 1.4.3-6 Limited contact dynamic compression plates (LC-DCP). Limited contact design for minimal contact with the bone without impairing the implant strength.

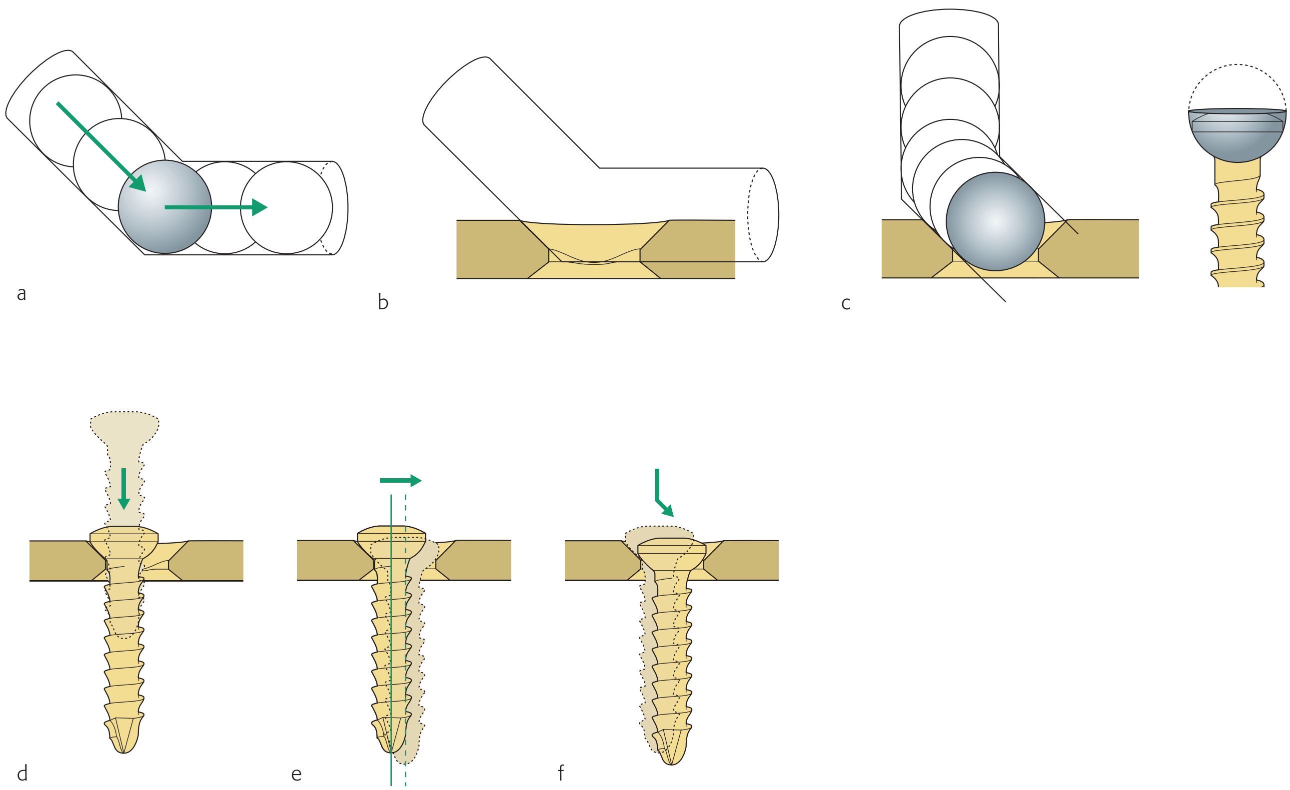


Fig 1.4.3-7a–f Compression with a plate.
a The screw head moves in the oval-shaped plate hole like a ball in an angled cylinder.
b The screw hole can be seen as a section of an inclined and a horizontal cylinder.
c The screw head can be interpreted as a section of a ball gliding down in the DC hole of the plate because of its spherical undersurface.
d The eccentrically placed screw arrives at the rim of the plate hole.
e–f As the screw is driven in, it glides within the plate hole to its final, centered position.

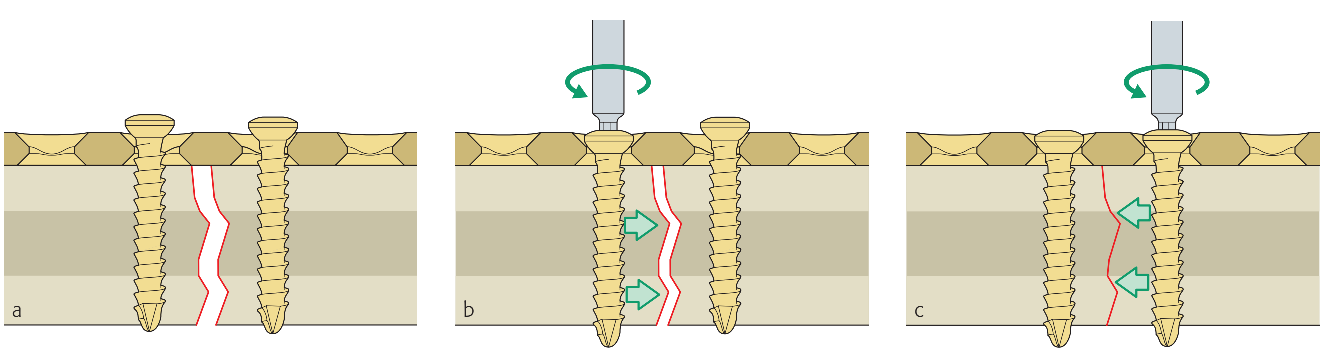


Fig 1.4.3-8a–c Compression with a plate.
a The two innermost screws should be placed eccentrically within the DC holes.
b As these screws are driven in, they approximate the fragments.
c With final tightening of the screws, compression is achieved. The remaining screws are placed in neutral position.

Locking plates have threaded plate holes. Since a locking screw will always lock centrically into the plate hole, it should be inserted strictly perpendicular to the plate in the 2.4 system. The Matrix Mandible locking plates allow for a screw angulation up to 15 degrees. However, it must be noted that conventional screws may also be used with a locking plate (**Fig 1.4.3-9**), but in this case the plate will not be locked to the screw.

Apart from that plates do come in different sizes (height, width, length), but in conventional plate systems they are typically described by the outer core diameter of the screws that are used along with a plate. Therefore, the term "plate 2.0" means that the plate is used together with 2.0 mm screws. This denomination does not say anything about plate dimensions and has been chosen to make communication between operating room personal and surgeons easier.

Plates have different sizes according to their purpose. Plates used to bridge defects in loaded areas such as the mandible (load bearing plates) need to be bigger in size compared with plates used for fixation in non-loaded areas, such as the frontal bone.

Plates do also come in different designs, which have evolved through many years of product development and clinical research. Whereas the first plates had a relatively simple bar-like design, newer plate designs have lateral groves to facilitate 3-D bending or undercuts to reduce the contact area between plate and bone thus allowing for soft-tissue ingrowth and better vascularization of the underlying bone. Other plate designs include special plates for defined anatomical regions, such as orbital plates. Their function is not so much fixation of bone fragments but reconstruction of orbital or facial walls.

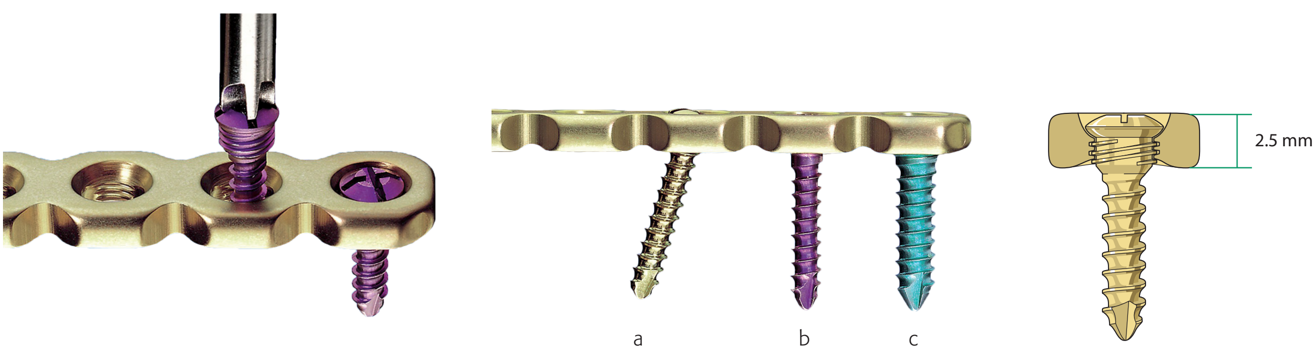


Fig 1.4.3-9 Locking reconstruction plate with threaded holes. 2.4 mm cortex screw (can be placed in an angled position) (a). 2.4 mm locking head screw (b). 3.0 mm locking head screw (c).

3.2 Craniofacial plates

The greatest offering in terms of diversity in size, shape, and application are for craniofacial plates. Craniofacial plates are available in the Matrix and conventional 1.0, 1.3, 1.5, and 2.0 mm plating systems. The plates offered vary greatly in length, width, and profile (**Fig 1.4.3-10**). Straight plates, multiple link adaptation plates, curved orbital rim plates, and strut plates make up the majority of the plates offered. The strut plate has the advantage of increased stability due to its cross-linked design. L-plates, oblique L-plates, X-plates,

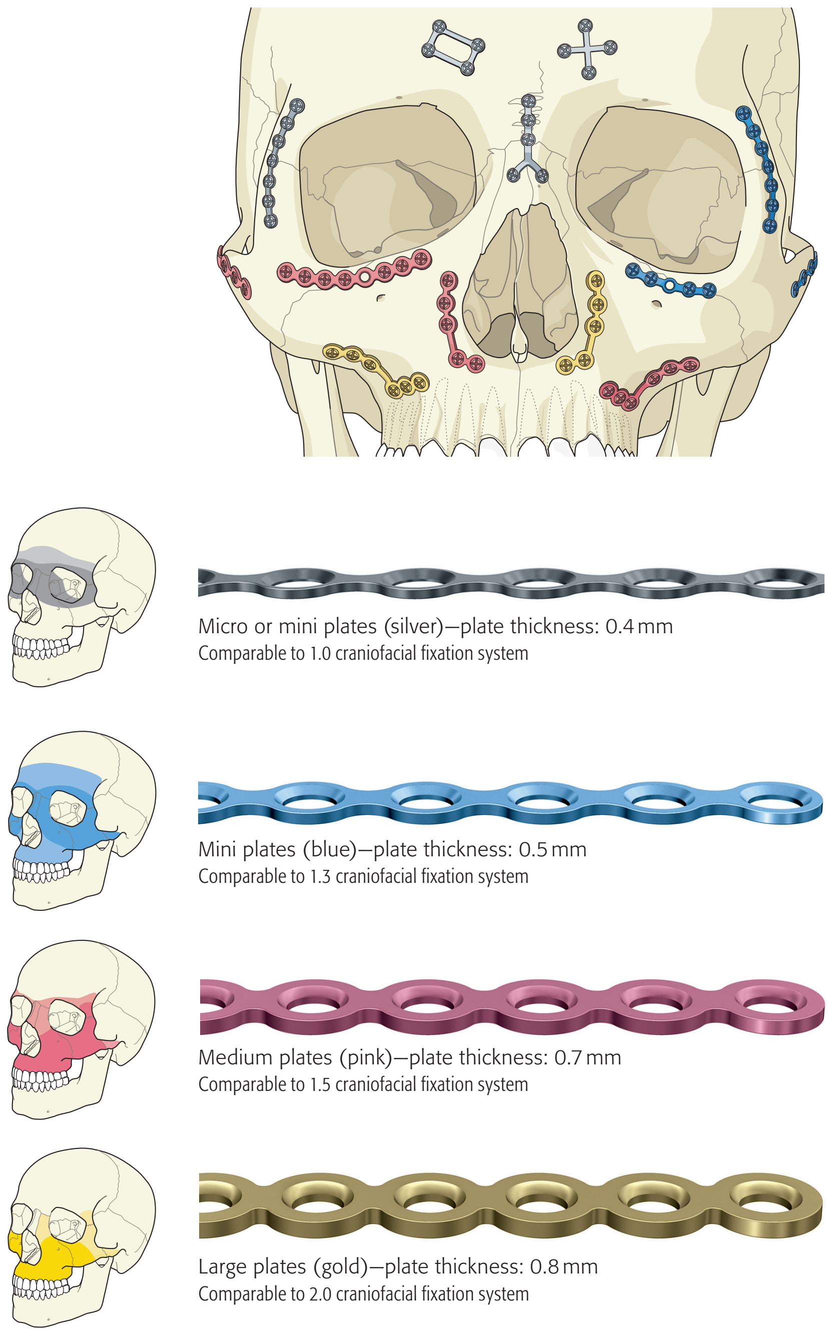


Fig 1.4.3-10 Craniofacial plates from the MatrixMIDFACE plating system are color coded according to plate thickness (0.4 mm–0.8 mm). All plates are used with one screw dimension.

Y-plates, Z-plates, T-plates, H-plates, double Y-plates, and box plates of multiple sizes and lengths complement the systems (**Fig 1.4-11**). Eight different internal orbital plates exist for custom reconstruction of internal orbital injury. Among other fixation devices are cranial burr hole covers, cranial clamps, and a multitude of mesh types (**Fig 1.4.3-12**).

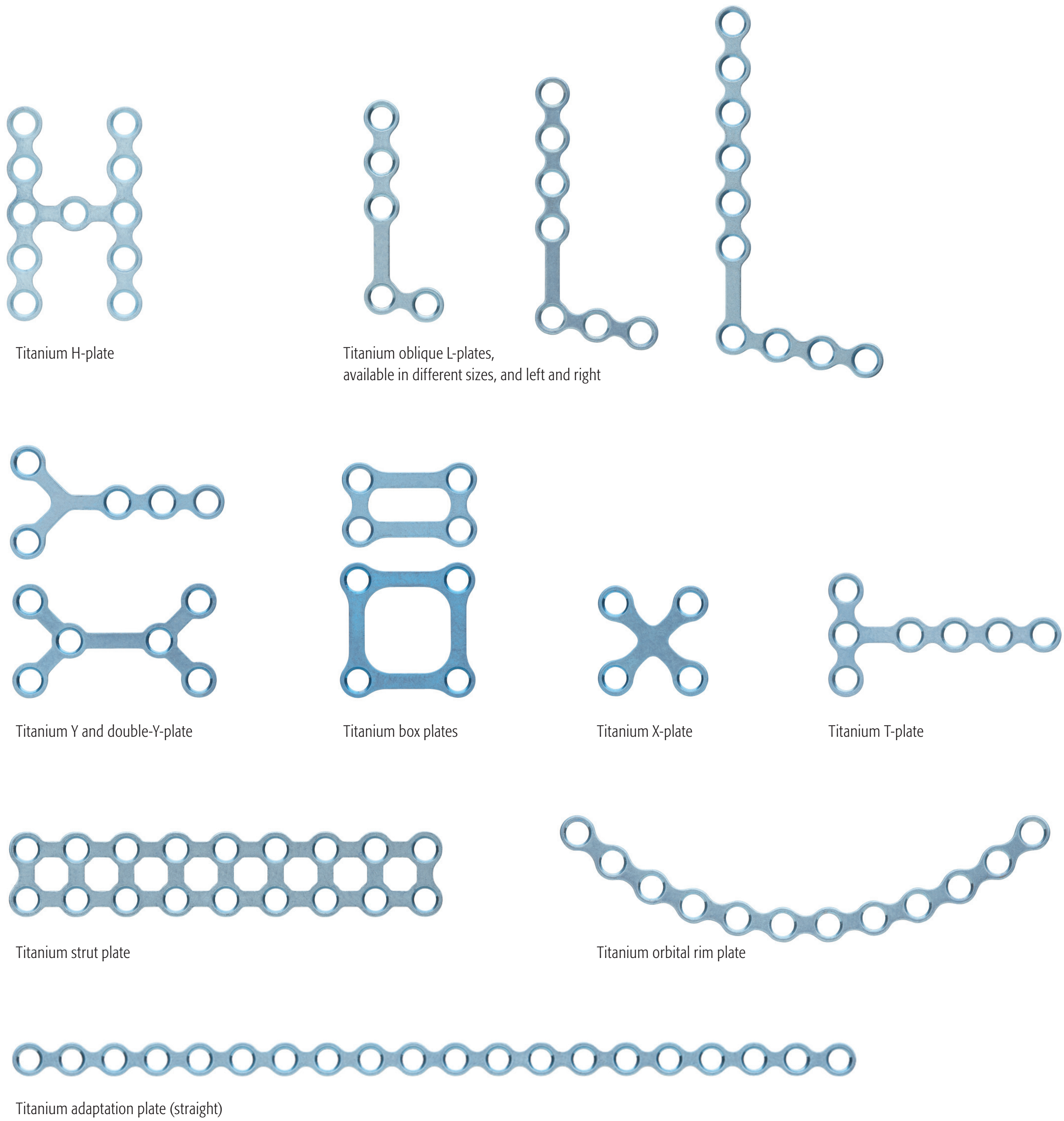
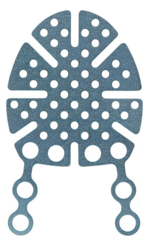
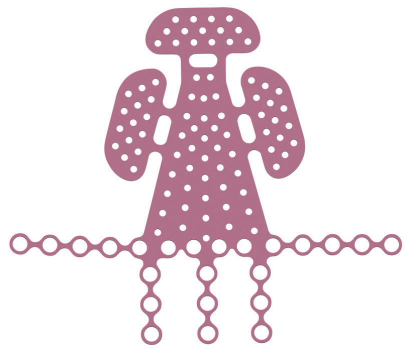


Fig 1.4.3-11 Matrix craniofacial plates are designed for MatrixMIDFACE screws. These plates are used mainly for the midface and cranial areas. They are available in different sizes, ranging from 0.4 mm to 0.8 mm.

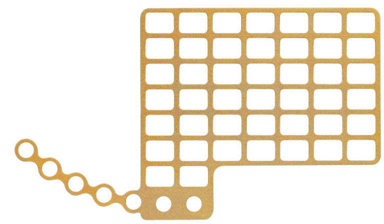


Titanium orbital floor plate, anatomic, small

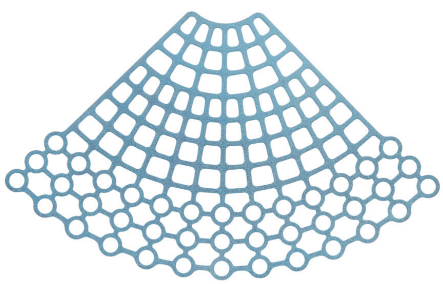
Titanium orbital floor plate, anatomic, large



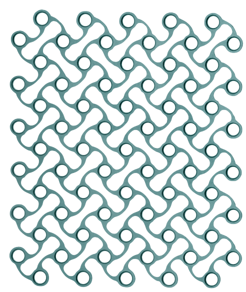
Titanium universal orbital floor plate



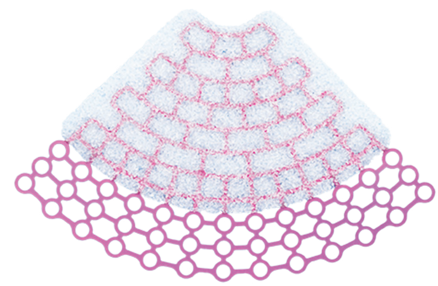
Titanium universal medial wall plate (available as left or right)



Titanium orbital mesh plate

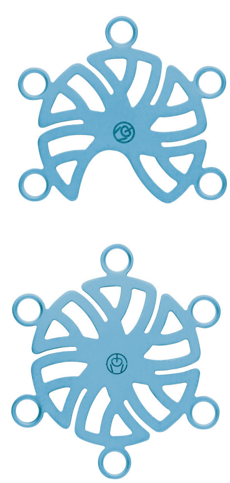


Titanium MatrixNEURO contourable mesh plate, malleable

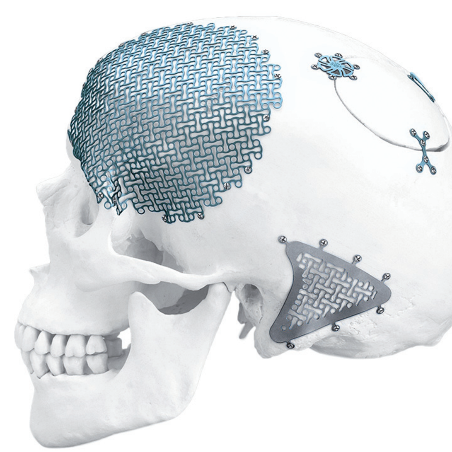


SynPOR titanium reinforced fan plate with exposed fixation holes

Titanium preformed orbital plate (available small and large, left and right versions)



Burr hole cover with and without shant



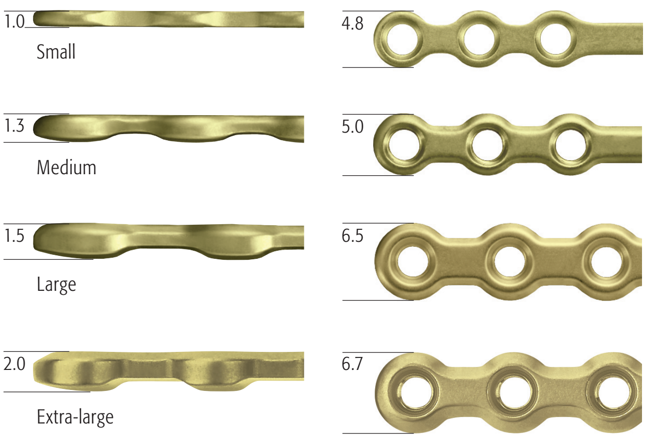
Two different types of meshes and burr hole covers in place (contourable mesh, mastoid plate, burr hole cover, double Y-plate).

Fig 1.4.3-12 Craniofacial plates: MatrixMIDFACE orbita plates, burr hole covers, and meshes.

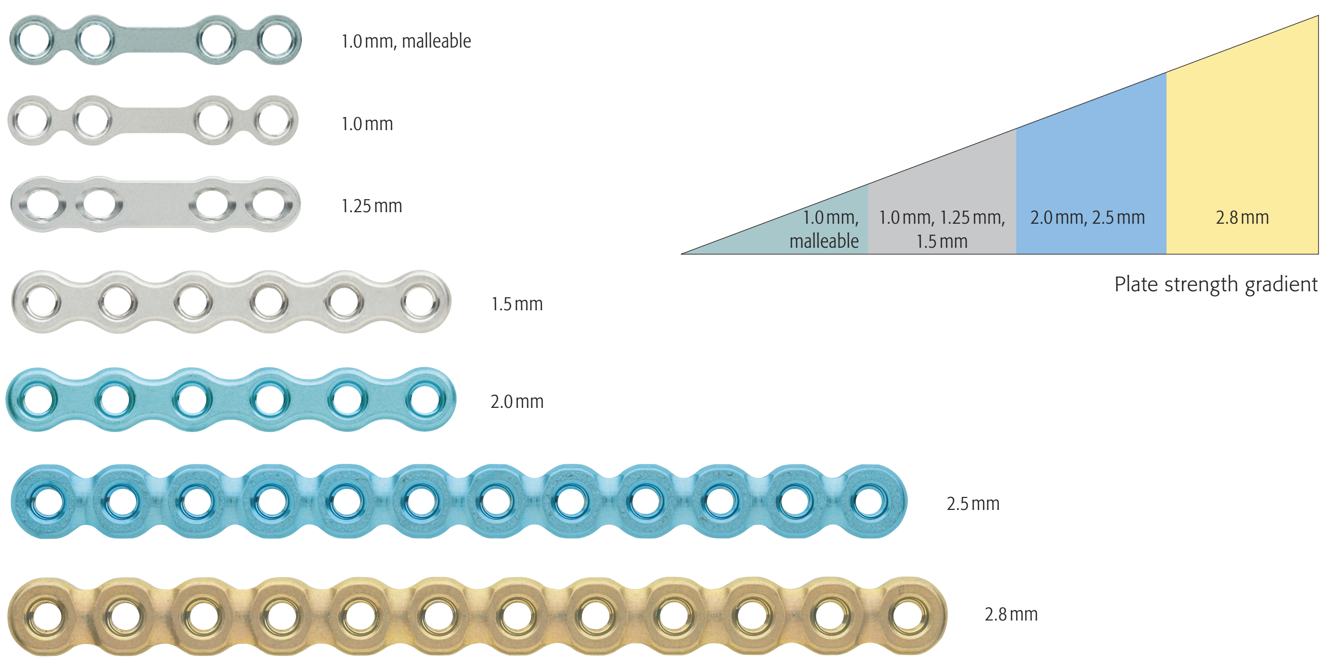
Author Richard H Haug

3.3 Mandibular plates

Numerous forms of mandibular plates have been developed for varying conditions and circumstances. Miniplates are available when indicated for fractures requiring minimal or moderate resistance to three-dimensional deforming forces, for so-called load-sharing situations (see chapter 1.5.6 Principles of stabilization). These may or may not use locking technology (**Fig 1.4.3-13a–b**). More rigid mandibular plates are fabricated in various forms. These include the universal fracture plate and limited contact dynamic compression plate



a



b

Fig 1.4.3-13a–b Mandibular plates.
a 2.0 Compact LOCK plates.
b MatrixMANDIBLE plate system.

(LC-DCP). The universal fracture plate has a chain-link design that allows for easy bending and limited bone contact that permits periosteal ingrowth (**Fig 1.4.3-14**). The undersurface of the LC-DCP also allows for limited bone contact, again permitting periosteal ingrowth.

Reconstruction plates have been developed for fixation of atrophic edentulous mandibles, multifragmentary fractures, or reconstruction requiring the load-bearing effects of a larger plate. These may or may not utilize locking technology (**Fig 1.4.3-15**). Additionally, four condylar head add-ons

Fig 1.4.3-14 Universal fracture plate.

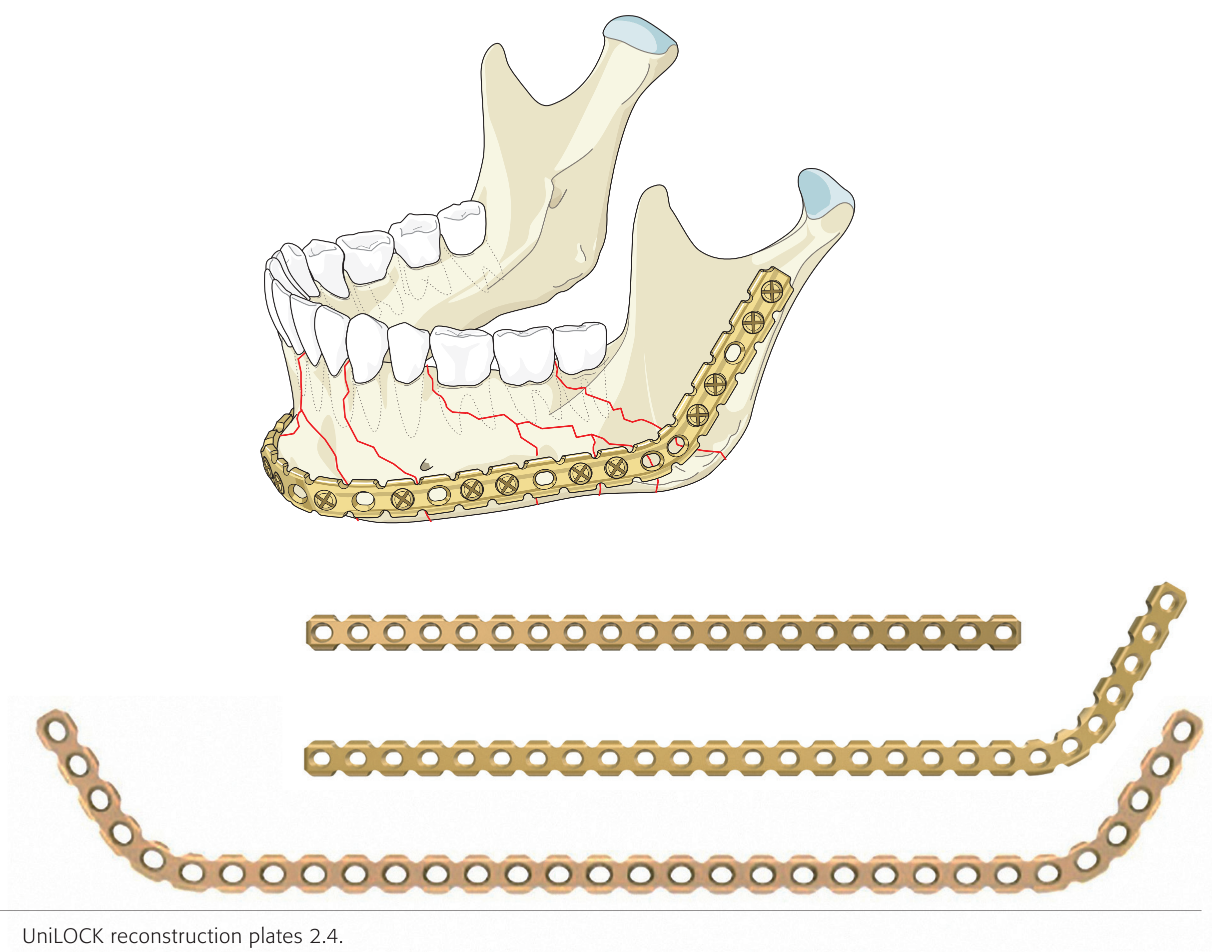


Fig 1.4.3-15 UniLOCK reconstruction plates 2.4.

are available for reconstruction plates, whose height can be adjusted in increments of 2 millimeters (0–6 mm) (**Fig 1.4.3-16**). Similar mandibular plates are available from the Matrix Mandible system. A newer development are the preformed reconstruction plates. These plates were designed after analysis of 1,000 CT-scans of human mandibles and come in three different sizes (**Fig 1.4.3-17a–b**).

Special anatomically shaped plates have been designed for the subcondylar region (**Fig 1.4.3-18**).

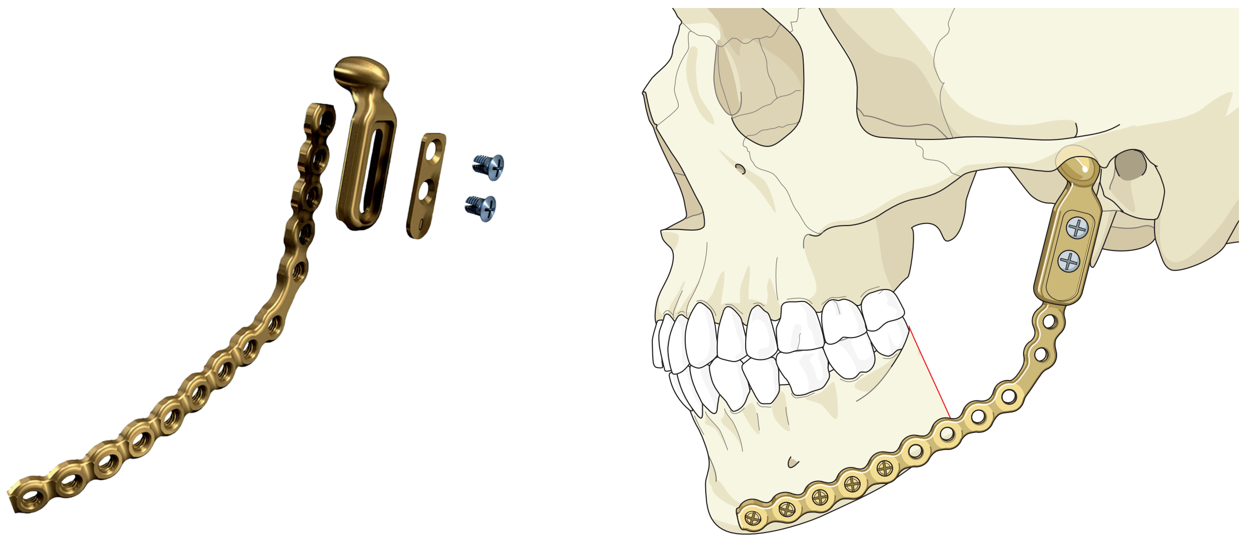


Fig 1.4.3-16 MatrixMANDIBLE reconstruction plate with condylar head add-on.

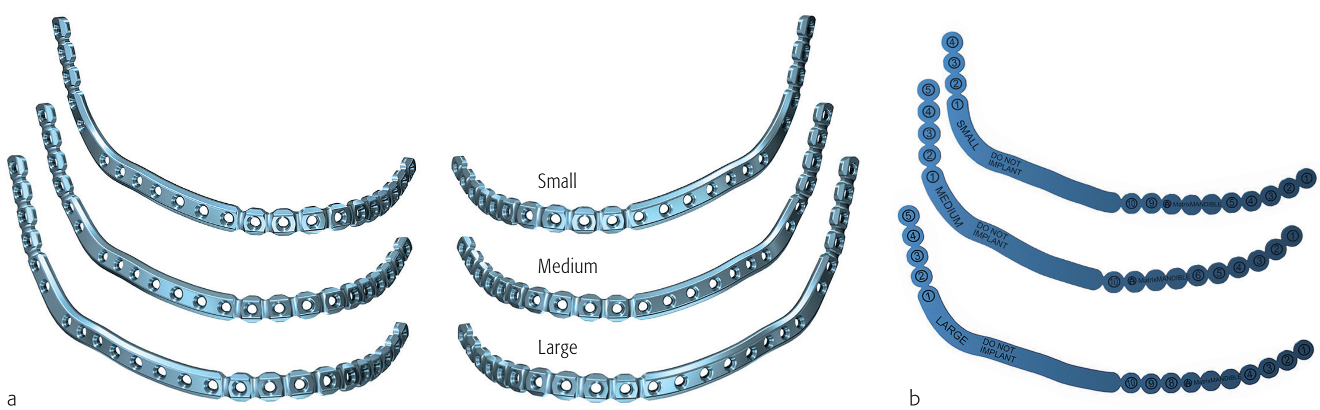


Fig 1.4.3-17a–b Preformed MatrixMANDIBLE reconstruction plates (a) and corresponding bending templates (b).

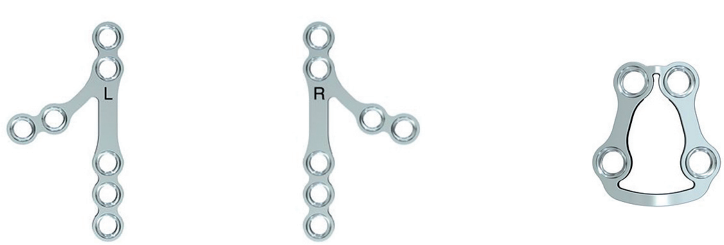


Fig 1.4.3-18 MatrixMANDIBLE subcondylar plates.

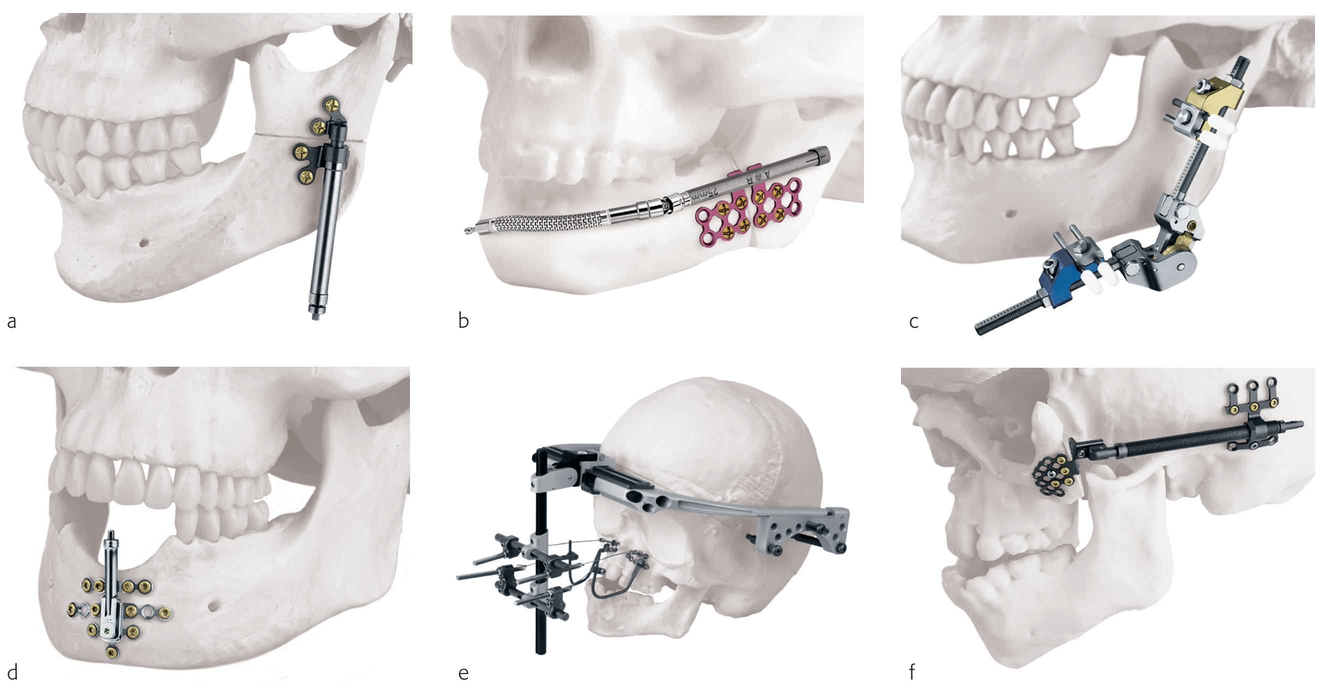
4 External fixators

External fixators are available for the mandible. External fixators are used for immediate stabilization in emergency situations (gun shot injuries, high-energy trauma) and for temporary defect bridging in oncology. The components are Schanz screws, mandible rods, and clamps (**Fig 1.4.3-19a–d**).

Fig 1.4.3-19a–d External fixation.
a External fixator fixed to the left mandible.
b Prebent rods.
c Schanz screws.
d Clamp.

5 Distraction devices

Decades after the development of distraction osteogenesis, a resurgence of interest has taken place within the surgical community. While initially a focus of attention for orthopaedic surgeons, much enthusiasm now exists among craniomaxillofacial surgeons for this technology. The first of the distractors to gain popularity was the single-vector distractor for mandibular application. While the first distractors of this type were applied externally, internal single-vector distractors are currently also available (**Fig 1.4.3-20a–b**). As technology has advanced and our understanding of the complexities of osteogenesis has matured, multivector distractors were developed. These multivector distractors have the ability to permit body and ramus elongation simultaneously (**Fig 1.4.3-20c**). The contours of the mandible and thus the esthetics of the face are more accurately established. Segmental distractors for ridge augmentation have also been developed (**Fig 1.4.3-20d**). The combination of experience with mandibular distraction and orthognathic surgery has permitted the development and refinement of external (**Fig 1.4.3-20e**) and internal maxillary distractors (**Fig 1.4.3-20f**). These distractors permit controlled advancement of the maxilla despite the challenging contours of the midface. For craniomaxillofacial deformities, osteotomies in combination with external distraction appliances and traction are alternatives to osteotomies, fragment positioning, and bone grafts. Internal midface distractors (**Fig 1.4.3-20g**) allow controlled advancement without the psychosocial effects of an external appliance.



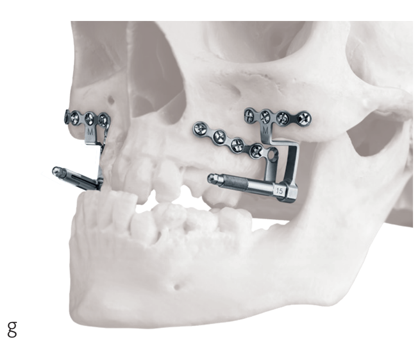
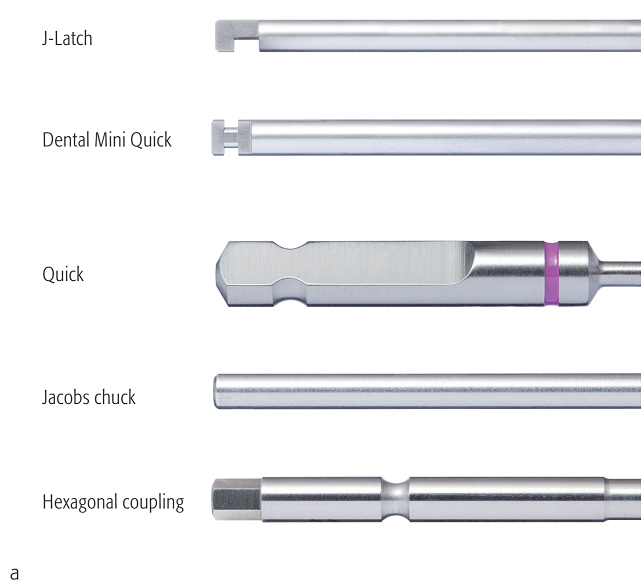


Fig 1.4.3-20a–g Distraction.
a Single-vector mandible internal distractor.
b Single-vector mandible internal distractor with flexible rod.
c Multivector mandible external distractor.
d Two-vector alveolar ridge distractor.
e Multivector external midface distractor.
f Single-vector internal lower midface distractor.
g Single-vector internal midface distractor.

6 Instruments

Drill bits: A selection of drill bits is used with the corresponding screws. These are twist drills that are standard (without stop), or with stop, and have shaft ends compatible with any power tool. These include hexagonal coupling, J-latch, and quick coupling (**Fig 1.4.3-21a–b**). The drill bit diameters correspond with the core diameter of the corresponding screws (**Fig 1.4.3-4**). The drill bits come in varying lengths for use with or without a trocar.

Taps: When tapping is preferred or needed (this is especially true for resorbable systems), a variety of taps are available. These are fluted and come with diameters that correspond to the outer thread diameter of the screws and are of varying lengths (**Fig 1.4.3-22**). The taps have quick coupling, hex coupling, or J-latch couplings that correspond to the appropriate handle. The sharp edges of the tap threads cut the bone while the flutes gather bone debris. These should be advanced three turns clockwise and then back once counterclockwise, and then advanced again three turns clockwise. This permits the flutes to adequately collect the bone debris, rather than the debris collecting along the threads and thereby preventing precise cutting of the screw receptacle site. Tapping should always be done by hand and not with power tools to avoid stripping and distraction of the thread within the bone.



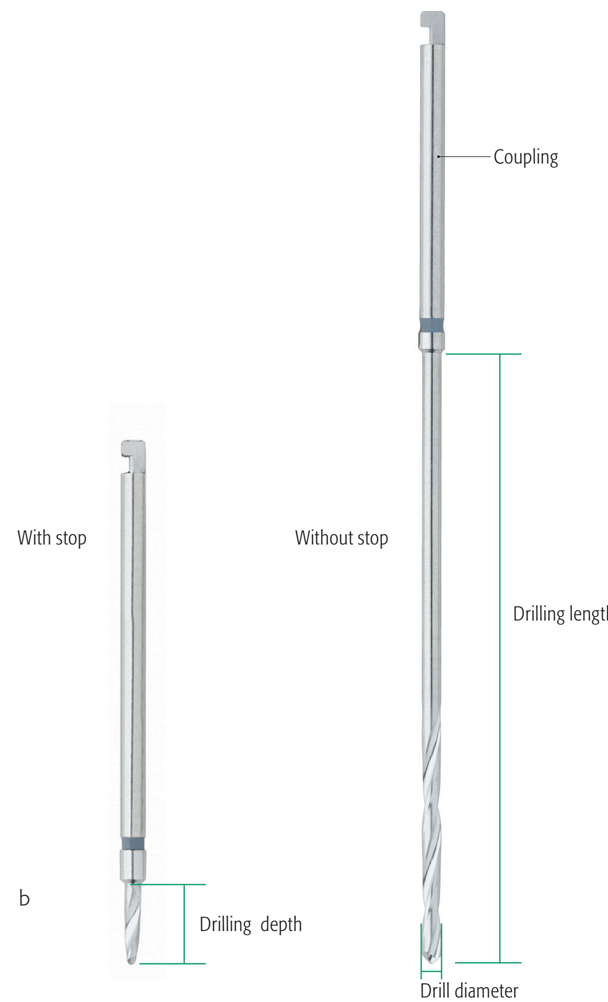


Fig 1.4.3-21a–b
a The various couplings for drill bits and screwdrivers.
b Drill bits consisting of shaft with coupling, drilling length, and drill diameter which corresponds to the core of the screw and cuts the pilot hole. The tips of the drill bits may be with or without stop.

Fig 1.4.3-22 Tap.

Handles: Handles may be required for taps, countersinks, or screw driver blades. These handles may be stationary without a rotating palm grasp, a jeweler's handle that permits rotation, or ratcheting (**Fig 1.4.3-23a–d**).

Screwdrivers: A number of different screwdrivers are available. Screw driver blades are available that fit into corresponding handles. These come in an array of variations that fit with cruciform, PlusDrive, and Matrix screws. They are either self-retaining or are used with a sleeve that holds the screw. The most unique is the 90° or right angle screwdriver which is useful for transoral ramus approaches, or for endoscopic approaches. This particular screwdriver possesses a handle, main body, head piece, extension arm, and screw holder (**Fig 1.4.3-24a–c**).

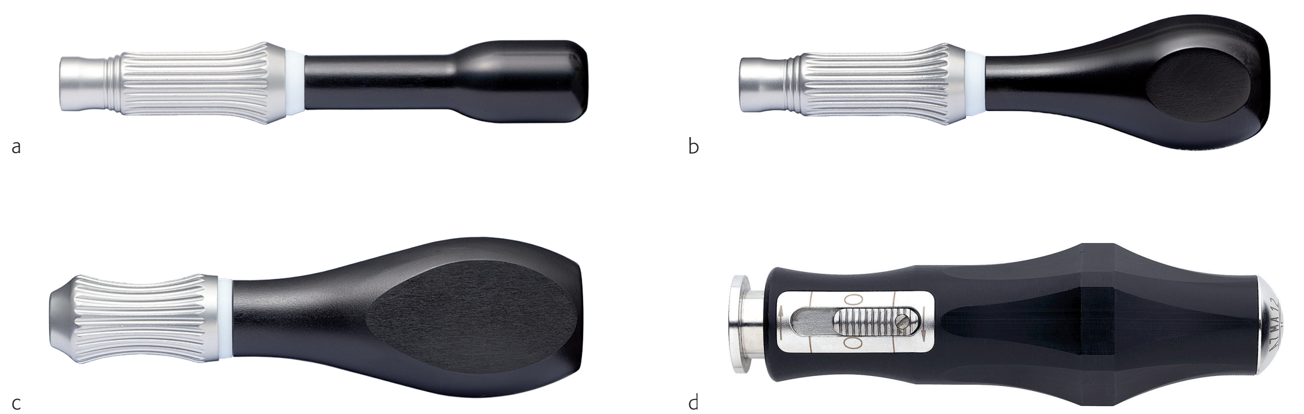


Fig 1.4.3-23a–d Handles.
a Small handle with hexagonal coupling.
b Medium handle with hexagonal coupling.
c Large handle with hexagonal coupling.
d Ratcheting screwdriver handle with hexagonal coupling.

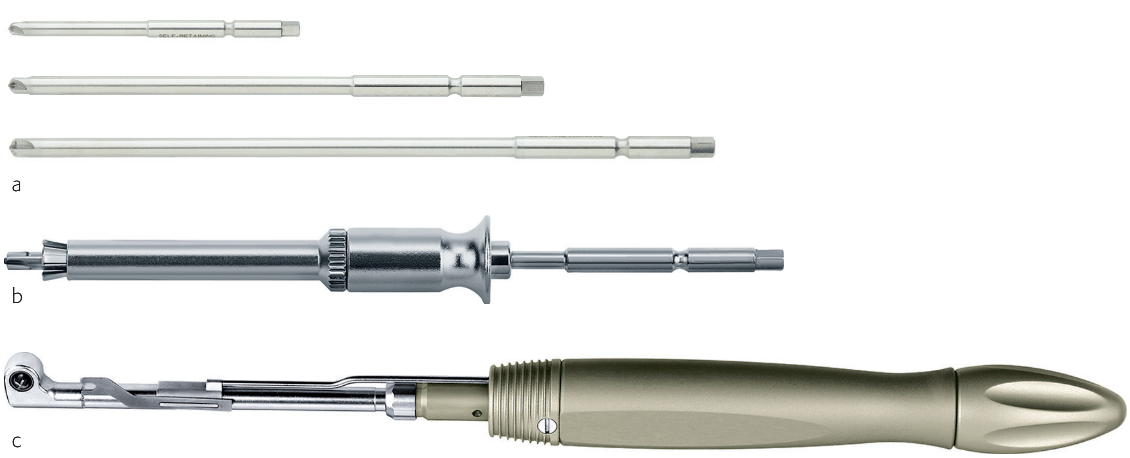


Fig 1.4.3-24a–c Screwdrivers.
a Screwdriver shaft MatrixMIDFACE, self-holding, with hexagonal coupling.
Short; length 52 mm. Medium; length 76 mm. Long; length 96 mm.
b Screwdriver shaft MatrixMIDFACE , with holding sleeve and hexagonal coupling.
Medium; length 79 mm. Long; length 95 mm (shown here).
c 90° angled screwdriver.

Drill guides: Drill guides are available for numerous specific purposes. The internal diameter corresponds to the appropriate drill to be used. They come in lengths for standard drill bits, or for use with a trocar. Neutral drill guides are designed to insert a screw centrally (neutral) into a plate hole. Eccentric drill guides are designed to place a screw eccentrically into a compression plate hole (see **Fig 1.4.3-7**). Threaded drill guides are available for use with locking plate and screw systems. They are threaded into the plate before the drill is introduced. The drill guides are intended to maintain concentricity of the drill hole and screw core and for soft-tissue protection **(Fig 1.4.3-25a–e)**.

Depth gauges: While numerous types of depth gauges are available for different applications, they have the same basic design. The shaft of the instrument contains the graduated markings. The blade has a tip that catches the underside of the bone. The blade is attached to a separate handle that is adjusted by the thumb of the dominant hand. Different lengths of shaft are provided to permit use through a trocar (**Fig 1.4.3-26**).

Countersink: When using the lag screw technique, countersinking the outer cortex of bone assures the appropriate receptacle site for the screw head. They are provided with centering pins that correspond to the appropriate core diameter. These are provided with a coupling that fits with the appropriate screwdriver handle (**Fig 1.4.3-27**). Countersinks should not be used with power tools.

Templates: Aluminum templates are available for plates. These templates are easily bendable in three dimensions permitting the recreation of the complex contours of the craniofacial skeleton. They can also be cut to fit the dimensions to be recreated. The plates can then be contoured using the template as a guide. These templates can be sterilized and re-used (**Fig 1.4.3-17b**).

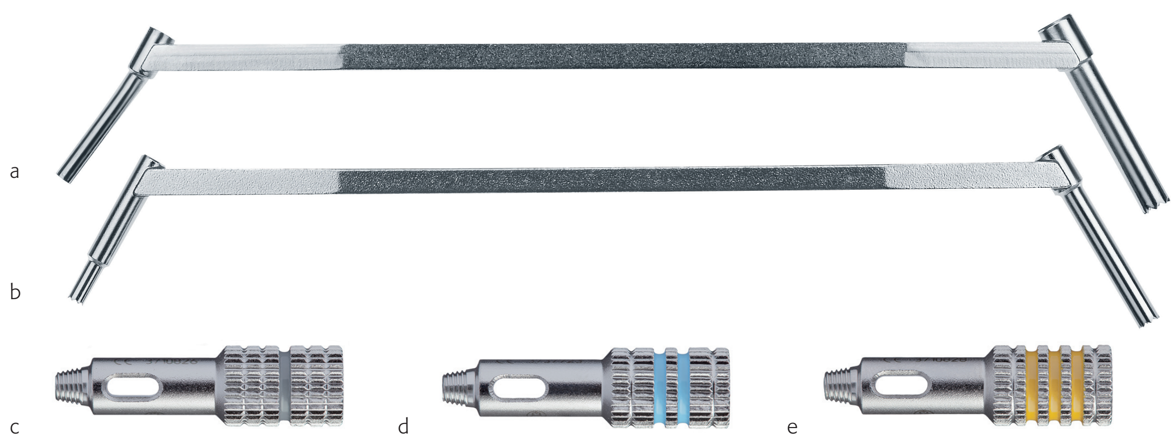


Fig 1.4.3-25a–e Drill guides.
a Nonthreaded double drill guide 2.4/1.8
b Nonthreaded double drill guide 2.0/1.5
c Threaded drill guide 1.5 (silver)
d Threaded drill guide 1.8 (blue)
e Threaded drill guide 2.4 (gold)

Fig 1.4.3-26 Depth gauge.

Fig 1.4.3-27 Countersink.

Bending irons and pliers: The bending of plates can be accomplished with three basic forms of instruments. The first and most simple are bending irons. They are single-unit instruments with a handle and stainless steel plate receptacle that are used to bend and contour mandibular plates. While simplistic, they are capable of engaging the plate to provide contouring in three dimensions (**Fig 1.4.3-28a–c**). Bending pliers come in two basic forms. The first is a single hinge and is useful for contouring miniplates and microplates (**Fig 1.4.3-29**). The second type of pliers uses the mechanical advantage of a fulcrum. This additional mechanical advantage permits easier contouring of miniplates or large mandibular plates (**Fig 1.4.3-30a–b**). The contoured anvil within the pliers' tips permits the creation of gentle curves.

Plate cutters: Three different forms of plate cutters are available for titanium plates. The simple shears construction works effectively for mesh and craniofacial plates (**Fig 1.4.3-31a–b**). The same shears concept is used with the shortcut plate cutter, yet without the fulcrum within the instrument (**Fig 1.4.3-31d**). The two separate and individual shears engage the plate which then acts as the fulcrum. This is designed

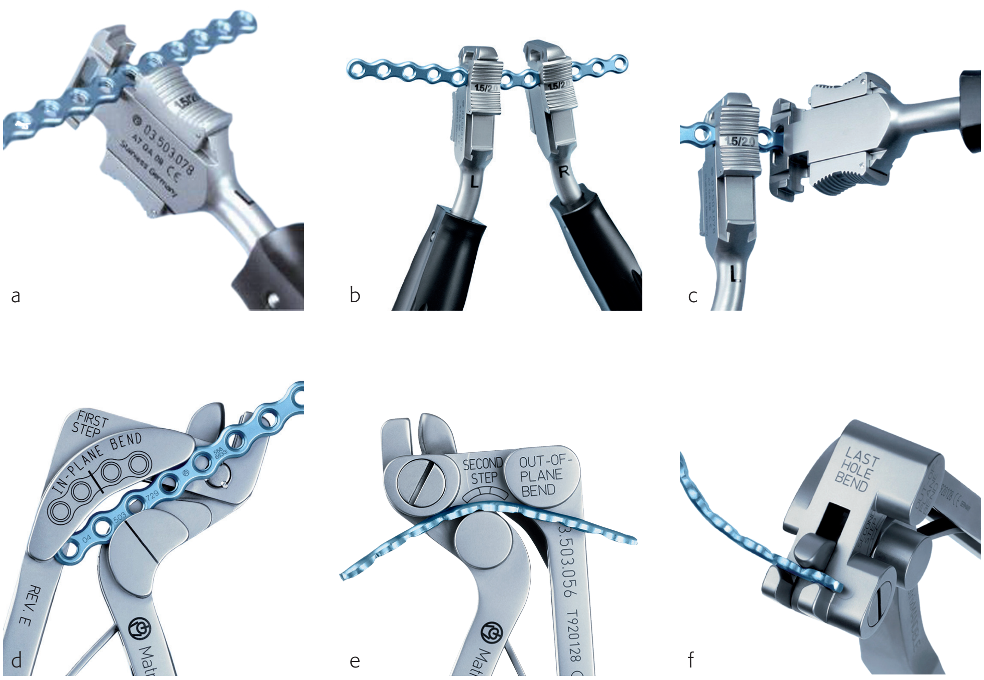


Fig 1.4.3-28a–f Bending irons and plier for MatrixMandible plates.

- **a** Bending iron: In plane bending.
- **b** Bending iron: Out of plane bending.
- **c** Bending iron: Bending the last segment of the plate and twisting.
- **d** Bending plier: In plane bending.
- **e** Bending plier: Out of plane bending.
- **f** Bending the last segment of the plate.

Fig 1.4.3-29 Bending plier for MatrixMIDFACE plates.

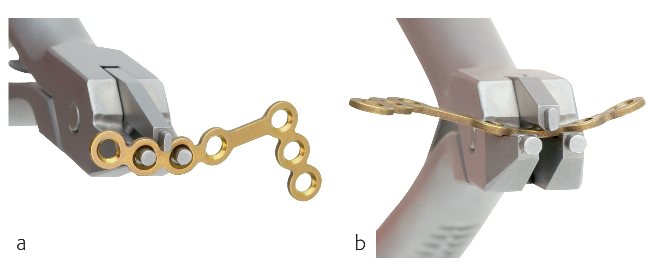


Fig 1.4.3-30a–b Three point bending plier with nose for Matrix-MIDFACE plates (fulcrum).

- **a** In plane bending.
- **b** Out of plane bending.

for cutting mandibular reconstruction or universal fracture plates. The third form is that of a plier with fulcrum and uses this additional mechanical efficiency to cut larger plates (**Fig 1.4.3-31c**).

Forceps: Forceps are designed for grasping screws and plates, for securing plates to bone, for plate contouring, and for pre-stressing bone. Plate and screw forceps for microplates and miniplates take the form of a hemostat or Castroviejo design. These fine-locking forceps are designed for the secure transfer and stabilization of smaller plates and screws. They can also be quickly released afterwards. For the mandible, plate-holding forceps with either a ball or foot are used to secure the plate to the bone (**Fig 1.4.3-32a**). The pointed tip of the forceps engages the bone, while the ball engages the receptacle for the screw, or the foot engages the shaft of the plate. Reduction forceps with points are essentially towel clamps with a more oblique angle of the tips (**Fig 1.4.3-32b**). The tips are inserted directly onto the bone surface, or into holes created in the outer cortex. As the ratchet is engaged, the bone is pre-stressed.

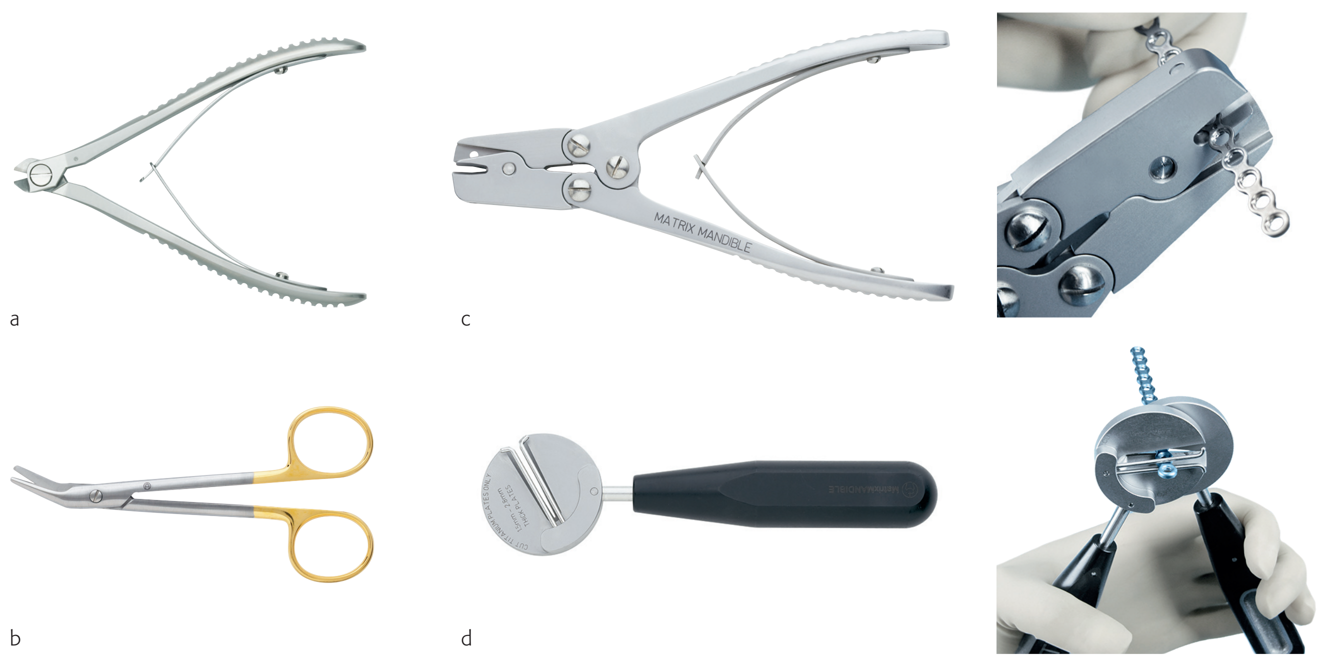


Fig 1.4.3-31a–d Plate cutting instruments.
a Plate cutter for MatrixMIDFACE plates.
b Cutting scissors for mesh plates, long.
c Cutting pliers for MatrixMANDIBLE plates 1.0 to 1.5, length 175 mm.
d Shortcut™ for MatrixMANDIBLE plates, thickness 1.5 to 2.8 mm, with rasp, required in pairs.

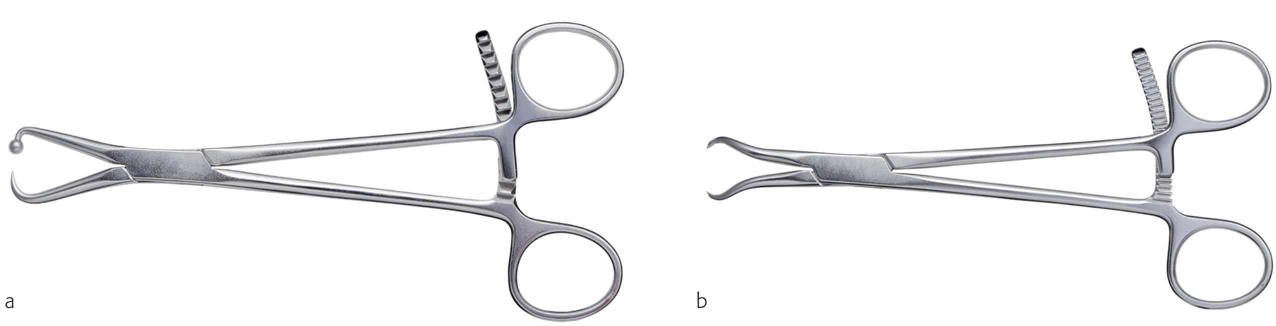


Fig 1.4.3-32a–b Forceps for the mandible.
a Bone holding forceps.
b Reduction forceps.

Transbuccal instruments: To avoid open transcutaneous approaches, especially for the ramus of the mandible, transcutaneous trocars have been developed. The basic components are the trocar handle (**Fig 1.4.3-33a**), the cannula (**Fig 1.4.3-33b**), and the drill sleeves (**Fig 1.4.3-33c**). The internal diameter of the cannula is slightly larger than the outer diameter of the drill sleeve and screwdriver that are inserted through it. Some designs permit interchangeable cannulas and drill sleeves of differing internal diameters, permitting multiple uses for the trocar handle and cannula. Various forms of cheek retractors may be applied to the cannula (**Fig 1.4.3-33d–f**). A trocar fits through the cannula to permit entrance and passage through skin, soft tissues, and mucosa. The transbuccal technique is illustrated in **Fig 1.4.3-34a–c**.

Fig 1.4.3-33a–f Transbuccal instruments.
a Handle.
b Cannula with obturator.
c Drill sleeve.
d-f Cheek retractors.