ORIGINAL ARTICLE

Principle and stability of locking plates

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Abstract. A new internal Mini-Locking-System was tested compared with conventional 2.0 mm Miniplates. Standardised osteotomies in the angular region of 16 human cadaver mandibles were fixed with a 6-hole-plate at the oblique line. Osteosynthesis and stability of fixation was proofed in a three-dimensional *in-vitro*-model in which functional load was simulated. Comparison of the different osteosynthesis techniques showed that in the case of Miniplate fixation torsion and gapping of the bone fragments occurred following plate application and screw tightening when the plates were pressed onto the bone, so last incongruences between bone surface and plate were transferred to the mobile bone fragments resulting in more extended gaps and torsion. This was only observed to a much lesser extent with the Mini-Locking-System due to the fixation principle avoiding pressure to the bone. During functional loading the Mini-Locking-System showed also a significant higher stability in comparison to conventional Miniplates. Due to the fixation method imitating the principles of a fixateur the screws form together with the plate and the cortical bone a frame construction. Loading forces are transmitted without the need of plate friction directly from bone over the screws to the plate resulting in higher stability. (Keio J Med 52 (1): 21–24, March 2003)

Key words: miniplate, osteosynthesis, locking-system, mandibular angle fracture

Introduction

With the development of osteosynthesis in maxillofacial surgery different systems have been designed which have become smaller, more simple to handle and avoid extraoral procedures. Meanwhile Miniplate fixation of mandibular fractures has become a standard treatment.[1] Nevertheless complications in Miniplate osteosynthesis of the mandible especially in the angular region have been described in up to thirty per cent of cases, like movement and loosening of screws following failure of fracture treatment.[2] Also plate pressure following disturbance of the blood supply and bone necrosis especially around the screws will lead to loss of plate friction.

In order to improve Miniplate osteosynthesis a new internal Mini-Locking-System has been developed in collaboration with the AO/ASIF-Institute (Davos, Switzerland).

Materials and Methods

Dimensions of the new Mini-Locking-System are comparable with conventional 2.0 mm Miniplate systems. In addition the selftapping 2.0 mm locking screw has a special double-lead thread beneath the screw head. The locking plate has corresponding threaded plate holes. During insertion the locking screw engages and locks into the threaded plate holes (Fig. 1).

In a preclinical investigation at the AO/ASIF-Institute (Davos, Switzerland) we proofed the handling and mechanical stability of the new Mini-Locking-System compared with the conventional 2.0 mm Miniplate system.

Standardised osteotomies in the right angle region of sixteen human cadaver mandibles were performed and fixed with one six-hole-plate (length 40 mm, thickness 1.0 mm) and 6 screws of each system (length 6.0 mm, outer diameter 2.0 mm) at the oblique line. Eight man-

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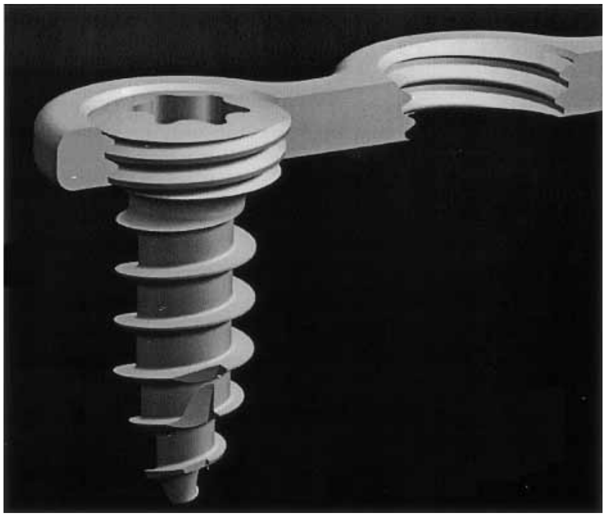

Fig. 1 Mini-Locking-System (plate thickness 1.0 mm, screw outer diameter 2.0 mm).

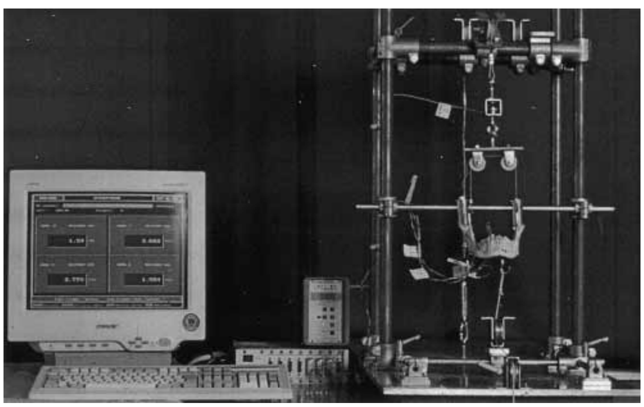

Fig. 2 Three-dimensional *in-vitro*-model.

dibles were fixed with the Mini-Locking-System and eight mandibles with conventional Miniplates. To exclude the influence of anatomic individuality the mandibles were prior divided concerning the match-paired method resulting in two equivalent test groups.

Following osteosynthesis gaps and torsion at the osteotomy site (cranial and caudal) were measured.

The mechanical stability of the different fixation methods was tested according to Kroon's method[3] based on a three-dimensional *in-vitro*-model (Fig. 2). Application of functional load by 20, 35, 50 and 65 N was performed at nine different positions along the row of teeth. The functional load was applied consecutively without tightening the screws for each load. Changes of dimension as a reaction to distraction or compression were computer-assisted recorded at three locations of the osteotomy (cranial, lingual, caudal) by means of strain gauges.

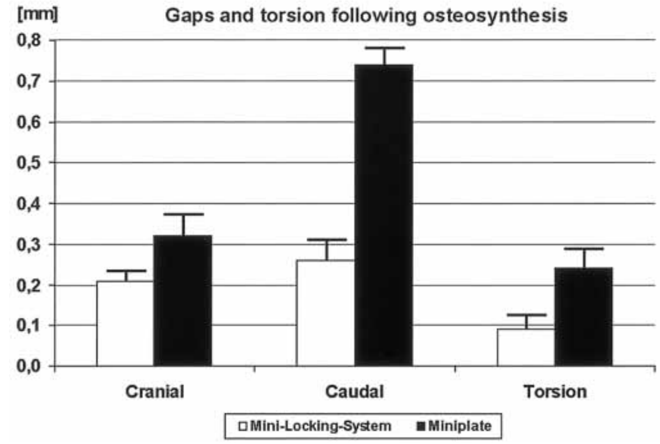

Fig. 3 Gaps and torsion following osteosynthesis. White bars = Mini-Locking-System. Black bars = Miniplate.

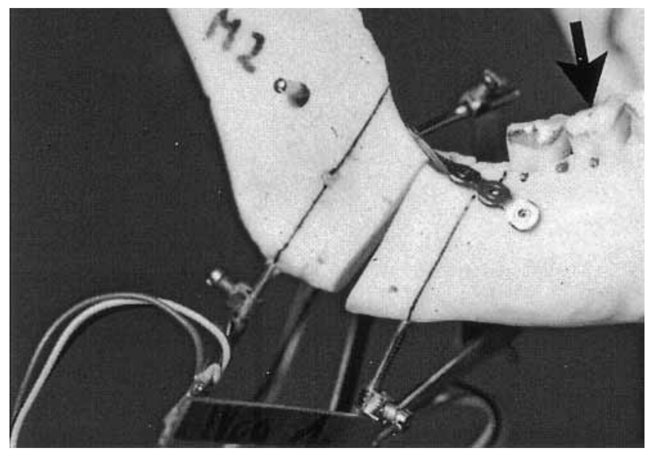

Fig. 4 Osteotomy mandibular angle fixed with Mini-Locking-System during functional loading. Typical dislocation at the caudal border of the mandible if the load was applied near to the osteotomy (arrow = loading point 6).

Statistical evaluations were performed using analyses of variance (General mixed model analysis of variance, Mann-Whitney-Test).

Results

Following osteosynthesis the mandibles treated with the Mini-Locking-System showed the lowest gaps and torsion. Compared with the Miniplates the differences were significant (Fig. 3). At the caudal site of the osteotomy the highest level of significance was found ($p = 0.010$).

During mechanical loading simulating the muscle forces we observed in both groups the typical increasing dislocations at the caudal border of the mandible if the load was applied nearer to the osteotomy (Fig. 4). Ex-

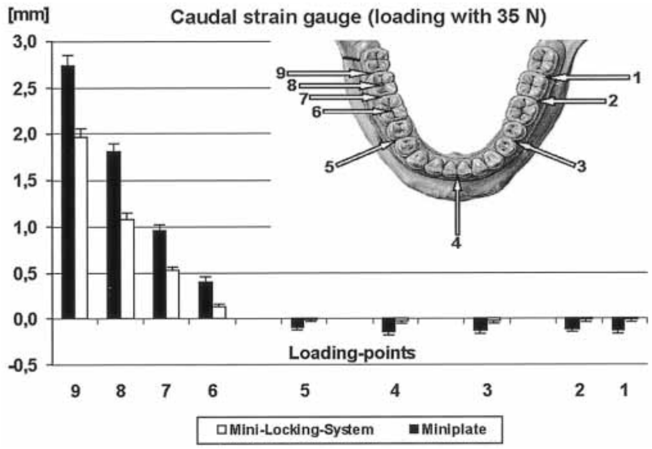

Fig. 5 Distraction and compression at the caudal site of the osteotomy (loading with 35 N). White bars = Mini-Locking-System. Black bars = Miniplate.

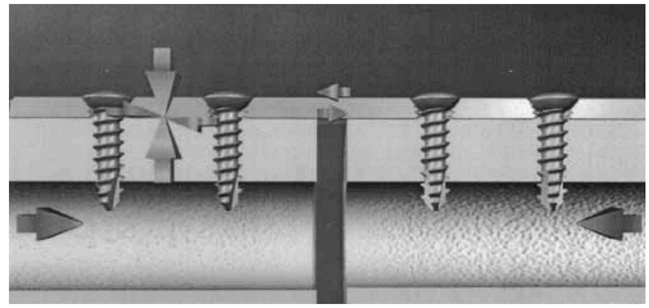

Fig. 6 Primary stability of conventional Miniplate. Arrows = load distribution and pressure/counter-pressure (friction) at the plate/bone.

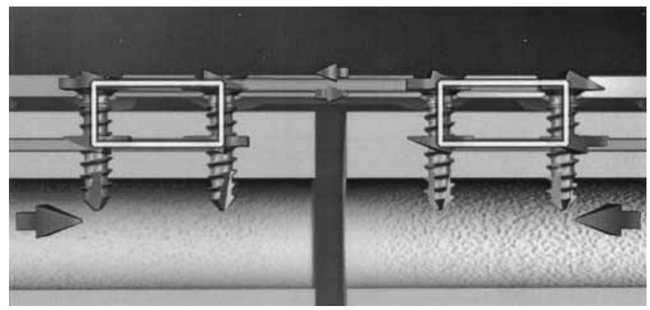

Fig. 7 Primary stability of Mini-Locking-System. Arrows = load distribution (transmission directly from the bone to the screws, from there to the plate and on the opposite side of the fracture again through the screws into the bone). Rectangles = frame constructs as result of screws locked into the plate as well as into the bone.

cept increasing dislocations no differences concerning the characteristic of the value distribution was found by increasing the functional load.

Looking on the different fixation methods the Mini-Locking-System showed the best stability. In relation to the four different loading forces the values in all loading-points were significant lower for the Mini-Locking-System compared with the Miniplates. The highest level of significance ($p = 0.015$) was detected at the caudal strain gauge (Fig. 5).

Discussion

Comparison of the different osteosynthesis methods showed that in case of Miniplate fixation increased torsion and gapping of the bone fragments occurred during screw tightening when the plates were pressed onto the bone.

This is the result of the different fixation method. When using conventional Miniplates it is essential to contour the plate precisely to the bone surface. Otherwise last incongruences between bone surface and plate will be transferred to the mobile bone fragments during tightening of screws resulting in more extended gaps and torsion and will lead to primary loss of reduction.

If the Mini-Locking-System is fixed with locking screws reduction remains nearly unchanged. Therefore the plate does not have to be contoured as precisely as with conventional plating systems.

During mechanical loading we observed in both groups the typical increasing dislocations at the caudal border of the mandible if the load was applied nearer to the osteotomy.[3,4]

On the other hand, the Mini-Locking-System showed the best stability. This is also the result of the different fixation methods.

With conventional technique tightening of screws presses the plate against the bone. This pressure generates friction which contributes significantly to primary stability (Fig. 6). At the screw thread only the side orientated to the plate is involved developing the pressure of the plate.

By the Mini-Locking-System loading forces are transmitted directly from the bone to the screws, from there to the plate and on the opposite side of the fracture again through the screws into the bone. Friction between plate and bone is not necessary for stability. On each fracture side the screws locked into the plate as well as into the bone result in a frame construct with high stability (Fig. 7). Forces to the screw are more favourably distributed over the whole thread contour.

In comminuted or defect fractures fixation with conventional plating systems can lead to secondary dislocation as soon as the pressure between plate and bone is no longer guaranteed. Plate fixation with locking screws can avoid this kind of secondary dislocation. Also in poor quality bone anchoring of screws can lead to screw loosening and subsequent loss of reduction. Due to the secure locking of the screw in the plate this problem can be avoided with the Mini-Locking-System.

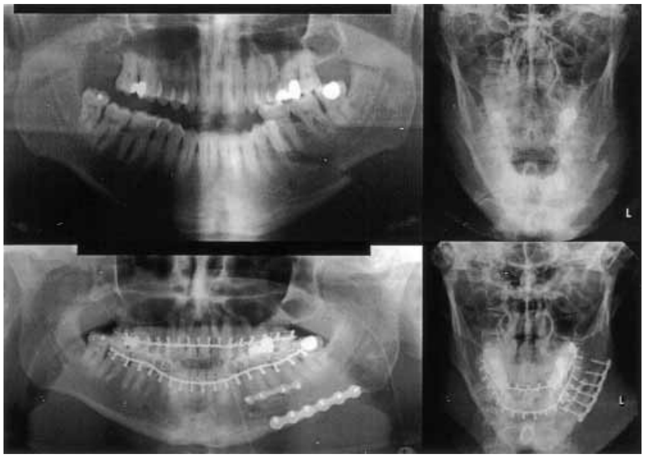

Fig. 8 Pre- and postoperative x-rays of a severe dislocated fracture, mandibular body left. Fixation with two Mini-Locking-Plates (small and medium).

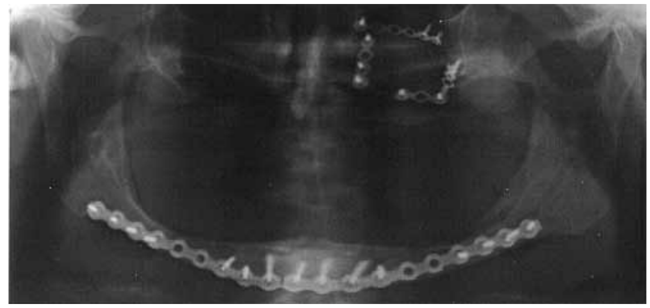

Fig. 9 Postoperative x-ray of a double-sided fracture of an atrophic mandible. Fixation with two Mini-Locking-Plates (medium). In addition a left zygoma fracture fixed with three Mini-Locking-Plates (small).

Conclusion

The new internal Mini-Locking-System combines two principles including several advantages. The locking principle prevents stripping as well as movement and loosening of screws. The fixation technique imitates the principles of a fixateur. This simplifies plate bending and decreases torsion or opening at the fracture site. The increased stability is a result of the frame construct and load transmission as described above. The absence of pressure underneath the plate prevents interference with the vascular supply of the bone and allows periosteum growing under the plates supporting fracture healing. This was observed clinically in all with Mini-Locking-Plates treated fractures during plate removal after a period of six months.

In addition to the small Mini-Locking-Plates, 2 larger plate profiles were designed accommodating a wide range of indications. The 2.0 mm screw fits all plate configurations and can be used mono- or bicortical. If necessary the threaded plate holes also accept non-locking screws which permits greater angulation.

First clinical experience with all 3 plate profiles showed excellent results. Especially in severe and comminuted fractures (Fig. 8) as well as in fractures of the atrophic mandible (Fig. 9) osteosynthesis with the Mini-Locking-System meanwhile has become a standard treatment in our clinic.

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