



BIOMECHANICAL EVALUATION OF THREE DIMENSIONAL TITANIUM MINIPLATES IN MANDIBULAR FRACTURE FIXATION

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ABSTRACT

The unique position of mandible on the face makes it one of the most commonly fractured facial bones and considered the most common fractures treated by oral and maxillofacial surgeon.

There are a number of methods used till date for the treatment of mandibular fractures. Traditionally, the treatment modalities have ranged from conservative measures such as maxillomandibular fixation by means of wiring, splints or arch bar fixation to open reduction with fixation. Most authorities today, advise open reduction and fixation by plates and screws which is necessary for most of the mandibular fractures.

This study was conducted to evaluate an in vitro biomechanical properties of 3 dimensional plates used for treatment of mandibular fracture treatment (fixation). For this purpose a 20 sheep mandible was used to make the biomechanical tests (compression-tensile –torsional) on the universal testing machine.

In the present study, the results of the mean yield compression and tension stresses revealed that the used fixation system proved to be highly efficient for supporting the fracture. In during the period of osteosynthesis, as their point of deformation under load is far away from the reported maximum forces suitable for normal osteosynthesis processes.

Three dimensional miniplates are easy to adjust, requires minimal tissue dissection thus least disturbance to the tissues. Its low profile design and space between plate holes permits excellent revascularization. Comparing the three dimensional plating system with conventional systems, only fewer plates and screws are needed to stabilize the bone fragments.

INTRODUCTION

Face is the window through which we perceive the world around us and the world notes us. The face is crucial, injuries to face results in divesting physical and emotional sequelae. Maxillofacial

trauma is a cause of grave concern due to the increasing road traffic accidents, violence and sports injury. The unique position of mandible on the face makes it one of the most commonly fractured facial bones. Mandibular Fractures are

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the most common fractures treated by oral and maxillofacial surgeon. Fractures of mandible occur more commonly than any other fractures of facial skeleton. Significantly decreasing the mechanical strength of the mandible can lead to fracture. If such a fracture is due to changes in the turnover of the bone or the development of a resorptive lesion such as a tumor, then such a fracture is called pathologic fracture. When the fracture is directly due to the impact of medical interventions such as removal of a third molar or faulty osteotomy design, then such a fracture is called an Iatrogenic fracture.⁽¹⁾

In particular, a fracture may occur in any anatomically normal bone that is loaded beyond its tolerance.⁽²⁾ Fracture may also occur in a bone that has been weakened by an underlying pathologic process, even if the forces to which it is subjected would usually be tolerated. Such fractures are called pathologic fractures.^(3,4) The bone of the oro-facial skeleton is most commonly involved in pathologic fractures is the mandible.⁽¹⁾

Mandibular fractures most commonly accompany facial trauma, with nearly half of the patients requiring surgical repair. 75% of fractures occur in males aged 20–30, and are often caused by physical assault; other causes include motor vehicle collisions, falls, and sports-related injury. Certain fracture patterns predominate,

Many studies of the relationship between the nature, the severity, and direction of traumatic force which result to fracture of mandible were conducted and most literature regarding the mechanism of fracture was based on clinical impression and opinion.⁽⁷⁻⁸⁾

Early investigators showed the linear fracture of long bone were initiated by bone failure resulting from tensile strain rather compressive strain.⁽⁹⁾

Huelke and Harger applied forces of varying magnitudes and direction to dried mandibles and observed the resultant production of tension

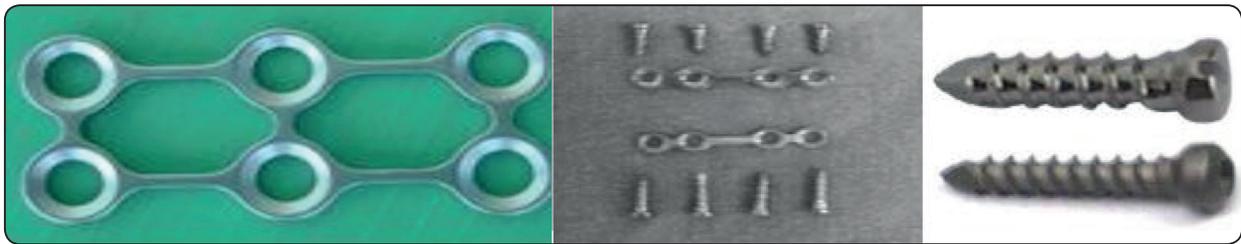
and compression. They found that > 75% of all experimentally produced fractures of the mandible were in primary areas of tensile strain, which supported a similar observation made earlier in long bone. A notable exception was that comminuted condylar head injury that was produced by a load parallel to the mandibular ramus was primarily the result of compressive force.⁽¹⁰⁾

When a force is directed along the parasymphysis-body region of the mandible, compressive strain develops along the buccal aspect, whereas tensile strain develops along the lingual aspect. This produces a fracture that begins in the lingual region and spreads toward the buccal aspect.⁽¹⁰⁾

Treatment of mandibular fractures has made significant advances over the years due to improved understanding of biomechanical principles, advances in biomaterials and instrumentation, and scientifically based research of treatment outcomes. The therapeutic goals in the treatment of such kinds of fractures depend on the arrangement of the bone fragments in their anatomical position, restoring functionality with least morbidity, and providing fracture stabilization. Treatment choices include closed or open techniques.⁽⁷⁾

The basic concept of three dimensional fixations is that a geometrically closed quadrangular plate secured with bone screws creates stability in three dimensions. The three dimensional plates are positioned parallel to fracture line. The cross linking provides the stability to the system.. The principle of the 3D fixation is further based on the idea that the plate is not positioned along the trajectories but over the weak structure lines. The fixation points of the plate remain in the vicinity of the fracture or osteotomy line.⁽¹⁰⁾

In spite of the small number of in vitro studies using 3D plates in fractures in the anterior region of the mandible, there are some authors who have reported the efficacy of the method, In two clinical studies, Jain et al. demonstrated the effectiveness



3D titanium mini plates

Miniplate & mini screws

Fig. (1) Showing 3D titanium mini plates& mini screws.

of 3D miniplates for fixation in the treatment of mandibular fractures in that region and analysed their advantages and disadvantages over a 2-month follow-up period. In the configuration used in their work, the material used proved to be less costly and readily adaptable, as well as reducing the operation time and providing greater stability.⁽¹¹⁾

Three dimensional miniplates are easy to adjust, requires minimal tissue dissection thus least disturbance to the tissues. Its low profile design and space between plate holes permits excellent revascularization.

Comparing the three dimensional plating system with conventional systems, only fewer plates and screws are needed to stabilize the bone fragments. The biomechanical and technical advantage of three dimensional miniplate systems promoted the current study to evaluate the biomechanical efficacy of three dimensional titanium miniplates as a viable treatment modality in the osteosynthesis of mandibular body fractures.

Various researches show that the 3D plating system offers more favorable biomechanical behavior than the conventional miniplates in terms of stability and strain resistance in different regions of mandible.^(12,13,14) The 1 mm standard 3D plate can withstand traction forces with value of 690 N which are almost the value of maximum load capacity of the mandible.⁽¹⁵⁾ The newly introduced 3D plating system provides definite advantages over conventional miniplates. The 3D plating

system uses fewer plates and screws as compared to conventional miniplates to stabilize the bone fragments. Thus it uses lesser foreign material, reduces the operation time and overall cost of the treatment as described by Zix et al. and Farmand et al.^(12,15,16)

The 3D plating system has a compact design and is easy to use. The 1.0 mm thick 3D plate is as stable as the much thicker 2–0 mm miniplate. This offers better bending stability and more resistance to out of plane movement or torque⁽¹²⁾. Whether one method is superior to another or not, it is difficult to determine.

Zix et al.⁽¹²⁾ concluded that 3D plating system is an easy to use alternative to conventional miniplates to treat mandibular angle fractures. Various researches show that the 3D plating system offers more favorable biomechanical behavior than the conventional miniplates in terms of stability and strain resistance in different regions of mandible.^(12, 13-16)

A biomechanical study investigated the effectiveness of fixation by 3-dimensional plates of simulated angle fractures in sheep mandible. It was shown that there was no failure in bone/screw interface. The results indicated that a 3-D plate can be used for fixation of mandibular angle fracture.⁽¹⁷⁾

P. Ricalde et al. (2005)⁽¹⁸⁾: conducted a study using Red oak wood board to simulate the mandible. Titanium and resorbable plates and screws in various configurations were used to stabilize pieces of the

wood. They were arranged in 6 different groups. The specimens were individually tested with a vertical load, while the test machine recorded the force-versus-displacement behavior automatically and concluded that the Overall, the titanium system was studied exhibited greater resistance to deformation from a vertical load than did the resorbable plate groups.

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The Aim of this study is an in-vitro study was to biomechanically evaluate the properties of the 3 dimensional titanium mini plates in mandibular fractures fixation.

MATERIALS AND METHODS

After the approval by the research ethical committee, 10 adult sheeps were used in this study with similar age (9–11 months). The animals were caged in the animal house of surgery department – Faculty of veterinary medicine – Zagazig university.

- Under the supervision by a veterinary, the selected animals were completely examined to rule out any diseases, vaccinated and housed under optimum conditions for 3 weeks being fed a natural diet till the time of experiment .

The selected sheeps were euthanized by intracardiac pentobarbital injection. 10 sheep mandibles with complete sets of teeth were separated from the skull and, were kept frozen at 40c till time of preparation.

Preparation of the fresh sheep mandibles:

- At room temperature, the mandibles were stripped of their soft tissue by a sharp dissector and divided in the anterior midline between the central incisors at the chin area using a bi-beveled 1.5 surgical osteotome 20 hemimandibles (right and left halves).
- The specimens were measured (height and width of the ramus, length of the mandible



Fig. (2) Showing condylar process were removed to avoid difficulty of fixation on the test jig during load application

and distance between the anterior limit of the foramen and the anterior border of the mandible) because the use of mandibles of disproportional sizes could interfere in the mechanical test.

- For creation of standardized osteotomies that simulate mandibular body fractures among all samples, a fracture line was determined by the aid of a prefabricated acrylic resin prefabricated guide and using fine band saw.
- The fracture line was planned to be situated midway between the last molar and the first molar (body area), bicortically & extending in oblique direction from superior border of mandible to inferior border of mandible. A wedge shape notch was done at inferior border to prevent resistance of bone to the load in the aim of characterizing of titanium miniplates material.
- The models were then uniformly sectioned with thin metal disc at low speed rotation & under copious saline irrigation following the predetermined fracture line.
- A wedge shape indentation was made at inferior border to prevent resistance of bone to the load in the aim of characterizing of titanium miniplates material.
- Soon afterwards, the selected experimental units were kept moist and refrigerated until all testing was complete.

The 20 prepared animal specimens were equally and randomly divided into 2 groups:

1. Bending test group (compression group): 10 hemimandibles with induced body fracture
 2. Tensile test group (tension group): 10 hemimandibles with induced body fracture
- The specimens of both groups were treated with the same fixation system (plates & screws) and prepared for mechanical testing.

Application of the fixation system:

- The application of the 3D titanium miniplates was carried out according to previously described methods.
- The proximal & distal segments were repositioned to original places by means of self retained bone forceps.
- The three dimensional mini plates were adapted by means of plate bending pliers.
- The adapted plates were placed on their planned sites, and preplanned sites of screw holes were marked such that, two holes were planned on each side of the induced fracture line, of which one hole is about 4-5 mm below the crestal bone and the other is 2mm above the inferior border of the mandible.
- The fixation system positions were standardized for the experiment with the help of a prefabricated acrylic resin guide.
- Screw holes were drilled using 1.5 mm titanium drill driven by straight hand piece, with a speed ranging from 6000-7000 RPM with cooling system & high torque .
- While the plate is in its place & screws are situated in the proper position, a screw driver with holding forceps was used to bring the screws into their proper places within their holes & fixation was confirmed.



Fig. (3) Showing border of mandible to inferior border of mandible.



Fig. (4) Showing mechanical testing (testing device).

- At the time of miniplate screwing, the hemimandible was stabilized using drops of prefabricated self polymerizing resin and the miniplates positioned to make perforation possible.
- The same operator carried out all perforations.
- The loads were progressively applied by the machine at a constant head speed of 10 mm/min and with forces measured in (Newtons) and all data were transferred and recorded with the connected computer.

Application of loads (Mechanical testing)

Testing devices:

1) Testing machine:

- All the hemimandibles of both groups were submitted to compression (group 1) & tensile loading (group 2) tests using the universal testing machine.
- This machine used a testing procedure in which the forces applied by the masticatory muscles were simulated in vitro. The models were positioned in such a way as to allow examination of the resistance of the osteosynthesis methods during simulated mastication.
- The equipment used for load testing was the LLOYD LR- 5 kN model of the Lloyd Universal Mechanical Testing Machine (Lloyd Instruments LTD, Segensworth, Fareham, England), connected to a computer with a specialized software.

2) Bending (compression) test device :

- For testing purposes, a specifically designed custom made 4-point biomechanical test jig was fabricated to be adapted to universal testing machine.

3) Tension test device :

- * The hooks were attached to the machine parts with the same mechanism as Bending (compression) test device.



Fig (5) Showing Two custom made metallic hooks were fabricated to be fixed to the upper and lower parts of the Instron machine.

Mechanical testing procedures :

1) *Bending (compression) test :*

- The custom made bending test device was attached to the testing machine and was used for compression test for Group (1) prepared samples.
- The samples were stabilized & firmly hold from ramus of mandible and incisor region with the aid of the lower compartment of custom made biomechanical test jig, as the elevated grooved bars represented a scaffold that will act as fulcrum to induce torque in the sample during loading.
- The motion of the testing machine head started from zero with the upper bending test device compartment moving downward slowly towards the fixed hemi mandible till touching occurred. Thus the elevated bars of both upper and lower bending test device compartments would act as 4-point biomechanical test jig.
- The mandibles with plating systems were progressively loaded with Continuous linear



Fig (6) Showing The custom made tension test device was attached to the testing machine and was used for compression test for Group (2) prepared samples.

vertical compressive loads that simulate the masticatory loads ranging from 0-400 N(107).

- Loading was increased till failure of the plating system occurred.

2) *Tensile test :*

- The samples were stabilized & firmly hold by the custom made device hooks attached to testing machine from the distal and proximal ends.
- The tensile test was performed by applying shear peel forces along the length of the attached specimen starting from zero point till failure of the plating system occurred.

3) *Force displacement measurement:*

- For both tests, displacement measurements was obtained using a precalibrated linear variable displacement transducer (LVDT) that was attached to the universal testing machine.

4) *Data collection:*

- The progression of loading and displacement either vertically or laterally was followed on the machine monitor, and the load value data in Newton, and extent in millimeters (mm) of any resulting displacement or fixation loosening observed between the two fractured segments during the experiment were noted.
- The experimental end point was defined as permanent deformation (twisting/fracture) of the plate and/or looseness of miniscrews.
- load\displacement data were recorded and the yield load and yield displacement and stiffness were observed.
- The data were transmitted to a computer that generated a data spreadsheet of force versus displacement.
- The data referring to the maximum force needed to bring instability and failure to the system were collected and subjected to statistical analysis.

- Data were presented as means, standard deviation (SD), standard error (SE), minimum values at which the displacement begins and maximum values. All of the quantitative data were analyzed statistically using IBM SPSS Statistics for Windows, version 20.0 (IBM Corp., Armonk, NY, USA).

RESULTS

The current study consists of two parts and was used to evaluate the biomechanical properties of three dimensional titanium miniplates.

During the experiment 20 6-holed (3x2) 3D titanium miniplates were used, each was fixed by 4 mini screws with a total of 80 mini titanium screws in 20 sheep hemi mandibles.

The loads were applied until the failure (permenant deformation) of the fixation system occurred which was considered the end point of failure.

A) Mode of specimens failure under loading: (Table 1, Fig.7)

The mode of fixation system failure of both groups:

1) Compression test (Group 1) :

A summary and descriptive analysis of these results and statistical analysis appear in (Table 2).

I. Yield load

In **group I (Compression test)** the mean was **(250.91 N)**, the standard deviation which was **(55.98)**, the standard error was **(17.70)** the maximum value which was **(355.53 N)** and the minimum value was **(182.74 N)**.

II. Yield displacement

In **group I (Compression test)** the mean was **(11.40mm)**, the standard deviation which was **(6.02mm)**, the standard error was **(1.90mm)**. The maximum value which was **(19.60mm)** and the minimum value was **(3.80mm)**.

TABLE (1) Statistical analysis of different modes of fixation failure among specimens of both groups.

Group	Group 1	Group 2
Failure mode	Compression	Tension
Plate fracture	3	0
Plate twisting only	4	7
Plate twisting and screw avulsion	1	1
Screws avulsion only	2	2
Total	10	10

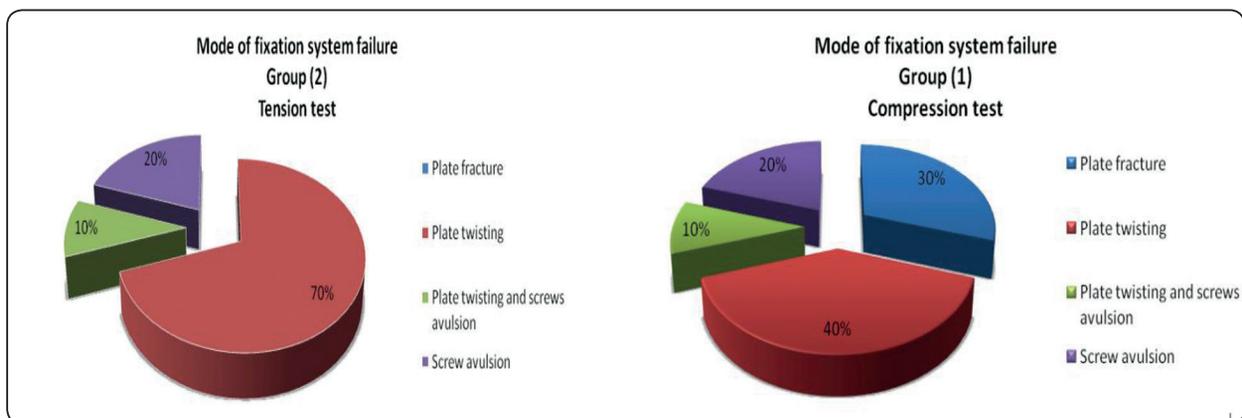


Fig. (7) Pie-chart for statistical analysis of different modes of fixation failure among specimens of both groups.

TABLE (2) Descriptive statistical analysis of Group 1 results

Parameter	Mean	SD	SE	Maximum	Minimum
Yield load (Newtons)	250.91	55.98	17.700	355.53	182.74
Yield displacement (mm)	11.40	6.02	1.90	19.60	3.80
Compression stiffness (N/mm)	28.07	14.30	4.44	48.30	15.76

TABLE (3) Descriptive statistical analysis of Group 1 results

Parameter	Mean	SD	SE	Maximum	Minimum
Yield load (Newtons)	267.20 N	49.42	15.63	322.23 N	186.92 N
Yield displacement (mm)	3.74 mm	0.56	0.18	4.60mm	2.88mm
Compression stiffness (N/mm)	72.03 N/mm	4.24	1.34	78.90 N/mm	64.90 N/mm

III. Stiffness

In **group I (Compression test)** the mean was **(28.07 N/mm)**, the standard deviation which was **(14.03)**, the standard error was **(4.44)**, the maximum value which was **(48.30 N/mm)** and the minimum value was **(15.76 N/mm)**.

Analysis of the correlation between the loading values and corresponding displacement in **Group 1** samples revealed highly significant strong positive correlation (**r = 0.945**) where **P-value was <0.001 (Table3) (Fig. 29)**.

2) Tension test (Group 2) :

A summary and descriptive analysis of these results and statistical analysis appear in **(Table 3)**.

I.Yield load

In **group II (Tension test)** the mean was **(267.20 N)**, the standard deviation which was **(49.42)**, the standard error was **(15.63)**, the maximum value which was **(322.23 N)** and the minimum value was **(186.92N)**.

II.Yield displacement

In **group II (Tension test)** the mean was

(3.47mm), the standard deviation which was **(0.56)**, the standard error was **(0.18)**, the maximum value which was **(4.60mm)** and the minimum value was **(2.88mm)**.

III. Stiffness

In **group II (Tension test)** the mean was **(72.03 N/mm)**, the standard deviation which was **(4.24)**, the standard error was **(1.34)**, the maximum value which was **(78.90 N/mm)** and the minimum value was **(64.90 N/mm)**.

Analysis of the correlation between the loading values and corresponding displacement in **Group 2** samples revealed highly significant strong positive correlation (**r = 0.984**) where **P-value was <0.001**.

C) Correlation between both groups :

I. Yield load

In comparison between two group according to yield load values as shown by the print out chart, both groups showed no statistically significant difference in mean yield load. **(Table .4)**,

TABLE (4): The means, standard deviation (SD) values and results of Student's t-test for the comparison between mean yield load of the two groups.

Group 1		Group 2		P-value
Mean	SD	Mean	SD	
250.91	55.98	267.20	49.42	0.499

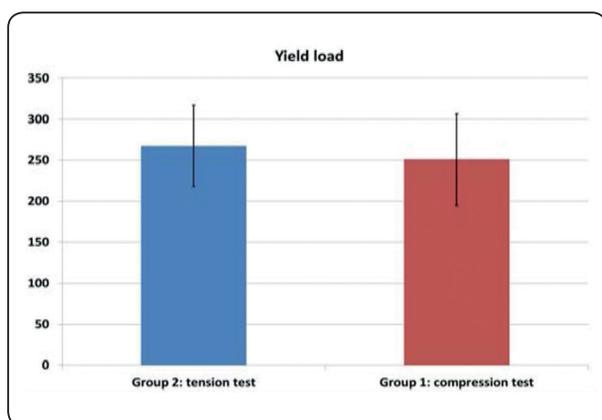


Fig. (8) Correlation between 2 groups.

DISCUSSION

Mandibular body fractures are considered common but there are discrepancies among the studies, such as epidemiological surveys, regarding their incidence. ⁽¹⁹⁾

In the surgical treatment of mandibular fractures, there are principles that should be followed for a successful outcome: fracture reduction (replacement of bone segments in their correct anatomical positions), fixation and containment of bone segments and immobilization at the fracture site. ⁽²⁰⁾

Champy et al. ⁽²¹⁾ have recommended functionally stable fixation using small miniplates through intraoral approaches, and the goal is to equalise tension and compression forces.

The use of miniplates is common nowadays but their behavior as tension bands is not completely

understood. The anatomical and functional complexity of tension zones is a challenge, and lack of adequate fixation may lead to malunion, non-union, less than ideal occlusion, and infection. ^(22,23)

Miniplates have advantages in this area in that they require small intraoral incisions and minimise the risk of damage to the anatomical structures by using monocortical screws. ⁽²¹⁾

This study tested the mechanical properties of the three dimensional titanium miniplates in vitro in accordance with other in vitro tests that have been carried out to describe the biomechanical behaviour of supporting devices in a trial to validate the various modes of fixation for mandibular fractures. ^(22, 23, 24)

When evaluating the functional stability of the fixations by simulating the vectors and load intensity that they will be subjected to, there is a need for a model simulating the human mandible anatomy.

In previous biomechanical studies for mandibular fractures variable sample sizes for testing samples were adopted. Some studies were carried out with a sample size of 5 hemi mandibles per group ⁽²⁵⁾; others used 10 hemi mandibles per group ⁽¹⁴⁾. In the present study 10 adult sheep hemi mandibles were used for each group.

Ten adult sheep mandibles with complete set of dentition were obtained, prepared and stored according to a previous study ⁽¹⁴⁾. The coronoid process and condyle process of each sheep mandible were removed because difficulty of fixation on the test jigs. ^(14, 26)

Each mandible was divided into 2 hemi mandibles, thus 20 hemimandibles were created. An oblique fracture line was created in each sample. ^(14, 32, 27)

Wedge bone shape was made at inferior border of the mandible to prevent resistance of bone to the load during the testing process in to allow for only assessment of the mechanical properties of the fixation system.

The fixation system was curved three dimensional titanium miniplates fixed in place by mono cortical titanium mini screws according to previous studies^(28,33). Reduction forceps were used to reduce the fractured sites, while all screw holes were drilled perpendicular to the mandible.⁽²⁹⁾

Drilling was 90 degree on bone surface, as in a previous studies it was reported that conventionally screws are inserted perpendicular to miniplates for better adaptation and maximum engagement of the threads of the screw into the bone to achieve more stability.^(30,31)

The application of the 3D titanium miniplates was carried out according to previously described methods.⁽⁸⁻¹¹⁾ Plates were applied in the mandibular body neutral zone.

The fracture line and the fixation system positions were standardized for the experiment with the help of a prefabricated acrylic resin guide. This was to prevent errors due to variables in repetition of fracture line creation procedures and fixation system application thereby diminishing the possibility of alterations among them that might result from manual preparation of the samples. Also, at the time of miniplate screwing, the hemi-mandible was stabilized using drops of prefabricated self polymerizing resin and the miniplates positioned to make perforation possible. The same operator carried out all perforations.^(27,28)

The force mechanisms involved in chewing and the forces experienced by the bones involved are highly complex. Axial loads are those that produce compression forces or tensions in a structure. They act at points of contact that may serve as a screen or friction zone and consequently they may be influential in inducing rotation or displacement. In a clinical situation, it is important to be aware that effects of bending forces are far more important than those of axial forces.⁽²⁹⁾

The third type of force involved is torque, which produces or tends to produce rotation or twisting.⁽²⁹⁾

It is known that in the fractures body and angle of the mandible, bone is normally subject to tension forces on its upper border and compression forces on its lower border.^(23,34)

The present study, the results of the mean yield compression and tension stresses revealed that the used fixation system proofed to be highly efficient for supporting the fracture In during the period of osteosynthesis, as their point of deformation under load is far away from the reported maximum forces suitable for normal osteosynthesis processes .

For body fractures, bite forces result in high bending moments, low torsion moments, and high shear forces .Displacement of the fracture fragments and effects of tension or compression at the site of fracture depend on the distance between loading point and fracture site.^(30,31)

The mandible is normally subjected to bending forces at its upper boundary part and to compression forces at its lower boundary part. Bite forces applied close to the fracture result in “negative” bending moments, which give a zone of compression in the alveolar region and a zone of tension at the lower border.⁽³¹⁾

Bite forces applied at the other bite points result in “positive” bending moments, with a compression zone at the lower border and a tension zone in the alveolar region. A positive torsion moment resulted in lingual displacement of the border of the fragment posterior to the fracture in combination with buccal displacement of the border of the fragment anterior to the fracture. A negative torsion moment resulted in the opposite effect.⁽³²⁾

In the present study, the greatest displacement registered in testing the groups is a response to the greater deformation they suffer, and this is especially demonstrated by the fact that in some of the tested samples the screws did not come out but remained in place until the limits of miniplate deformation had been attained.

The explanation for this would be that the energy provoking deformation stemming from the force being applied and the way that the system uses that energy in deforming the plate, limits the forces that might eventually displace the screw so that it becomes an event that takes longer to occur. From the biomechanical point of view, such deformations in the plates are actually beneficial, but only up to the point where they reach the limits of their elasticity. Once that point has been passed, they no longer favour fixation stability because they are unable to go back to normal once the force has ceased and accordingly make the fracture reduction and fixation obtained by the treatment unfeasible. ⁽³⁶⁾

As reported by previous clinical studies, 3D systems demonstrated greater stability and resistance in comparison to one- or two-plate systems and provided a less invasive and more biocompatible alternative for one- or two-plate systems. ^(35, 32)

Within the limitation of this study and based upon the results, it is obviously evident that the proposed hypothesis considering that three dimensional miniplates would be an efficient alternative for other fixation techniques of mandibular body fractures was true.

It is important to note that the laboratory techniques, such as the mechanical assays used in this study, are only auxiliary methods that determine potential differences among the different fixation systems. Therefore, the results of this study should be evaluated with further clinical trials, where the fracture characteristics, material availability, patient status, surgeon preferences, and other factors should be considered to determine the best treatment method.

CONCLUSION

- Three dimensional miniplates are easy to adjust, requires minimal tissue dissection thus least disturbance to the tissues.

- The results of this study show higher stability of the system against tension forces than compression forces.
- The three dimensional miniplates would be an efficient alternative for other fixation techniques of mandibular body fractures.
- Further clinical studies are recommended to evaluate fracture characteristics, material availability, patient status, surgeon preferences, and other factors that could affect the treatment outcomes.
- Further biomechanical studies are recommended to evaluate the mechanical behavior of the used fixation system in other fractured regions of the mandible.

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