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Biomechanical evaluation of malleable noncompression miniplates in mandibular angle fractures: an experimental study

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Abstract

The purpose of this experimental study was to test the reliability of a single malleable titanium miniplate using Champy's method of fixing fractures of the mandibular angle. Eighteen sheep hemimandibles were used to evaluate 2 plating techniques. The groups were tested with either a single non-compression titanium miniplate or a single malleable titanium miniplate. A cantilever bending biomechanical test model was used for the samples. Each group was tested with vertical forces using a servohydraulic testing unit. The displacement values in each group at each 10 N stage up to 90 N were compared using 2-way analysis of variance (ANOVA). The displacement values for the 2 groups differed significantly ($p < 0.01$). The variance analyses showed that the biomechanical behaviour of a single non-compression miniplate was better than that of a single malleable miniplate. The non-compression miniplate fixed by screws had greater resistance to occlusal loads than the malleable plate fixed by screws, and the malleable plate alone was not sufficient to withstand the early postoperative bite force.

Keywords: Mandibular angle fracture; Malleable plate; Champy method

Introduction

The angle is one of the most commonly fractured sites in the mandible.[1–3] Fixation with plate and screws is widely used, and placing a single non-compression titanium miniplate at the superior border, as described by Champy et al., is a standard method in the management of fractures of the mandibular angle.[4–7] The volume of the original Champy miniplates has been reduced by half, which makes them more malleable, and there has been no increase in complications when they are used for mandibular fractures.[8] Potter and Ellis[9] also reported that malleable miniplates provide adequate fixation for most fractures of the angle.

The bite force during the early postoperative period after repair of a mandibular fracture is considerably less than the bite force of a healthy person. Maximum bite force is reported to be about 70 N during the first week, increasing to 130–135 N by the sixth week.[10,11] These measurements are compatible with the measurements recorded after saggital split ramus osteotomy as about 65 N at 2 weeks and 130 N at 4 weeks.[12] The bite forces in the early postoperative period of patients treated for fractures of the mandibular angle or having orthognathic surgery are much less than those recorded later in the postoperative period or in people who have not had an operation.

The purpose of this experimental study was to test the reliability under loads of up to 90 N of a single titanium malleable miniplate inserted using Champy's method for the repair of fractures of the mandibular angle, and to gain an understanding of the routine use of these miniplates.

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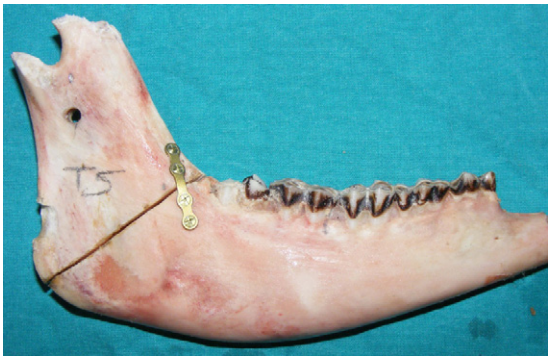

Fig. 1. A single titanium 4-hole non-compression miniplate.

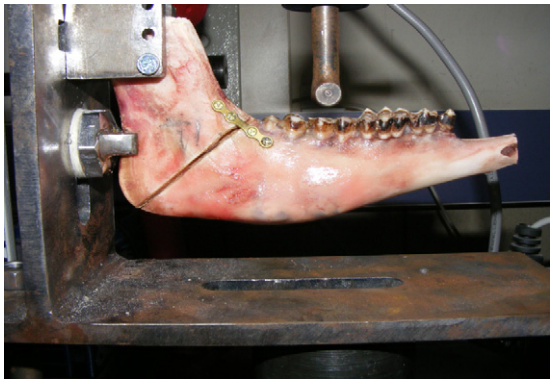

Fig. 3. Specimens adapted to the fixation apparatus.

Material and methods

We used 18 similar sheep hemimandibles taken from a market's meat department. The soft tissues were stripped off the mandibles and they were divided into two pieces from the anterior midline between the central incisors. The specimens were kept moist and refrigerated until the experiment had been completed. All coronoid processes and anterior bony segments were removed so that the mandibles could be easily fixed in the apparatus. The models were sectioned uniformly with a saw from the retromolar region, on a line that connected to the angle of the mandible. A bicortical osteotomy was then made using a saw, extending in an oblique direction in the area of the mandibular angle at roughly 45°, extending from the retromolar region into the inferior aspect of the mandibular angle. The hemimandibles were randomly divided into 2 groups of 9, and fixed with 2 different plating techniques.

In the first group, a single titanium 4-hole non-compression miniplate, with screws 2.0 mm in diameter and 5 mm long, was adapted on the external oblique ridge (Trimed Titanium Implant System, Ankara, Turkey). In the second group, a single titanium 6-hole malleable non-compression miniplate, with screws 1.6 mm in diameter and 5 mm long, was adapted on the external oblique ridge (Trimed Titanium Implant System, Ankara, Turkey) (Figs. 1 and 2).

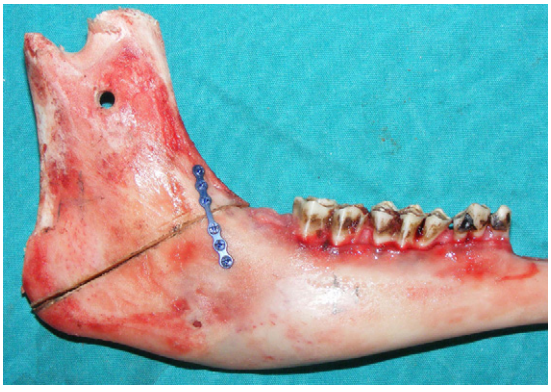

Fig. 2. A single titanium 6-hole malleable non-compression miniplate.

The occlusal surface of the dentulous portion, where the load was applied, was flattened with a bur to achieve a smooth contact surface. Each fixed specimen was mounted on a servohydraulic testing unit (TST 2500 mxe, ELISTA Electronic Informatic System Design Ltd., Istanbul, Turkey) with a fixation apparatus that consisted of 2 portions. A hole 5 mm in diameter was drilled transversely through the ramus process, and a steel fixation screw was placed through this hole to stabilise the superior proximal segment of the mandible. The other portion existed in the posteroinferior ramus and prevented backward and lateral movement of the inferior proximal segment of the mandible. Additionally, the system contained a cylindrical steel rod to be applied to the occlusal load (Fig. 3).

The testing unit was equipped with a 2500-kg load cell (maximum load capacity of 5000 kg), which was set to produce linear displacement at a rate of 10 mm/min. Initially, a 5-Newton (N) preload was applied to the specimens to apply the same load to all specimens at the beginning of the test when the loading was recalibrated to zero. Each hemimandible was then subjected to a continuous, vertically linear load until it broke. During the test, load and vertical displacement data were recorded digitally, and load–displacement graphs were drawn by dedicated software (tst 2500 mxe, ELISTA Electronic Informatic System Design Ltd., Istanbul, Turkey). The significances of differences in displacement values in each group at each 10 N stage up to 90 N were compared using 2-way analysis of variance (ANOVA).

Results

The displacement values in each group expressed as mean (SD) for each 10 N increment up to 90 N are shown in Tables 1 and 2; they differed significantly ($p < 0.01$). The variance analyses showed that the biomechanical behaviour of a single titanium non-compression miniplate placement was better than that of the malleable plate except at 10–20 N.

Table 1
Mean (SD) displacement values (mm) in the 9 hemimandibles given a single non-compressive miniplate at each increment of force.

Time	10 N	20 N	30 N	40 N	50 N	60 N	70 N	80 N	90 N
1	0.40	0.86	1.19	1.50	1.80	2.07	2.43	2.81	3.21
2	0.82	1.76	2.26	2.54	2.91	3.50	4.13	4.86	5.90
3	0.21	0.57	0.90	2.20	2.52	3.00	3.32	3.96	4.27
4	0.60	1.23	1.49	1.88	2.23	2.60	3.06	3.58	4.20
5	0.66	1.18	1.62	2.10	2.63	3.08	3.54	4.07	4.60
6	0.20	0.61	0.90	1.18	1.60	2.07	3.05	3.77	4.04
7	0.53	1.08	1.47	1.84	2.25	2.69	3.06	3.45	3.82
8	0.61	1.06	1.48	1.73	2.14	2.48	2.81	3.18	3.56
9	0.13	0.60	0.99	1.54	2.05	2.67	3.05	3.40	3.80
Mean (SD)	0.46 (0.24)	0.99 (0.39)	1.37 (0.45)	1.83 (0.42)	2.24 (0.42)	2.68 (0.48)	3.16 (0.48)	3.68 (0.6)	4.16 (0.78)

Discussion

The fixation of fractures of the mandibular angle is possibly more critical than fixation of fractures located in other regions of the mandible. Fractures of the angle are associated with the highest rate of postoperative complications of all mandibular fractures,[1,13–15] which might be related to the use of different techniques of fixation.[15] The preferred type of fixation is still controversial.[15–17] Since the introduction of the Champy miniplate, the potential effectiveness of the method has been shown in many clinical studies.[18–21] However, some studies on fractures of the mandibular angle have suggested that using a single miniplate is a simple and reliable technique with relatively few major complications.[15] When the volume of the original Champy miniplates was reduced by half to make them more malleable, there was no increase in the incidence of complications after fractures of the mandibular angle.[8] The only clinical study on the use of malleable titanium miniplates for such fractures evaluated the results in patients treated for fractures of the mandibular angle with a single, thin, malleable miniplate designed for use in the midface.[9] They showed that this plate provides adequate fixation for most fractures of the angle. However, an unacceptable rate of fracture of the plate was noted, and the plate could not be recommended for routine use for fractures of the angle.

The adult human man may generate a maximal bite force of 300–400 N.[22] This magnitude is reduced after trauma to the masticatory system. It might be explained by direct trauma or operative trauma to the masseter muscles. Alternatively, to protect neuromuscular mechanisms of the masticatory system after fracture of the bone, muscle-splinting components are activated or deactivated to take the force of the damaged bone.[12] Vertical bite forces are reported to be 31% and 52% of molar forces obtained within the control group at the first and sixth week after treatment of fractures of the angle.[10,11] Considering these findings, the vertical forces applied in in vitro studies were more than the bite forces in patients with fractures of the mandibular angle.

We evaluated the reliability of fixation during the early postoperative healing period. We tested our titanium materials using a maximum force of 90 N; we could not apply a load of greater than 90 N because the malleable plates fractured. This finding supports the fact that there has been an unacceptable rate of fracture of the plate during the early postoperative period.

In conclusion, our results clearly show that malleable plates had insufficient stability to support fractures of the mandibular angle alone. From a clinical perspective, we think that intermaxillary fixation may be needed to support the malleable miniplate fixation system during the early postoperative period after a fracture of the mandibular angle. However, the success or failure of treatment of such fractures depends not only on the design of the plate and the diameter of the screws, but also on some of the many compounding factors such as the direction of the fracture line, the occlusal status of the patient, the presence of wisdom teeth in the line of fracture, and the sex of the patient.

Table 2
Mean (SD) displacement values (mm) in the 9 hemimandibles given a single malleable miniplate at each increment of force.

Time	10 N	20 N	30 N	40 N	50 N	60 N	70 N	80 N	90 N
1	0.41	0.92	3.28	4.06	5.20	5.62	6.03	6.46	6.98
2	0.56	1.60	2.43	2.98	3.52	4.21	6.01	6.84	7.21
3	1.14	2.20	3.46	3.81	4.10	4.50	4.80	5.21	5.30
4	0.55	1.14	1.54	1.97	2.40	2.90	3.45	4.10	4.73
5	0.62	1.54	2.60	3.00	3.58	3.96	4.20	4.52	4.86
6	0.32	0.96	1.28	1.64	2.02	2.30	2.56	2.91	3.22
7	0.23	0.76	1.30	1.77	2.26	3.21	3.83	4.36	4.82
8	0.96	1.70	2.26	2.80	3.34	3.91	4.44	4.88	5.76
9	0.40	1.10	1.56	2.00	2.70	3.03	3.40	3.88	4.83
Mean (SD)	0.58 (0.3)	1.32 (0.48)	2.19 (0.84)	2.67 (0.9)	3.24 (1.02)	3.74 (0.33)	4.30 (1.17)	4.80 (1.23)	5.30 (1.23)

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