IDR International Dental Research

Original Article

Effect of plate configuration on resistance in mandibular angle fractures

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Abstract

Aim: The aim of this in-vitro experimental study is to compare the biomechanical behaviors of three single-miniplate osteosynthesis configurations used in the treatment of mandibular angle fractures.
Methodology: Fifteen synthetic polyurethane hemimandible replicas including the medullar and cortical portions were used in this study. The replicas were divided randomly into three groups (n = 5/group). Data from the three groups were compared using analysis of variance and the Tamhane T2 test. p<0.05 were considered to indicate significance. The replicas in all groups were fixed with 7-mm-long self-tapping screws and 2.0-mm four-hole miniplates in three different configurations external oblique, lateral angulus superior and lateral angulus inferior configuration.
Results: The replicas were tested on a servo-electric test machine, and the data were transmitted to a computer for analysis of peak displacement and peak force. Peak load and peak displacement did no differ significantly among the three groups.
Conclusion: This experimental study showed that the torsional forces resulting from the fixation of miniplates for the treatment of mandibular angle fracture did not differ among the three configurations tested.

Keywords: Mandibula, fracture, stabilisation.

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Received: 25 October 2019
Accepted: 19 April 2020

Access Online

DOI:
10.5577/intdentres.2020.vol10.no1.2

How to cite this article: Polat ME, Ghahramanzadeh asl H, Yanık S. Effect of plate configuration on resistance in mandibular angle fractures. Int Dent Res 2020;10(1):6-11. https://doi.org/10.5577/intdentres.2020.vol10.no1.2

Introduction

Mandible, the only moving cranial bone, is the tenth most commonly fractured human bone and the second most commonly fractured bone in the facial region. The etiologies of mandibular fracture include trauma incurred during fights, motor vehicle accidents, work accidents, falls, and sports accidents, as well as pathological conditions and firearm injuries, with the incidences of each differing among societies (1, 2).

Reported anatomical distributions of mandibular fracture sites vary widely, with some authors reporting the angulus as the most commonly fractured site and others identifying the corpus, symphyseal, and condylar regions (3-6). Mandibular angle fractures are notable not only for their high rate of occurrence, but also because they are associated with a high rate of postoperative complications (7, 8).

Although numerous methods for the treatment of mandibular fracture have been developed, the miniplate osteosynthesis introduced by Champy (5) in 1975 is accepted most widely (9). However, whether optimal treatment is achieved using one versus two miniplates remains controversial (10, 11). In comparative studies, similar rates of complications, including nonunion, malunion, malocclusion, plaque fracture, osteomyelitis, and local abscess development, occurred in patients treated with two or single miniplates. It is also stated that two miniplates seem to confer no extra benefit to patients with mandibular angulus fracture. (10, 11). In addition to the lower rate of serious complications, an advantage of the single miniplate technique is that minimal dissection is required and the volume of implanted material is accordingly smaller (12, 13).

Champy et al. described the placement of a single miniplate on the superior aspect of the mandibular angle along the “ideal lines of osteosynthesis” (5). This goal can be achieved with different surgical techniques. The transoral technique involves intraoral incision through the oral mucosa, whereas the transbuccal approach involves intraoral incision and the creation of a small incision through the facial skin, which allows for the insertion of a transbuccal trocar for drilling and screw placement (6, 8, 9). Moreover, as the transbuccal approach exposes the fracture site completely, it provides excellent visibility (3, 10). However, it requires bending of the plate to facilitate its placement in the neutral midpoint area of the mandible (8). Additional limitations of the transbuccal approach include the requirements for an appropriate armamentarium and training of the surgeon in the use of a transbuccal trocar (6, 10). By contrast, the placement of a miniplate intraorally on the lateral surface of the mandible permits angular screw insertion. However, no reported study has compared the fixation stability achieved with the transbuccal approach, intraoral approach or extraoral approach. It is clear that for different configurations, different surgical approaches, which has different risks, needed.

It is reported that the predominant sagittal bending non-working side of the mandibula results as torsion on the working side of mandibula especially in the body region. Also, it is reported that this torsion resulted in the narrowing of the mandibula on clenching and incisal biting. This narrowing was caused by torque produced by the elevator muscle forces of the mandibula. Torsional forces in mandibular fractures have been reported to reach up to 1000 Newton (9).

Thus, in the present study we compared the biomechanical behaviors of three single-miniplate configurations as following external oblique, lateral angulus superior and lateral angulus inferior configurations which are used in the osteosynthesis of mandibular fractures in the angulus region.

Materials and Methods

Fifteen synthetic dentate mandible replicas made of polyurethane resin with medullar and cortical portions (Synbone CF 8596; Malans, Switzerland) were used in this study. They were divided into three groups (n = 5 each). For each miniplate, a 2.0-mm four-hole bar system was used. In the first group, the miniplates were placed on the external oblique ridge according to the Champy method to duplicate the external oblique configuration and intraoral approach (5). In the second group, the miniplates were placed in the middle of the fracture line to duplicate the lateral angulus superior configuration and the use of a trocar via transbuccal approach. In the third group, the miniplates were placed along the lower fracture border as lateral angulus inferior configuration and the extraoral approach (Fig.1).

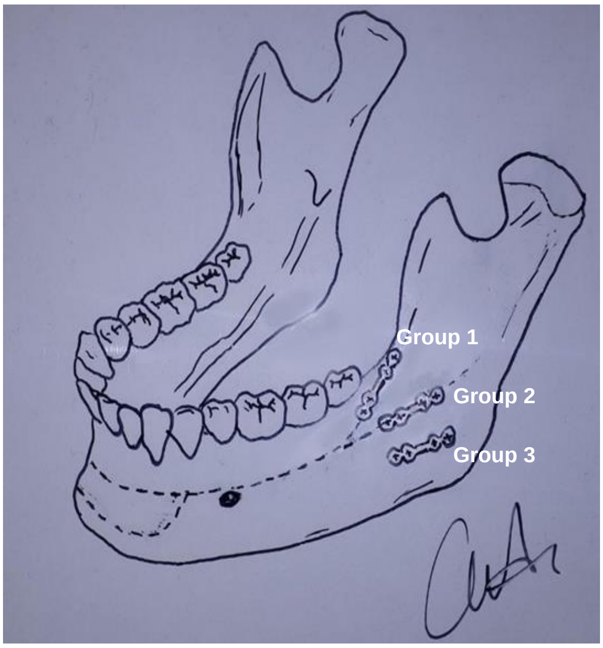

Figure 1. Fixation Configurations

All osteotomies were performed according to a standard protocol. The starting point of the osteotomy, defined as point A, was set 3 mm distal to the last mandibular molar. A line was then traced from this point perpendicular to the mandibular base. The most inferior point of this perpendicular line was marked as point C, and a position 10 mm posterior to point C was marked as point B. Sectioning was performed from point A to point B. The procedure was standardized using an acrylic guide (Fig. 2).

All miniplates were first drilled and fixed to the hemimandible to avoid adaptation problems, especially in the intraoral group. The screws in the distal segment were removed and the osteotomy was them performed using a diamond disc. Thereafter, the screws in the distal segment were replaced in the drilled sites.

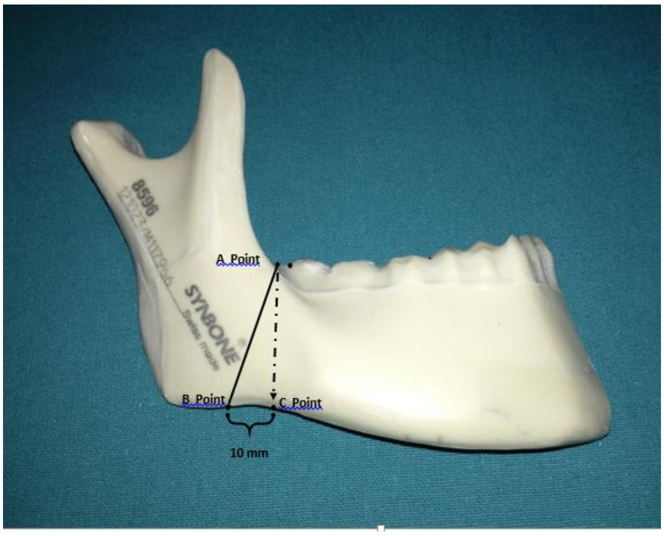

Figure 2. Sectioning Procedure

Figure 3. Loaded sample

The miniplates in all three groups were subjected to torsion testing under static conditions. For each mandible replica, the two fragments were placed in the test apparatus (Jinan NDW-200) as shown in Figure 3. Torsion was exerted at a rate of 5°/min, and the results were recorded on a computer (Trapezium version 2.15; Kyoto, Japan). The maximum load (kN) and maximum displacement (°) were then determined.

Statistical Analysis

Statistical analyses comprised analysis of variance and between-group comparisons using Tamhane's T2 test. P values<0.05 were considered to indicate statistical significance.

Results

Values of peak load (Newtons) and for displacements of three groups are presented in Table 1. Without any statistically significant differences lateral angulus inferior configuration had the least mechanical resistance among groups, regardless of displacement, and intraoral group had the greatest mechanical resistance.(Table 1-2) When the displacement values evaluated intraoral group showed better results than the other groups but there were no statistically significant differences between groups as peak loads comparisons.(p>0.05)

The three groups did not differ significantly in terms of the response to a load applied at the same site. Peak displacement and peak force resistance also did not differ significantly. However, the numerical values of the intraoral group suggested a better resistance response (Table 1-2).

Table 1. Between group comparisons

Between group Comparisons		p values for peak forces	p values for peak displacements
External Oblique Ridge Group	Lateral Angulus Superior Group	,294	,475
	Lateral Angulus Inferior Group	,196	,983
Lateral Angulus Superior Group	External Oblique Ridge Group	,294	,475
	Lateral Angulus Inferior Group	,927	,634
Lateral Angulus Inferior Group	External Oblique Ridge Group	,196	,983
	Lateral Angulus Superior Group	,927	,634

Table 2. Descriptive variables

	Groups	n	Mean	Std. Devaition
Force (N)	External Oblique Ridge Group	5	978,0	213,9
	Lateral Angulus Superior Group	5	778,4	96,0
	Lateral Angulus Inferior Group	5	742,0	104,7
Displacement (°)	External Oblique Ridge Group	5	85,6	23,2
	Lateral Angulus Superior Group	5	106,6	23,4
	Lateral Angulus Inferior Group	5	90,4	21,0

Discussion

The mandibular angle is one of the most commonly fractured sites in the mandible, and this fracture type has the highest rate of complications. The strategies used in the treatment of mandibular angle fractures include closed reduction with intermaxillary fixation (IMF), open reduction, and internal fixation with or without IMF. Open reduction allows for good anatomical repositioning and immediate mandibular function. However, with advances in miniplate/screw systems, most angle fractures are treated by rigid internal fixation (14, 15).

Two-plate fixation has been suggested to offer several advantages over one-plate fixation, but this assertion remains controversial. Moreover, the use of a single miniplate in fracture repair is simpler, minimizes the amount of osteosynthesis material required for the procedure, and causes fewer complications (16). Accordingly, in this study we examined whether the configuration of single miniplates affects torsional forces during the repair of mandibular angle fractures (9). The elasticity of the polyurethane mandible replicas used in the investigation is very similar to that of human bony structures and allowed for the simulation of physiological conditions (17). Bredbenner and Haug compared the biomechanical characteristics of polyurethane mandible replicas with cadaver mandibles and demonstrated that the replicas are suitable for biomechanical studies of experimental fractures (18).

After the surgical treatment of mandibular fracture, the masticatory forces generated by jaw movements are restored slowly over time. The forces are weakest on the second postoperative day, due to edema and pain (9). In healthy adults, biting forces can reach up to 400 N; following mandibular fracture, the forces are reduced by a protective mechanism involving the neuromuscular structure of the chewing system. In mandibular angle fractures, the tension and compression zones vary according to the region in which the force (bolus) is loaded (19, 20).

Patients with mandibular fractures tend to chew food using the molar region opposite the fracture site.

The masseter and medial pterygoid muscles pull the posterior mandible upward while the bolus in the incisal or unfractured molar region obstructs or strengthens mandibular rotation after a certain distance. Then, regardless of the course of the fracture line, the posterior fracture segment continues to rotate. As a result of these movements, a gap is present between the superior edges of the fracture line, with reduced opening at the inferior margin or relative compression. Torsional forces are generated along the mandibular fracture line such that its upper side rotates medially in the transverse plane (21). However, we could not find a study comparing these torsional forces in mandible angular fractures in the literature. Finite element studies related ostheosythesis configuration of mandibular angular region fractures are present in the literature (22). According to them when one miniplate osteosyhthesis employed for treatment the miniplate should positioned superior as posibble for higher load resistance. In our study although there were no statistically significant differences between three configuration the higer one showed numerical better resistance than the others as it was mentioned in the literature before.

In jaw fractures, torsion is exerted by the bulging of the lower jaw below the fracture. Feller et al. examined the effects of torsion on different microplate and miniplate fixtures (9). They found that fixation was more rigid with the use of two miniplates/microplates than with the use of a single miniplate/microplate. In addition, movements caused by torsion loads resulted in stress on the miniplates, which would adversely impact patients' healing times. According to Champy (5), because of the torque that develops in the anterior region of the mandible, fixation should be performed so as to ensure a force tolerance of up to 1000 N. However, a subsequent study showed that fixation with a double miniplate resulted in 4.25 times less resistance at 700 N/mm than did fixation with a single miniplate (9).

The treatment of mandibular fracture depends on the fracture type, anatomical location of the fracture line, amount of displacement of the fractured segments, and the patient's dentition. Despite the advantages of an extraoral approach over open reduction, such as better visualization and the simpler procedure required for insertion of the fixation plate, this approach also has very important disadvantages, including unaesthetic scarring and a greater risk of facial nerve damage. The intraoral approach avoids severe scarring and injury to the facial nerve, and has thus become more widely employed, although its drawbacks are that plate fixation and reduction of the fracture segments are challenging. A third route of access to mandibular angle fractures is the transbuccal approach. Visualization of the fracture site and reduction of the segments are similar to the intraoral approach, but a small incision through the facial skin is required to allow for the insertion of a transbuccal trocar, for subsequent passage of the drill and other instruments (23).

Kumar et al. evaluated complication rates following use of the intraoral, extraoral, and transbuccal approaches in 80 patients with mandibular fractures (23). The authors found no significant difference among the three techniques in terms of the complication rate (24). In a clinical study, Wan et al. compared the transoral and transbuccal approaches to the internal fixation of mandibular angle fractures (25). They reported fewer postoperative complications, including screw loosening, infection, and the need for plate removal, with the transbuccal than with the transoral technique. They attributed this difference to the anatomical position of the transoral plate. The authors also pointed out that many biomechanical studies of transoral plates have been conducted, but similar studies of transbuccal plates are lacking (25).

Sugar et al. (14) conducted a clinical study in which 140 mandibular angle fractures were treated by fixation with single miniplates in the transbuccal and intraoral configurations. The rate of postoperative complications was lower in the group treated using the transbuccal approach. In the present study, no significant difference was observed among the three groups. The different complication rates reported in the literature may reflect the difficult intraoral dissection required for intraoral screw insertion.

To our knowledge, this study is the first to compare the external oblique configuration, lateral angulus superior and lateral angulus inferior configuration. Omezli et al. also used polyurethane mandible replicas to compare intraoral and transbuccal configurations of single miniplates, and found no significant difference between groups with respect to vertical loads (23). We compared the mechanical resistance following intraoral, transbuccal, and extraoral miniplate fixation in the treatment of mandibular angle fractures. Our results showed that the biomechanical properties of the miniplates placed on the external oblique ridge were similar in the three groups.

The similarity of resistance of these three groups indicated that the external oblique ridge configuration which introduced by Champy and can be applied by intraoral approach has sufficient resistance on torsional forces. Surgical approaches for these three configurations are different from each other and intraoral approach without extraoral scar formation is seems to have least postoperative complication risks copared to transbuccal and extraoral approaches (5). One of the goals of this study is to find the configuration that provides adequate stabilization with low-risk surgical approach.

Conclusions

In conclusion, our study demonstrated that the configuration of single miniplates has no effect on fixation stability in mandibular angle fracture treatment. All one miniplate configurations can be employed in terms of torsional forces resistance but external oblique configuration seems to be more preferable than other configurations due to the low risk of surgical approach related complications. However, the divergent outcomes of clinical and biomechanical studies must be noted. The biomechanical properties of a treatment modality are not the only factors that influence healing. Thus, our results remain to be confirmed in prospective clinical studies that include the assessment of postoperative complication rates.

Peer-review: Externally peer-reviewed.

Author Contributions: Conception – M.E.P., S.Y.; Design – M.E.P., H.G.A.; Supervision – S.Y., H.G.A.; Materials – N.A.; Data Collection and/or Processing – M.E.P., H.G.A.; Analysis and/or Interpretation – M.E.P., H.G.A.; Literature Review – M.E.P., S.Y.; Writer – M.E.P., S.Y.; Critical Review – M.E.P., S.Y.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study has received no financial support.

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