Comparison of stability of titanium and absorbable plate and screw fixation for mandibular angle fractures

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Objective. The purpose of this experimental study was to compare the stability of titanium and absorbable plate and screw fixation systems for mandibular angle fractures.

Study design. Twenty-one sheep hemimandibles were used to evaluate 3 different plating techniques. The groups were fixated with a single titanium plate, a single absorbable plate and double absorbable plates. A cantilever bending biomechanical test model was used for the samples. Each group was tested with vertical forces by a servohydraulic testing unit. The displacement values in each group at each 10 N stage up to 100 N were compared using the 2-way analysis of variance test.

Results. The displacement values for the 3 groups differed significantly ($P < .05$). The variance analyses showed that titanium plate placement had more favorable biomechanical behavior than others. In addition, the 2 absorbable plates group had more favorable biomechanical behavior than a single absorbable plate group but it was not significantly different at 10 to 40 N.

Conclusion. The study demonstrated that titanium plate and screw fixation system had greater resistance to occlusal loads than absorbable plate and screw systems. In addition, a second absorbable plate orientation provides a more favorable biomechanical behavior than a single absorbable plate placement. **(Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008;xx:xxx)**

The angle is one of the most frequent fracture sites after traumatic events involving the mandible.[1-3] Plate-and-screw fixation has been a standard approach in the management of mandibular angle fractures and various treatment methods have been recommended.[4-6] In general, when it is evaluated, one of the most chosen from these treatment methods is the technique of placing a single titanium miniplate at the superior border to fix fractures of the mandibular angle, as described by Champy et al.[7-9] Currently, absorbable plate-and-screw fixation systems are also used for treatment of mandibular angle fractures.[10-15] These biologically degradable materials cause no clinically important long-term inflammatory or toxic reactions in humans.[16] Even the various clinical studies have confirmed the efficiency of absorbable plates and screws for the treatment of mandibular angle fractures lately; as far as we found, biomechanically there is only 1 report on the use of absorbable miniplates and screws for mandibular angle fractures.[17] The purpose of this experimental study was to compare the stability of titanium and absorbable plate-and-screw fixation systems for mandibular angle fractures.

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MATERIALS AND METHODS

Twenty-one hemimandibles taken from similar sheep (mean weight 40 kg, fed on the same diet, collected from the same abattoir, and slaughtered similarly) were used in this investigation. The mandibles were stripped of their soft tissues and divided in the anterior midline between the central incisors. The specimens were kept moist and refrigerated until all testing was complete. Because of the difficulty in placing the mandibles in the fixation apparatus, all coronoid processes and anterior bone segments were removed. The models were sectioned in a uniform manner 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. The osteotomy was made at approximately 45 degrees extending from the retromolar region into the inferior aspect of the mandibular angle. This was a complete through-and-through bicortical osteotomy. The hemimandibles were randomly divided into 3 groups of 7, and fixated with 3 different plating techniques.

In the first group, a single titanium 4-hole noncompression miniplate, with 2.0 mm in diameter and 5 mm in length screws, were adapted on the external oblique

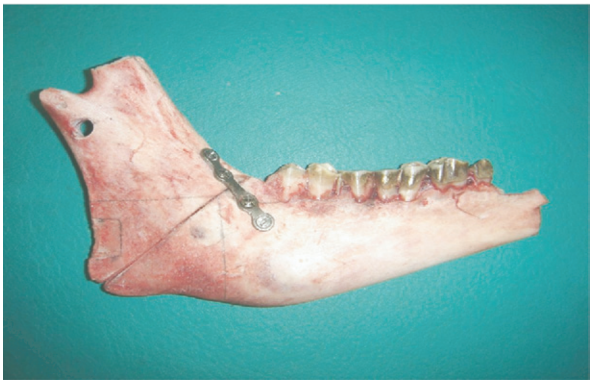

Fig. 1. A single titanium 4-hole noncompression miniplate.

Fig. 2. A single 4-hole absorbable plate (PLLA + PLDLA).

ridge (Trimed Titanium Implant System, Ankara, Turkey). In the second group, a single 4-hole absorbable plate, with 2.5 mm in diameter and 6 mm in length screws (PLLA + PLDLA), were adapted along the buccal aspect of the external oblique ridge (Inion CPS 2.5 Biodegradable Fixation System, Tampere, Finland). In the last group, two 4-hole absorbable plates, with 2.0 mm in diameter and 5 mm in length, screws (PLLA + PLDLA) were adapted on the fracture site with biplanar position for fixation (Inion CPS 2.0 Biodegradable Fixation System, Tampere, Finland) (Figs. 1 to 3). The occlusal surface of the dentulous portion where was applied load force was flattened with a bur. Smooth surface contact was aimed with this procedure. Each fixed specimen was mounted on a servohydraulic testing unit (TST 2500 mxe, ELISTA Electronic Informatic System Design Ltd. İstanbul, Turkey) with a fixation apparatus. The fixation apparatus 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 the this hole to stabilize the superior proximal segment of the mandible. The other portion existed in the postero-inferior ramus and it prevented backward and lateral movements of the inferior proximal segment of the mandible. Additionally, the system contained a cylindrical steel rod to be applied of occlusal load (Fig. 4).

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 100 N. 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., İstanbul, Turkey). The displacement values in each group at each 10-N stage up to 100 N were compared using the 2-way analysis of variance test.

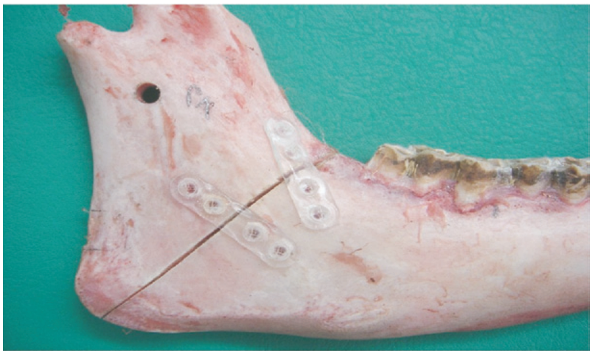

Fig. 3. Two 4-hole absorbable plates (PLLA + PLDLA).

RESULTS

The groups' displacement values for each 10-N increment up to 100 N are shown in Tables I to IV. The displacement values for the 3 groups differed significantly ($P < .05$) (Table IV). The variance analyses showed that titanium plate placement had more favorable biomechanical behavior than others. In addition, the 2 absorbable plates group had more favorable biomechanical behavior than a single absorbable plate group but it was not significantly different at 10 to 40 N (Fig. 5). No plate fixation system or hemimandible failures (breakage or fracture) were observed within the 0- to 100-N test range.

DISCUSSION

Fixation of mandibular angle fractures is possibly more critical than fixation of fractures located in other regions of the mandible. Angle fractures are associated

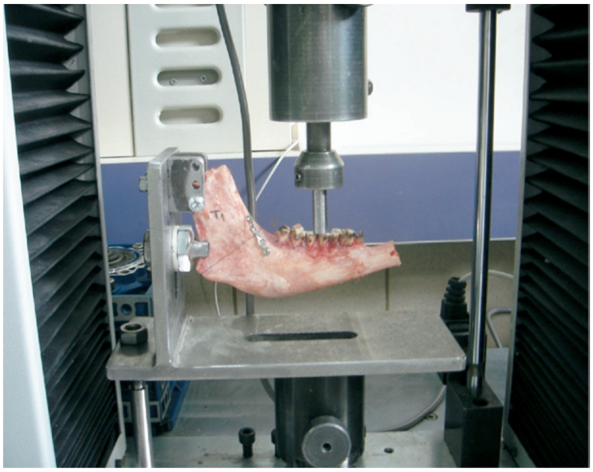

Fig. 4. The specimen that was adapted to the fixation apparatus.

with the highest rate of postsurgical complications of all mandibular fractures.[1,18-20] This finding might be related to the use of different fixation techniques.[20] In the literature, discussion is still ongoing about the preferred type of fixation.[20-23] Since the introduction of the Champy miniplate in treatment of mandibular fractures, the potential and effectiveness of this method has been demonstrated in many clinical studies.[24-30] Ellis[20] performed various treatment methods on mandibular angle fractures and they also concluded that using a single miniplate is a simple and reliable technique with a relatively small number of major complications.

Following fracture treatment of the mandible, the occlusal force in the early postoperative period is considerably less than the healthy person's force of the bite. This condition might be explained by traumatic or operative trauma to the masseter muscles or to protective neuromuscular mechanisms of the masticatory system when after bone fracture, muscle splinting components are activated or deactivated to take forces of the damaged bone.[31] Gerlach and Schwarz[32] showed that the mean bite force in 22 patients who had mandibular angle fractures was 69.91 N at 1 week, 92.39 N after 3 weeks, and 130.43 N after 6 weeks postoperatively. They also concluded that the vertical force applied in in vitro studies were more than bite forces in patients with mandibular angle fractures.

In this study, we aimed that evaluating of fixation reliability in early postoperative healing period in mandibular angle fractures. We tested our titanium and absorbable materials using a maximum force of 100 N because we could not apply load of more than 100 N in specimens that were fixed absorbable materials.

Mechanical testing was conducted using the cantilever bending method in this study. The basic cantilever bending principles of a force applied to the teeth while maintaining the proximal bone secure was not altered. This technique was previously reported to assess stiffness of a sheep mandibular fracture wound.[33]

As far as we know, in the literature, biomechanically there is only 1 report on the use of absorbable miniplates and screws for mandibular angle fractures. Chacon et al.[17] compared the stability of titanium and absorbable fixation systems for mandibular angle fractures with a biomechanically experimental study. They found significant biomechanical differences between a 2.0-mm titanium miniplate and a 2.1-mm absorbable plate when used to treat a mandibular angle fracture following Champy's principles.

In the literature there are a few clinical studies that use absorbable materials in mandibular angle fractures. Yerit et al.[10,11] performed two 2.0 mm absorbable plate (SR-PLDLA) for patients who had angle fractures and did not use postsurgical intermaxillary fixation (IMF). Another study by Kim and Kim[12] reported the fixation of mandibular angle fractures with a single 2.4-mm self-reinforced poly-L/D-lactide plate; they used postsurgical İMF in 2 weeks. Landes and Balon[13] preferred double osteoyntheses with 1 monocortical plate at the superior border and a second plate at the inferior margin. When the studies with the Inion system were investigated, Wood[14] published a study about biodegradable poly-L/D-lactide fixation of 68 mandibular fractures using 1 single 2.5-mm plate in angle fractures. Mucosal exposure of the plates and infection occurred in 19 patients. In these patients, fractures of the mandible were later treated with 2.0-mm orthognathic plates inserted by a transbuccal approach and applied postoperative IMF (median 14 days). Laughlin et al.[15] performed a single 2.5-mm absorbable plate for patients who had angle fractures and also applied postsurgical IMF in all patients (2 weeks).

When the foregoing clinical studies were evaluated, it was seen that thick absorbable plates and wide diameter screws were used in the treatment of angle fractures with single absorbable plate and screws. We also used a thicker absorbable plate, wider diameter, and longer screws in second group when compared to the single titanium group. Besides, 2.0-mm plates were preferred in third group.

The absorbable materials consisting of copolymer of L-lactide/LD-lactide were used in clinical studies[10-15] associated with mandibular angle fractures and a biomechanical study that was made by Chacon et al.[17] In the present study, we also used absorbable plates and screws consisting of an amorphous injection-molded copolymer of L-lactide/LD-lactide/trimethylene carbonate (TMC). These plates have been reported to resorb slowly, maintaining 70% of their initial strength

Table I. Displacement values in the titanium group at each force increment

Titanium	10 N	20 N	30 N	40 N	50 N	60 N	70 N	80 N	90 N	100 N
T1	0.13	0.38	0.82	1.29	1.79	2.56	3.23	4.09	4.71	5.20
T2	0.18	0.40	0.64	1.01	1.76	2.03	2.31	2.60	2.90	3.15
T3	0.20	0.36	0.49	0.64	0.85	1.09	1.40	1.77	2.21	2.82
T4	0.21	0.49	0.76	1.07	1.41	1.82	2.44	3.00	3.61	4.26
T5	0.18	0.27	0.42	0.56	0.72	0.97	1.28	1.62	2.07	2.52
T6	0.28	0.58	0.91	1.21	1.54	1.90	2.26	2.61	2.94	3.32
T7	0.17	0.30	0.64	0.86	1.04	1.20	1.36	1.55	1.73	2.01

Table II. Displacement values in a single absorbable group at each force increment

PLDLA/PLLA CPs 2.5	10 N	20 N	30 N	40 N	50 N	60 N	70 N	80 N	90 N	100 N
R1	0.82	1.92	3.21	4.26	5.45	6.72	7.76	#	#	#
R2	1.18	3.46	4.95	5.83	6.87	7.67	8.56	9.39	10.46	11.61
R3	1.51	2.29	3.42	4.50	5.69	7.28	8.68	#	#	#
R4	1.34	3.10	4.00	4.77	5.76	6.64	7.36	8.13	9.15	10.47
R5	1.61	2.79	3.78	4.44	5.07	5.70	6.26	6.95	7.54	8.79
R6	1.54	3.15	3.95	4.63	5.36	6.38	#	#	#	#
R7	0.71	1.17	1.82	2.81	3.47	4.11	4.86	6.55	7.41	#

#We did not reach any value in this load.

Table III. Displacement values in the double absorbable group at each force increment

PLDLA/PLLA CPs 2.0	10 N	20 N	30 N	40 N	50 N	60 N	70 N	80 N	90 N	100 N
rr1	0.85	1.69	2.30	3.06	4.21	5.32	7.11	8.91	10.71	*
rr2	0.94	1.97	2.73	3.10	3.41	3.80	4.50	5.54	*	*
rr3	0.86	1.82	2.38	3.16	3.59	3.85	4.06	5.15	6.26	7.22
rr4	0.78	1.24	2.41	3.05	3.36	3.90	4.60	5.61	7.21	*
rr5	1.02	2.07	3.71	4.77	5.34	5.88	6.51	7.23	8.39	*
rr6	1.30	3.13	3.86	4.63	5.21	5.97	6.86	7.53	8.55	9.34
rr7	1.01	1.91	2.74	3.51	4.33	5.16	6.28	7.55	8.31	*

*We did not reach any value in this load.

Table IV. Displacement values for the 3 groups differed significantly ($P < .05$)

Groups	Mean	Median	SD	Minimum	Maximum
Titanium	1.587	1.325	1.192	0.130	5.200
PLDLA (2.5 single plate)	5.171	4.950	2.696	0.710	11.610
PLDLA (2.0 Double plate)	4.418	3.980	2.419	0.780	10.710

at 9 to 14 weeks, with 42% bulk resorption by 40 weeks, and are completely resorbed by 2 to 4 years. Additionally, the presence of TMC has a strong impact on the malleability (flexibility) of the final products and contributes to the product's ease of use.[15]

According to our results, the titanium fixation system showed the best stability among the groups. And the 2 absorbable plate groups had more favorable biomechanical behavior than a single absorbable plate group but it was not significantly different at 10 to 40 N. Even the second absorbable plate that was adapted to the lateral buccal surface of the mandible increased the stability after 40 N. When clinical conditions are considered, this procedure led to several disadvantages, including dissection of the periosteum on large areas, requiring the transbuccal approach, risk of alveolar

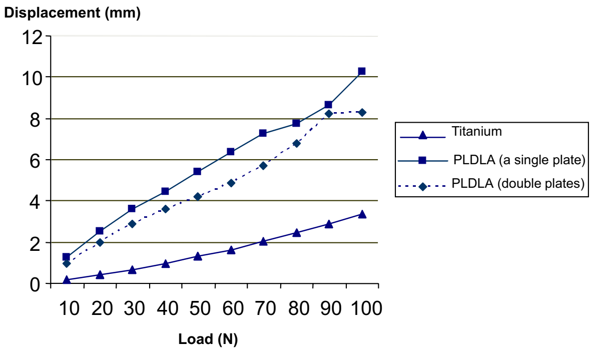

Fig. 5. Load-displacement curves for the 3 groups drawn through the mean displacement values at each increment.

nerve damage, prolonging the operation time, and increasing the cost.

Even if it is a major advantage that absorbable materials do not necessitate a second surgical procedure, when using absorbable materials in bones that are exposed lateral and torsional forces like the mandible during the mastication, it can be a necessary additional effort intended for increase of stability (increasing the number of plates or screws, using of postsurgical IMF). In addition, in wet circumstances, hydrolytic breakdown presumably starts after hydration and may reduce the plate's resistance.

Although the manufacturer advises the application of light elastic IMF for 3 days to enable the plate to attain maximum strength, when our results and clinical studies using the Inion absorbable system are considered, IMF may be needed to support the absorbable plate and screw fixation systems in the early postoperative period after mandibular angle fractures.

In this study, comparison of different fixation systems was performed for experimental models in only simple noncommunited fractures. Also, the other fractures (unfavorable or communited) involving the mandibular angle might be tested biomechanically to each other.

In conclusion, the present experimental study demonstrated that the titanium plate-and-screw fixation system had greater resistance to occlusal loads than absorbable plate-and-screw systems, statistically. In addition, a second absorbable plate orientation provides a more favorable biomechanical behavior than a single absorbable plate placement.

REFERENCES

1. Chuong R, Donoff RB, Guralnick WC. A retrospective analysis of 327 mandibular fractures. J Oral Maxillofac Surg 1983;41: 305-9.
2. Ellis E 3rd, Moos KF, el-Attar A. Ten years of mandibular fractures: an analysis of 2,137 cases. Oral Surg Oral Med Oral Pathol 1985;59(2):120-9.
3. Haug RH, Prather J, Indresano AT. An epidemiologic survey of facial fractures and concomitant injuries. J Oral Maxillofac Surg 1990;48:926
4. Luhr HG. Compression plate osteosynthesis through the Luhr System. In: Kroger E, Schilli W, editors. Oral and maxillofacial traumatology. Chicago: Quintessence; 1982; pp 308-370.
5. Iizuka T, Lindqvist C. Rigid internal fixation of fractures in the angular region of the mandible: an analysis of factors contributing to different complications. Plast Reconstr Surg 1993;91: 265-71.
6. Ellis E 3rd, Walker LR. Treatment of mandibular angle fractures using one noncompression miniplate. J Oral Maxillofac Surg 1996;54(7):864-71; discussion 871-2.
7. Champy M, Wilk A, Schnebelen JM. Tretment of mandibular fractures by means of osteosynthesis without intermaxillary immobilization according to F.X. Michelet's technic. Zahn Mund Kieferheilkd Zentralbl 1975;63(4):339-41.
8. Champy M, Lodde JP, Jaeger JH, Wilk A, Gerber JC. Mandibular osteosynthesis according to the Michelet technic. II. Presentation of new material. Results. Rev Stomatol Chir Maxillofac 1976;77(3):577-82.
9. Champy M, Lodde JP, Schmitt R, Jaeger JH, Muster D. Mandibular osteosynthesis by miniature screwed plates via a buccal approach. J MaxilloFac Surg 1978;6:14-21.
10. Yerit KC, Enislidis G, Schopper C, Turhani D, Wanschitz F, Wagner A, et al. Fixation of mandibular fractures with biodegradable plates and screws. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2002;94(3):294-300.
11. Yerit KC, Hainich S, Turhani D, Klug C, Wittwer G, Ockher M, et al. Stability of biodegradable implants in treatment of mandibular fractures. Plast Reconstr Surg 2005;115(7):1863-70.
12. Kim YK, Kim SG. Treatment of mandible fractures using bioabsorbable plates. Plast Reconstr Surg 2002;110(1):25-31; discussion 32-3
13. Landes CA, Ballon A. Indications and limitations in resorbable P(L70/30DL)LA osteosyntheses of displaced mandibular fractures in 4.5-year follow-up. Plast Reconstr Surg 2006;117(2): 577-87; discussion 588-9
14. Wood GD. Inion biodegradable plates: the first century. Br J Oral Maxillofac Surg 2006;44(1):38-41.
15. Laughlin RM, Block MS, Wilk R, Malloy RB, Kent JN. Resorbable plates for the fixation of mandibular fractures: a prospective study. J Oral Maxillofac Surg 2007;65(1):89-96.
16. Edwards RC, Kiely KD, Eppley BL. Fixation of bimaxillary osteotomies with absorbable plates and screws: experience in 20 consecutive cases. J Oral Maxillofac Surg 2001;59:271-6.
17. Chacon GE, Dillard FM, Clelland N, Rashid R. Comparison of strains produced by titanium and poly D, L-lactide acid plating systems to in vitro forces. J Oral Maxillofac Surg 2005;63(7): 968-72.
18. James RB, Fredrickson C, Kent JN. Prospective study of mandibular fractures. J Oral Surg 1981;39:275-81.
19. Iizuka T, Lindqvist C, Hallikainen D, Paukku P. Infection after rigid internal fixation of mandibular fractures. A clinical and radiologic study. J Oral Maxillofac Surg 1991;49:585-93.
20. Ellis E 3rd. Treatment methods for fractures of the mandibular angle, Int J Oral Maxillofac Surg 1999;28(4):243-52.
21. Levy FE, Smith RW, Odland RM, Marentette LJ. Monocortical miniplate fixation of mandibular fractures. Arch Otolaryngol Head Neck Surg 1991;117:149-54.
22. Luhr HG. The development of modern osteosynthesis Mund Kiefer Gesichtschir 2000;4(1):84-90.
23. Gear AJ, Apasova E, Schmitz JP, Schubert W. Treatment mo-

dalities for mandibular angle fractures. J Oral Maxillofac Surg 2005;63(5):655-63.
24. Gerlach KL, Pape HD. Prinzip und Indikation der Miniplatten-osteosynthese. Dtsch Zahnaerztl Z 1980;35:346-8.
25. Pape HD, Herzog M, Gerlach KL. Der wandel der unterkeifer-frakturversorgung von 1950 bis 1980 am beispeil der Kölner Klinik. Dtsch Zahnarztl Z 1983;38:301
26. Cawood JI. Small plate osteosynthesis of mandibular fractures. Br J Oral Maxillofac Surg 1985;23(2):77-91.
27. Wald RM, Abemayor E, Zempleny J, et al. The transoral treatment of mandibular fractures using noncompression miniplates: a prospective study. Ann Plast Surg 1988;20:409.
28. Moore MH, Abbott JR, Abbott AH, Trott JA, David DJ. Monocortical non-compression miniplate osteosynthesis of mandibular angle fractures. Aust N Z J Surg 1990;60(10):805-9.
29. Bolourian R, Lazow S, Berger J. Transoral 2.0-mm miniplate fixation of mandibular fractures plus 2 weeks' maxillomandibular fixation: a prospective study. J Oral Maxillofac Surg 2002; 60(2):167-70.
30. Chritah A, Lazow SK, Berger JR. Transoral 2.0-mm locking miniplate fixation of mandibular fractures plus 1 week of maxillomandibular fixation: a prospective study. J Oral Maxillofac Surg 2005;63(12):1737-41.
31. Tate GS, Ellis E 3rd, Throckmorton G. Bite forces in patients treated for mandibular angle fractures: implications for fixation recommendations. J Oral Maxillofac Surg 1994;52(7):734-6.
32. Gerlach KL, Schwarz A. Bite forces in patients after treatment of mandibular angle fractures with miniplate osteosynthesis according to Champy. Int J Oral Maxillofac Surg 2002;31(4):345-8.
33. Rahn B, Cordey J, Prein J, Russenberger M. Biomechanics of osteosynthesis in the mandible. Fortschr Kiefer Gesichtschir 1975;19:37-42.

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