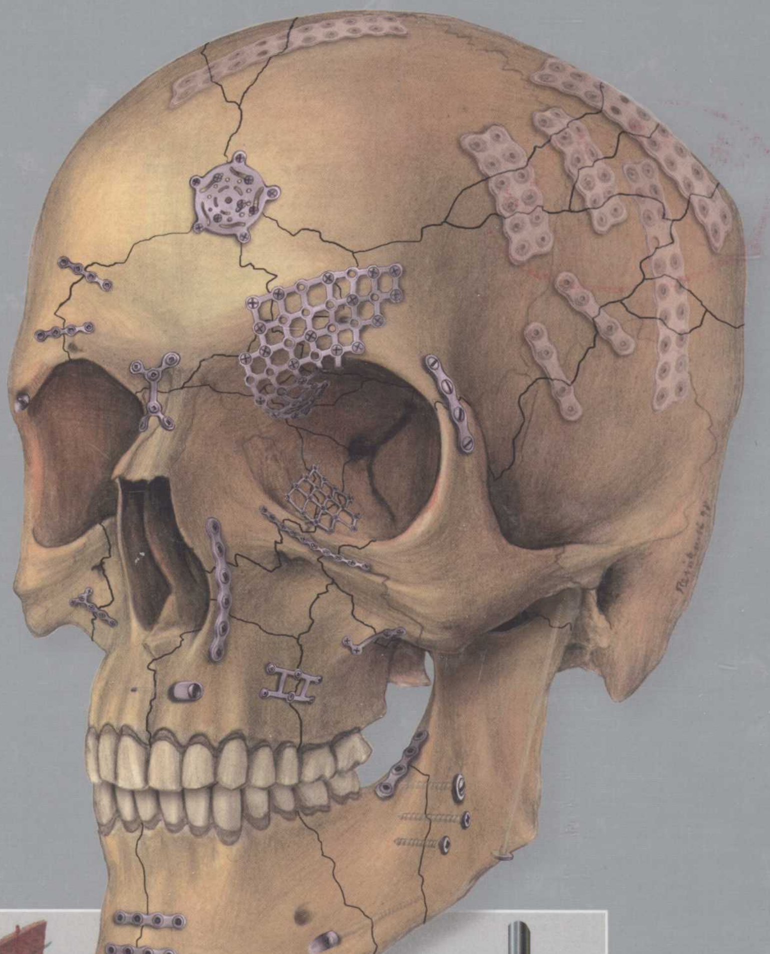
Atlas of Craniomaxillofacial Osteosynthesis

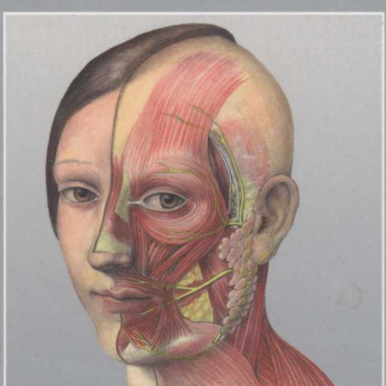
Microplates, Miniplates, and Screws

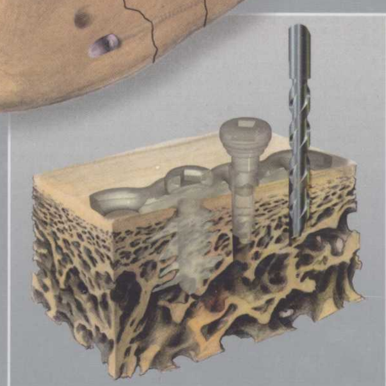
Franz Haerle and Maxime Champy
Bill Terry

Illustrated by
Andreas Reinhardt

2nd edition







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Atlas of Craniomaxillofacial Osteosynthesis

Microplates, Miniplates, and Screws

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Preface

Miniplate osteosynthesis without interfragmentary compression is now considered the best treatment for fractures of the mandible. The experimental and clinical investigations that allowed the advantages of this technique to be demonstrated were carried out in Strasbourg by a team drawn from the Department of Maxillofacial Surgery of the Faculty of Medicine, the Higher National School of Arts and Industries, and the Research Group in Bone and Joint Biomechanics of Strasbourg.

This research was purposely limited to the biomechanical study of osteosynthesis of the horizontal body and mandibular angle. It was concluded that the best method of surgical treatment in mandibular fractures was inevitably the result of a compromise in which all the constraints under which the operator works should be taken into account. These include anatomical and physiological conditions, biological requirements with regard to the equipment used, mechanical properties of the mandible and mechanical characteristics of miniaturized equipment set against the forces which are exerted on the bone, surgical imperatives.

The choice of osteosynthesis by small plates in other sectors of facial surgery (such as mandibular condyles, midfacial surgery, and orthopedic surgery) arises in part from the therapeutic orientation of the surgeon, based on nonexperimental but logical deductions from investigations carried out on the mandible, partly from the convenience that the plates offer, and is finally confirmed by the results obtained.

The improvements in quality of treatment of facial injuries far exceed the expectations that we had following the results of the first biomechanical research in the early 1970s.

The essential objectives of our biomechanical and clinical research were to apply the rigorous principles of modern orthopedic surgery to maxillofacial surgery and to reduce the empiricism which all too often guides the choice of therapy.

I should like to extend my thanks to the engineering students A. Boyoud, J. Patti, B. Sustrac, and J. P. Villebrun as well as to engineering professors Schmidt and Freund from ENSAIS; to Prof. I. Kempf and Dr. J. H. Jaeger, founder and chief manager, respectively, of the research group at the Centre de Traumatologie, and to Dr. J. P. Loddé, the surgeon responsible for maxillofacial surgery in this team; to Dr. J. M. Schnebelen, a faithful and committed colleague during the long and difficult phase of preparation; and finally to all those young colleagues who enthusiastically accepted and reviewed the technique as well as the new biomechanical drafts, Dr. A. Mariano, Dr. L. G. Gastello, Dr. P. Mercks, and Dr. M. J. Rauscher.

Many thanks are owed to all oral and maxillofacial surgeons who have disseminated the concept of miniplate osteosynthesis internationally, both by their convictions and by the quality of their work. They are too numerous for me to name them all individually. Some of them are co-authors of this book, including in particular Prof. Dieter Pape and Prof. Klaus Gerlach, with whom I have enjoyed a prolific scientific cooperation.

Maxime Champy

Introduction to the First Edition

In the past intermaxillary fixation has been the traditional method for supporting bone ends in close apposition to allow undisturbed bone healing of fractures of the facial skeleton and also of osteotomies after orthognathic surgical procedures. Although techniques of fracture immobilization utilizing bone plates and screws were described by Lambotte (1913), Warnekros (1917), and Wassmund (1927), it was not until the late 1960s and early 1970s that Hans Luhr (1968), Bernd Spiessl (1969), Wilfried Schilli (1969), and Rüdiger Becker (1973) popularized this technique and introduced methods of bicortical compression utilizing maxiplates and screws for the fixation of mandibular fractures. Such techniques are often utilized in an extraoral approach and open reduction. The basic principles require anatomical reduction, stable internal fixation, and a surgical technique causing minimal trauma to achieve early, pain-free mobilization. To allow bicortical screw fixation of the mandible bone, plates have to be positioned at the lower border to avoid damage to the dental roots and also to the inferior alveolar canal. Application of compression plates at the site of compression at the lower border is biomechanically unfavorable resulting in distraction at the area of tension, namely the upper border of the mandible, and also causing distraction in the dental arch. In addition, application of compression to the convex buccal surface of the mandible results in distraction of the fracture on the lingual side, which is very difficult to overcome.

Maxime Champy and coworkers (1975) developed the technique of Francois Michelet and A. Moll (1971). He described a method of monocortical fixation using miniaturized plates applied to the narrow surface of the mandible via an intraoral approach. He studied the tension and compression forces of fractured mandibles and found that miniplate application on the tension side of the mandible produced adequate stability to render inter-maxillary fixation unnecessary. The technical advantages of miniplate osteosynthesis are as follows: plates are small and easily adapted, they are applied monocortically, the approach is intraoral and they provide functional stability since the system is biomechanically balanced. Subsequently the method has been accepted worldwide.

As a tribute to his home town, Champy founded the Strasbourg Osteosynthesis Research Group (SORG), together with Dieter Pape. SORG comprises an international group of surgeons with a clinical and scientific interest in osteosynthesis techniques. The aims of SORG are to foster scientific development at all levels by controlled clinical studies and research, individual and collaborative publications, continuing educational courses and by the development of new techniques and improved instrumentation to further develop the principle of osteosynthesis in the fields of oral and craniomaxillofacial surgery.

Although miniplate osteosynthesis is directed to the management of mandibular fractures, the principles of osteosynthesis have now been applied to orthognathic surgery, craniofacial surgery, treatment of midfacial fractures, reconstructive bone surgery, and to reconstructive preprosthetic surgery including dental implantology. Although there are many different designs of miniplates and screws used throughout the world, these variants are all based on the original concept developed by Maxime Champy.

This book is written by many surgeons who have extensive experience in osteosynthesis techniques utilizing plates and screws with different systems. For this reason different techniques appear in the text, using different systems devised by Champy. It is for the reader to decide which technique is preferable. This book serves as an atlas of surgical procedures and offers clinical guidelines for using mini and microplate osteosynthesis in the craniomaxillofacial region.

We thank the editorial staff at Thieme International for their professionalism and attention to detail, John Cawood and Peter Ward Booth for checking the English, Andreas Reinhardt for the illustrations, and Verena Hinz for typing the manuscript.

Franz Haerle
Bill C. Terry

Introduction to the Second Edition

The *Atlas of Craniomaxillofacial Osteosynthesis* has been a topical work for almost 10 years. It has been reprinted twice, and has even been published in the Korean language.

Owing to continuous demand, we gladly complied with the wishes of Thieme Publishers and—together with the authors—have systematically revised the text, corrected the illustrations, and have overseen the completion of many new and revised chapters with new authors, in order to update them in line with current developments in osteosynthesis.

We thank the editorial staff of Thieme Publishers for their professional cooperation, Andreas Reinhardt for the illustrations, and Verena Hinz for typing the manuscript.

Franz Haerle
Bill C. Terry

Table of Contents

1 Anatomical Aspects and Biomechanical Considerations for the Body of the Mandible, the Midface, and the Cranium

Maxime Champy and Patrick Blez

Monocortical miniplate osteosynthesis is based on precise anatomical considerations and extensive biological and mechanical experiments that have led to the development of specific instruments and hardware.

Anatomical Considerations

The Mandible

Following innovative intraoral miniplate osteosynthesis (Michelet, Deymes, and Dessus, 1973), experimental work and clinical application have demonstrated that monocortical fixation by miniplates is strong enough to withstand the different strains created by masticatory forces (Champy et al., 1975; Champy et al., 1976a, b; Champy et al., 1977; Champy et al., 1978a, b; Champy and Lodde, 1976; Champy and Lodde, 1977; Jaeger, 1978). Because fixation is accomplished by anchoring the miniplates to the bone by means of screws, it is important to know both:

- the regions where the bone provides the screws with a firm anchorage
- the topography of the dental apices and inferior alveolar nerve, to avoid damaging them when inserting the screws

The outer cortex of the body of the mandible has an average thickness of 3.3 mm; it is particularly strong and offers a good anchorage for the osteosynthesis screws. The cortical bone is thicker in the chin region and is reinforced laterally by the oblique line, which runs from the coronoid process to the molar region. In the symphysis region cross-sections of the mandible show the thickest cortex to be at the lower border; behind the third molar it is stronger at the upper border (**Fig. 1.1**).

Near the alveolar process the thickness of the bone is variable; the anatomy of the tooth roots and the structure of the bone do not allow screw fixation in this region (Gerber, 1975). To avoid damaging the root apices, it is safe to place the screws away from the occlusal plane by a distance of at least three times the length of the crown of the tooth.

The inferior alveolar nerve runs in the mandibular canal, from the lingula to the mental foramen, on a concave course. Measurements show that, from back to front, it runs ever closer to the outer cortex and to the lower

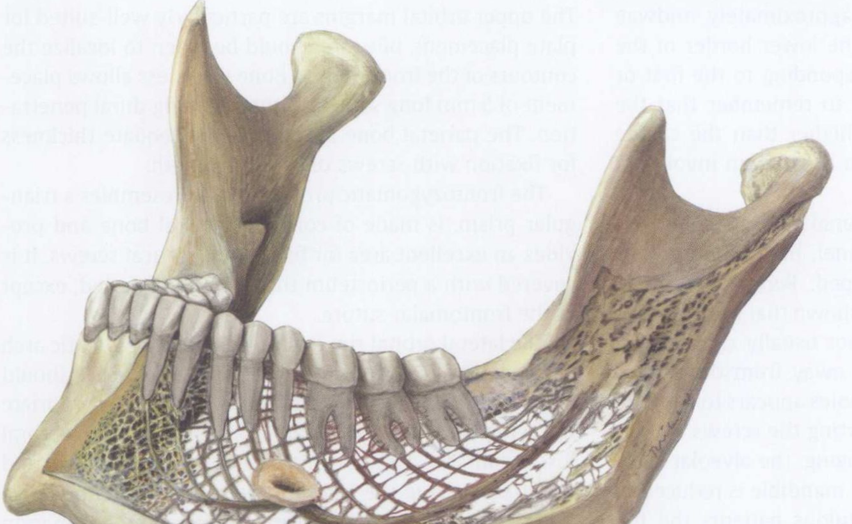

Fig. 1.1 Lateral view of a mandible. The lateral and inner cortex of the body of the mandible is taken out.

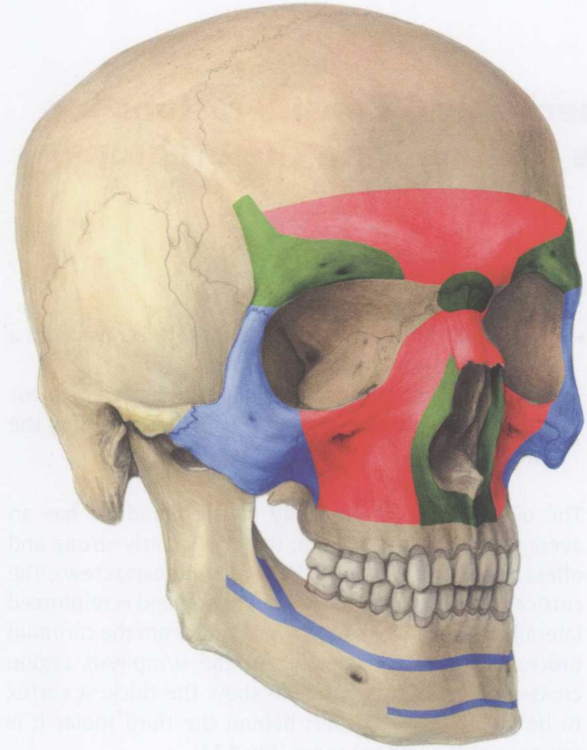

Fig. 1.2 Elective zones of miniplate osteosynthesis. Favorable regions are colored blue. The red zone is a region where microplates can be used. The green zone is a region where microplates or miniplates can be used.

border. At its lowest point it is 8–10 mm away from the basilar border of the mandible. Although the average thickness of the cortex in that region is 5 mm, it may be less than 3 mm in some cases. About 1 cm before the mental foramen, the canal turns upward and forward (Härle, 1977). The foramen lies approximately midway between the alveolar crest and the lower border of the mandible on a vertical line corresponding to the first or second premolar. It is important to remember that the mental foramen sometimes lies higher than the canine apex. Therefore, osteosynthesis in this region involves a certain risk of apical injury.

In most cases the mandibular canal surrounds the neurovascular bundle as a bony tunnel, but sometimes its bony structure is poorly developed. Repeated tests in freshly prepared mandibles have shown that the intrusion of a screw into the canal does not usually cause nerve injury, because the nerve moves away from the instrument (Gerber, 1975). Drilling the holes appears to be more dangerous to the nerve than inserting the screws.

It should be noted that, with aging, the alveolar bone atrophies and the structure of the mandible is reduced to the two cortical layers. In edentulous patients the flat upper border of the mandible is composed of sclerous bone, giving poor anchorage for the screws.

One should keep in mind that in children the mandibular body is occupied by dental germs.

The alveolar bone is covered with attached mucosa. When a fracture occurs, the gum is often lacerated, exposing the mandibular bone to the risk of infection from the oral cavity if treatment is not instituted within 12 hours.

During the first years of life, the blood supply of the mandible depends on the inferior dental artery (Cohen, 1960). Later, periosteal vascularization increasingly takes over. In the adult subject, as demonstrated by Bradley (1975), the blood supply relies entirely on the periosteum of the basilar process. This area should therefore be treated with care. Extensive periosteal stripping should be avoided to preserve the blood supply. For this reason a transmucosal rather than a transcutaneous approach is preferred.

The Midface and the Cranial Bones

In the facial and cranial skeleton the thickness of cortical bone is variable. The use of miniplate osteosynthesis in cranial and midface surgery has been advocated by Loddé and Champy (1976), and Champy, Loddé, and Grasset (1977). Short miniscrews of 3 mm or 5 mm in length should be used in cranial surgery. Those areas where the cortical bone is thick and therefore suitable for osteosynthesis include the cranium, the nasal bone, the zygomatic bone, the orbital rim, the marginal rim of the piriform aperture and the zygomatic buttress (Mariano, 1978). Elsewhere the cortical bone that constitutes the walls of the various cavities is thin and does not provide a very solid anchorage for osteosynthesis screws, and is only suitable for fixation with microscrews and microplates (**Fig. 1.2**).

The frontal bone ranges from 4 to 9 mm in thickness. The upper orbital margins are particularly well-suited for plate placement, but care should be taken to localize the contours of the frontal sinus. Bone thickness allows placement of 5 mm long screws without risking dural penetration. The parietal bone also provides adequate thickness for fixation with screws of 3 mm in length.

The frontozygomatic process, which resembles a triangular prism, is made of compact cortical bone and provides an excellent area for fixation of cortical screws. It is covered with a periosteum that is easily elevated, except at the frontomalar suture.

The lateral orbital rim extending to the zygomatic arch provides sufficient bone for screw fixation. The eye should be protected during the operation by using an appropriate retractor. After Champy et al., 1975, the anterior cerebral fossa can be avoided; its deepest point is located 16–20 mm above the frontomalar suture, or 5 mm above a horizontal line tangential to the upper orbital margin (**Fig. 1.3**).

Fig. 1.3 Localization of the anterior cerebral fossa. Its deepest point lies 16–20 mm above the frontomalar suture, 5 mm over the tangential line of the upper orbital margin.

The lower orbital rim is also an area of thick cortical bone. However, because neither muscular force nor any strain is exerted on it, its fixation with a plate seems unwarranted. If isolated fragments require immobilization, absorbable ligatures or microplates are mechanically sufficient.

The maxilla has only two buttresses made of compact and strong bone: the lateral inferior aspect of the piriform aperture (medial or nasomaxillary buttress), and the lateral or zygomatic or maxillary buttress. The importance of these pillars or buttresses was described in 1928 by Sicher and Tandler, by de Brul (1970) and more recently by Manson, Hooper, and Su, 1980. The anterior wall of the maxillary sinus is thin and less suitable as a support for miniplates.

Finally, remember that many cavities exist in this area, some of which contain organs that must be preserved, such as the dura, the eyes, and the dental roots. The walls of the frontal, maxillary, and ethmoid sinuses, the nasal fossae, and the buccal cavity are generally thin and fragile. Protrusion of screws into these cavities should be avoided, as there is a risk of causing infection, particularly in the frontal sinus and the nasal cavity.

Biomechanical Principles

Physiology is the scientific study of the properties and functions of tissues in living beings.

Mechanics is the scientific study of the equilibrium of forces and the movements that generate them.

Biomechanics is the study of biological phenomena with the objective of proposing explanations or therapeutic solutions for such phenomena (e. g., fractures). In practice it consists of an amalgamation of knowledge from engineers and biologists.

The biomechanical principles of monocortical miniplate osteosynthesis are based on mathematical and experimental studies performed in Strasbourg, France, by the Groupe dEtudes en Biomecanique Osseuse et Articulaire de Strasbourg. The objective of this biomechanical research is to reduce as much as possible the empiricism that too often guides the surgeon's choice of treatment, and to obviate the need for experimental human research—or even illegal human and animal experiments. This research work, which concerned the mandible only, resulted in the development of a stable, elastic, dynamic osteosynthesis system that is able to guarantee fracture healing without either maxillomandibular fixation or interfragmental compression (Champy in Huckel, 1996). This has been achieved as a result of the following considerations and experiments.

Goals

The ideal method of treating mandibular fractures is one that establishes a functional therapy by movement. Therefore, it should aim for:

- re-establishment of previous occlusion
- perfect anatomical reduction
- complete and stable fixation, allowing painless mobilization of the injured region
- maintenance of the blood supply of the fragments, of the fracture surfaces, and of the surrounding tissues

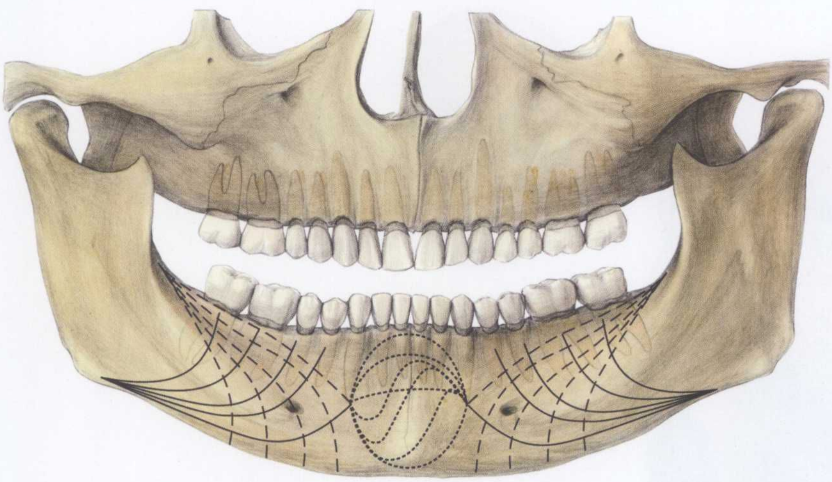

Fig. 1.4 Forces exerted on the mandible from the angle of the mandible to the incisor region. Throughout the body of the mandible, biting forces produce tension forces (dashed lines) at the upper border and compressive forces (solid lines) at the lower border. Torsion forces are produced anterior to the canines (dotted lines).

The biomechanical requirements for optimal osteosynthesis are that:

- the plates and screws must withstand the various stresses due to those tensile and torsional forces to which the mandibular bone is typically subject
- the plates have to be malleable for easy adaptation to the bone surface, especially in the curved symphysis and molar region, to secure anatomical reduction and to restore perfect dental occlusion
- the dimensions of the plates should ensure minimal periosteal elevation and fracture site exposure; furthermore, the oral mucosa must be able to cover the plate without any difficulty, without any dead space around the plate and the head of the screws
- the size of the screws has to be appropriate for the thickness of the cortex

Masticatory Stress Distribution in the Mandible

Knowledge of masticatory stresses exerted on the mandible is fundamental, because these stresses determine the rational design and positioning of osteosynthesis plates and their mechanical characteristics.

The activity of the muscles of mastication can be divided into temporalis forces, masseter forces, and reactive biting forces. The latter have the most adverse effects on immobilization of the fracture. These forces vary from patient to patient. By means of strain gauges connected to a Wheatstone bridge, maximal biting forces in young men with healthy teeth were measured. The following values were obtained:

- incisor region: 290 N (Champy–Loddé) 265 N (Meyer)
- canine region: 300 N (Champy-Loddé) 300 N (Meyer)
- premolar region: 480 N (Champy-Loddé) 480 N (Meyer)
- molar region: 660 N (Champy-Loddé) 506 N (Meyer)

The interaction of these forces varies from patient to patient and affects the degree of fracture displacement that must be overcome by treatment.

It is important to understand the distribution of strains created within the mandible as a result of these external forces. Physiologically coordinated muscle function produces tension forces at the upper border of the mandible and compressive forces at the lower border (Weigele, 1921; Winkler, 1922; Motsch, 1968; Küppers, 1971; Boyoud and Paty, 1975; Champy and Lodde, 1976; Tillmann, Härle and Schleicher, 1983). In addition, Sustrac and Villebrun (1976) and Weigele (1921) demonstrated that torsion forces are produced anterior to the canines (**Fig. 1.4**).

In every mandibular fracture these forces cause distraction at the alveolar crest region, accentuated by the degree of trauma and by contraction of the muscles of the floor of the mouth, which can lead to displacement of the fragments. The compressive force at the lower border is a dynamic and physiological force, which is exerted permanently on the fractured fragments along their basilar border (Boyoud and Patty, 1975; Champy and Lodde, 1976; Ewers and Härle, 1985a). This compression is due to muscular tonus and increases during masticatory function. When the osteosynthesis is adequately performed, and provided there is no defect in the fracture site, this dynamic compression exactly equals the physiological strains that are exerted on an intact mandible (Champy and Lodde, 1976; Tillmann, Härle and Schleicher, 1983).

The momentums of compression, tension, and torsion have been established using a mathematical model of the mandible using the formula $E = F \times L/d$, where E is the state of constraints, F the masticatory forces, L the distance from chin to the fracture line, and d the distance from the plate to the lower border of the mandible.

In any method of fixation of a fractured bone, friction forces controlling shearing and torsion stresses are a very important factor of stability. These forces between fracture surfaces exist due to interdigitation and are enhanced by compression forces. With interdigitation of poor quality, friction forces are reduced or even nonexistent. A double plate fixation is then necessary. This is the case in surgical interruptive osteotomy, fractured atrophic mandible, infected fracture, pseudoarthrosis, and reconstructive surgery (Champy and Lodde, 1975).

Definition of an Ideal Osteosynthesis Line on the Mandible

Given the unique anatomy of the mandible, this biomechanical study defines an ideal osteosynthesis line for the mandibular body (**Fig. 1.5**). It corresponds to the course of a tension line at the base of the alveolar process inferior to the root apices. In that region a plate can be fixed with monocortical screws, as follows:

- behind the mental foramina the plate is applied immediately below the dental roots and above the inferior alveolar nerve
- at the angle of the jaw the plate is placed ideally on the inner broad surface of the external oblique line; if this has been destroyed, the plate is fixed on the external cortex as high as possible (**Fig. 1.5**)
- in the anterior region, between the mental foramina, in addition to the subapical plate, another plate near the lower border of the mandible is necessary to neutralize the torsion forces

The result of such a monocortical stable–elastic–dynamic osteosynthesis is the neutralization of the distraction and torsion strains exerted on the fracture site, while physiological self-compression strains are restored. Interfragmentary compression by means of rigid plate and bicortical screws does not permit this effect. In cases of comminuted fractures it is necessary to apply additional plates to re-establish the physiological strains and to neutralize torsion strains (**Fig. 1.6**).

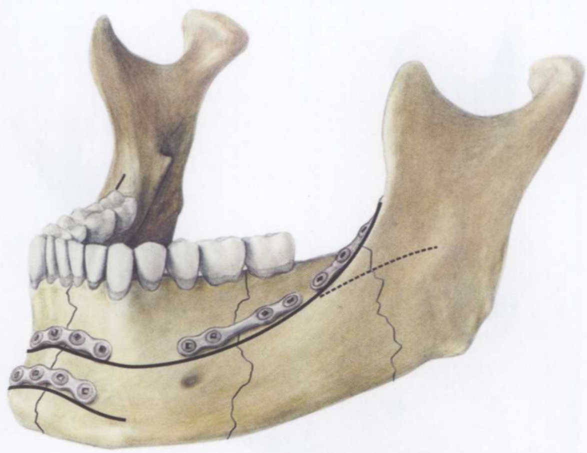

Fig. 1.5 The ideal osteosynthesis position and ideal osteosynthesis line on the mandibular body.

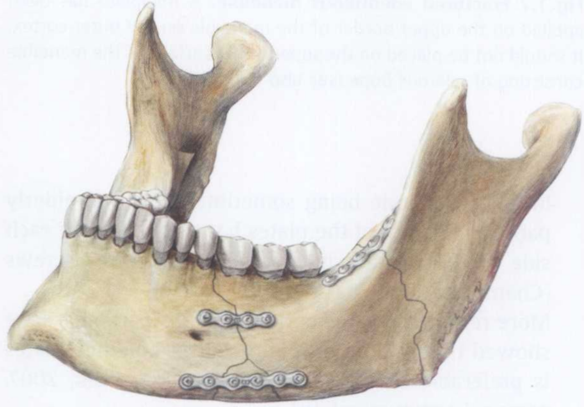

Fig. 1.6 Osteosynthesis position on the mandibular body with a comminuted fracture and a displaced basal triangle segment. The small fragment may be replaced in anatomical position between larger mandibular segments, so that the compressive forces at the lower border can re-establish the physiological strains when the miniplate neutralizes the distraction forces at the upper border. The fracture on the mandibular angle is fixed on the inner surface of the external oblique line.

Other Therapeutic Applications

- An osteotomy of the mandible with a saw corresponds to a loss of substance of 1–2 mm. Therefore, neither interdigitation nor friction forces occur between the two separated surfaces of the fragments. Bringing the fragments close together will have bad consequences for dental occlusion. A double plate fixation is necessary to maintain the preoperative position of the fragments and to re-establish a correct occlusion (Champy and Lodde, 1975).
- In the edentulous mandible the correct position of the plate is on the outer cortex of the mandible, where the biting forces produce tension forces at the upper border of the mandible. The plate should never be fixed on the upper flat surface where the bone is sclerous (**Fig. 1.7**).
- In the case of an advanced atrophy of the mandible, tension and compression strains are concentrated in a narrow bundle. Fracture surfaces are very narrow and friction forces between them are small. These small surfaces do not offer the miniplate an adequate support for the compressive forces, thus even the reduced masticatory forces entail the risk of deformation or rupture of the plate. The mathematical formula $E = F \times L/d$, defined above, demonstrates that the strains exerted on the plate are inversely proportional to the distance between the plate and the lower border. A double plate fixation is then necessary, with a distance of at least 2 mm in between.
  Where the vertical dimension of the buccal cortex is less than 1 cm, a reinforced plate has to be used.