Comparative evaluation of bite force analytical study following mandibular osteosysthesis using three-dimensional and conventional locking miniplates

ABSTRACT

Aims and Objectives: The aim is to study the effectiveness of 2 mm three-dimensional (3D) titanium miniplates and 2 mm conventional titanium miniplates in osteosynthesis of mandibular fractures by comparing the change in bite force.

Methodology: The study comprised forty patients of age group 20–40 years, weighing 55–75 kg having mandibular fractures. Patients were randomly divided into two equal groups In Group A, twenty patients underwent osteosynthesis using 3D titanium miniplates (2.0 mm system), whereas in Group B, twenty patients underwent osteosynthesis using conventional titanium miniplates (2.0 mm system). After fixation of fracture segments with miniplates, the patients were assessed on the basis of evaluation of bite force at incisor, right molar and left molar region after 1, 3, 6 , and 8 weeks. Comparison of change in bite force was done between Group A and Group B at different follow-ups at incisor, right molar, and left molar.

Results: Bite force recordings showed increasing values at subsequent follow-ups, corresponding to the healing of the fracture in both groups. At follow-up III (6 weeks) and IV (8 weeks), bite force values reached near to those in healthy individuals. A significant difference was observed in change in bite force of Group A and Group B at incisor left molar and right molar on subsequent followups. 3D titanium miniplate requires less surgical exposure of the underlying fracture site, with a minimal traction of the surrounding soft tissue.

Interpretation and Conclusion: 3D miniplates in mandibular fractures are efficacious enough to bear masticatory loads during the osteosynthesis of fractures. It gives the advantage of greater stability, increased bite force, reduced implant material, and 3D stability.

Keywords: Bite force, mandibular fractures, osteosynthesis, three-dimensional miniplates, two-dimensional miniplates

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INTRODUCTION

The incidence of oral and maxillofacial injuries has been increased in the past few decades due to increase in automobilization and industrialization. Correct surgical technique with less error margin is required for treating such fractures. The main aim in the treatment of maxillofacial trauma is to restore anatomical form, esthetics and function. Immobilization of the jaws is still the main treatment strategy. For fractures requiring open reduction various plating system for osteosynthesis have been used such as arbeitsgemeinschaft für osteosynthesefragen bicortical plating system, two-dimensional miniplating system, resorbable plates and screws, lag screws, and Three-dimensional (3D) miniplating system. Miniplate

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osteosynthesis, first introduced by Michelet *et al*.[1] in 1973 and further developed by Champy *et al*. in 1976[2] and is today's standard for the treatment of the mandibular fracture. In recent literature, more and more cases have been reported in which metal depositions were found in the direct neighborhood of titanium miniplate or in peripheral organs following osteosynthesis. Hence, there is a need for minimizing the size and amount of osteosynthesis material.

3D miniplating system was introduced by Farmand and Dupoirieux.[3] The basic concept of 3D fixation is that a mechanically closed quadrangular plate fixed with bone screws provides more stability in three dimensions. The 3D miniplates are positioned perpendicular to the fracture line, adapted to the bone according to Champy's principles and are secured with monocortical selfcutting screws. The screws adapt each part of the plate separately without any tension to the bone. This interlinking gives the stability to the plating system. 3D miniplates are easy to adjust and requires minimal tissue dissection thus minimally compromising the blood supply. This design allows fixation points are close to fracture line. Its low profile design and space between plate holes permits excellent revascularization.

The aim of this study is to evaluate the effectiveness of 2 mm 3D titanium miniplates and 2 mm conventional titanium miniplates in osteosynthesis of mandibular fractures by comparing the change in bite force.

METHODOLOGY

The study comprised forty patients age group 20–40 years, weighing 55–75 kg, with mandibular fractures, reported to the Department of Oral and Maxillofacial Surgery, Government Dental College, Kozhikode, Kerala. Patients with isolated fractures of the mandible (single/multiple) were selected. Patients having mandibular fracture with comminution and infection were excluded. Furthermore, relevant medical history was taken, and patients with a history of diabetes, long-term steroid therapy, compromised immunity and associated bone pathology were excluded from the study. Informed consent was obtaained to participate in the study. Patients were diagnosed on the basis of clinical examination and radiographic interpretation. Routine blood investigations were done.

Patients were randomly divided into two equal groups of 20 each. Group A patients underwent osteosynthesis using 2.0 mm 3D miniplates, whereas Group B patients underwent osteosynthesis using 2.0 mm conventional miniplates. The healing of fracture was assessed clinically and biomechanically.

All the patients were operated either under general anesthesia (nasotracheal intubations) or local anesthesia. Strict asepsis was followed. In this study, the fracture sites were exposed through an intraoral, sublabial approach or extraoral, submandibular approach as required. Following reduction of the segments and temporary maxillomandibular fixation, a suitable plate was selected and bent with the plate bending pliers to confirm the proper adaptation of plates to the bone surface. Later screws of suitable length were selected for fixation of the plate. The 3D titanium miniplate was then positioned in such a way that the horizontal cross-bars were perpendicular to the fracture line, and the vertical ones were parallel to it. In the symphysis and parasymphysis region, placement of the superior cross-bar was in a subapical region. Posterior to the mental foramen the plates were aligned with the superior cross-bar between the roots and inferior alveolar nerve and the lower cross-bar placed below the nerve. A rectangular plate was preferred in these cases. At the angle region, the plate was adapted and fixed along the inferior border. Holding the plate perpendicular to the reduced fracture, holes were drilled strictly perpendicular to the bone surface, and hence that the drill hole was monoaxial. The superior holes were drilled strictly monocortically and directed into the space between the roots. The superior screws were tightened first followed by the inferior ones [Figure 1].

Two-dimensional miniplates were placed along the ideal lines of osteosynthesis as described by Champy *et al.* In parasymphysis fracture patients, six hole straight miniplate was adapted at the lower border keeping at least two holes on each side of the fracture line. Holes were drilled using drill bit along with copious saline irrigation to prevent thermal damage to the bone. Screws were tightened in the drilled hole. Another 4 hole miniplate was fixed approximately 4–5 mm above the lower plate. To treat fractures near the

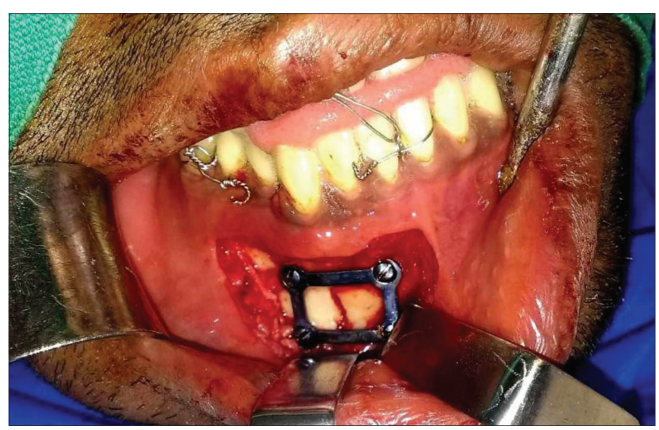


Figure 1: Three-dimensional miniplate fixation

mental foramen, the plates were adapted and placed below the foramen [Figure 2]. Intermaxillary fixation (IMF) was released, and occlusion was checked. The site was closed in layers with 3-0 chromic catgut and 3-0 silk. All patients were put in IMF with elastics for 7–10 days.

Bite force recording

All bite force measurements were made using indigenous bite force recorder. All measurements were made with the patient seated with the head upright, looking straight and in the natural head seating position. The patients were asked to remain in this position throughout the trial and to refrain from extraneous movements. Bite force was recorded at the incisor, right and left molar regions. The patients were instructed to bite as forcefully as possible on the pads of bite force gauge to the maximum level and bite force values were recorded [Figures 3 and 4].

Criteria's for assessment

Review of patients was done at 1, 3, 6 and 8 weeks postoperatively. The following parameters were assessed:

- Bite force measurement at incisor region in Group A and Group B
- Bite force measurement at right molar region in Group A and Group B
- Bite force measurement at left molar region in Group A and Group B
- Comparison of change in bite force at different sites in Group A and Group B.

RESULTS

In the present study, the most common cause of injury was found to be road traffic accident. Most common age group of patients who underwent surgery were between 20 and 40 years (60%). Parasymphysis alone was the most commonly involved site, followed by parasymphysis along with angle. Preoperative occlusion was found to be deranged in all the patients in both the groups. The functional occlusion was achieved postoperatively in all the patients. In the present study, maximum number of patients were treated within period of 8–11 days (45%) after the injury. Meantime period between injury and definitive management was seen to be 8.7 days.

Clinical evaluation

First, bite force was recorded at incisor, left molar and right molar region in a population of fifty healthy adult male of age group 20–40, weighing 55–75 kg, to calculate the average bite force in normal individuals. The values were in the order of 13.3 ± 7.5 kp in the incisor and 47.3 ± 9.2 kp and 48.3 ± 7.4 kp in left and right molar regions, respectively. In Group A, value of incisor bite force increased significantly at progressive follow-ups compared to that recorded preoperatively [Table 1]. In Group B, value of incisor bite force increased significantly at progressive follow-ups compared to that recorded preoperatively [Table 2]. At follow up I, II, III and IV significant difference was observed in change in incisor bite force of Group A and Group B, i.e., the change in bite force at incisor region was more in Group A

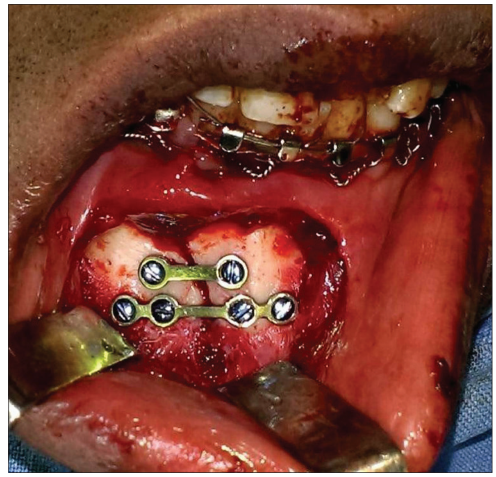


Figure 2: Conventional miniplate fixation

Figure 3: Bite force recorder

Figure 4: Bite force recording in a patient

as compared to Group B on subsequent follow-ups [Graph 1 and Table 3].

In Group A, value of right molar bite force increased significantly at progressive follow-ups compared to that recorded preoperatively [Table 4]. In Group B, value of right molar bite force increased significantly at progressive follow-ups compared to that recorded preoperatively [Table 5]. At follow up I, II, and IV, significant difference was observed in change in right molar bite force of Group A and Group B. At follow-up III, no significant difference was observed in a change in right molar bite force of Group A and Group B [Graph 2 and Table 6].

In Group A, value of left molar bite force increased significantly at progressive follow ups compared to that recorded preoperatively [Table 7]. In Group B, value of left molar bite force increased significantly at progressive follow-ups compared to that recorded preoperatively [Table 8]. At follow up I, significant difference was observed in change in left molar bite force of Group A and Group B. At follow up II, III, and IV, no significant difference was observed in change in left molar bite force of Group A and Group B [Graph 3 and Table 9].

Table 1: Incisor bite force in (Kp) in Group A

Follow up	Bite force Mean±SD	Change Mean±SD	't'	'P'
Preoperative	2.23±0.42			
1 week	5.60±0.53	3.47±0.84	14.8	<0.001
3 week	7.3±0.68	1.62±0.75	19.9	<0.001
6 week	11.87±1.2	4.43±1.4	26.50	<0.001
8 week	20.49±1.48	9.2±1.94	46.8	<0.001

Table 2: Incisor bite force in (Kp) in Group B

Follow up	Bite force Mean±SD	Change Mean±SD	't'	'P'
Preoperative	3.2±0.42			
1 week	4.58±0.54	1.30±0.31	14.84	<0.001
3 week	6.9±0.43	2.41±0.35	39.6	<0.001
6 week	9.45±0.84	2.67±0.51	37.1	<0.001
8 week	12.3±0.78	3.85±2.02	39.72	<0.001

Table 3: Comparison of changes in incisor bite force in (kp) in Group A and B

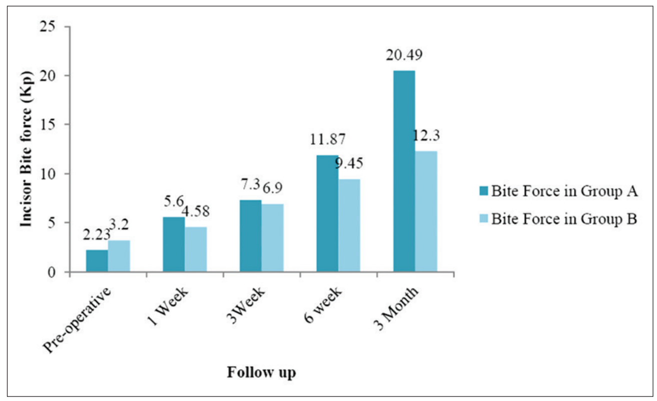
Follow up	Group A Mean±SD	Group B Mean±SD	't'	'P'
1 week	3.47±0.84	1.30±0.31	8.23	<0.001
3 week	1.62±0.75	2.41±0.35	3.39	<.05
6 week	4.43±1.4	2.67±0.51	4.19	0.001
8 week	9.2±1.94	3.85±2.02	6.24	<0.001

Table 4: Right molar bite force (kp) in Group A

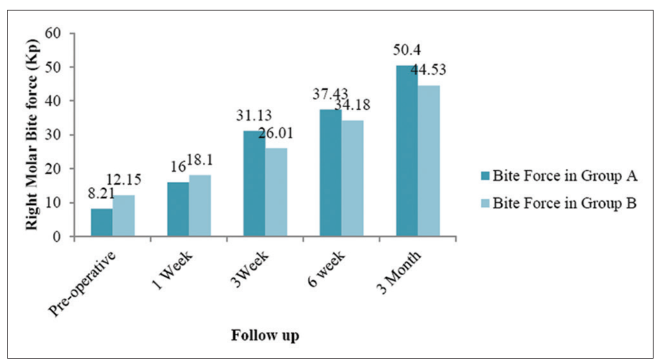
Follow up	Bite force Mean±SD	Change Mean±SD	't'	'P'
Pre-operative	8.21±1.01	–	–	–
1 week	16.0±1.3	7.89±1.72	14.59	<0.001
3 week	31.13±1. 8	15.02±2.0	32.42	<0.001
6 week	37.43±1.80	7.42±2.54	40.89	<0.001
8 week	50.4±1.4	13.03±2.05	71.96	<0.001

DISCUSSION

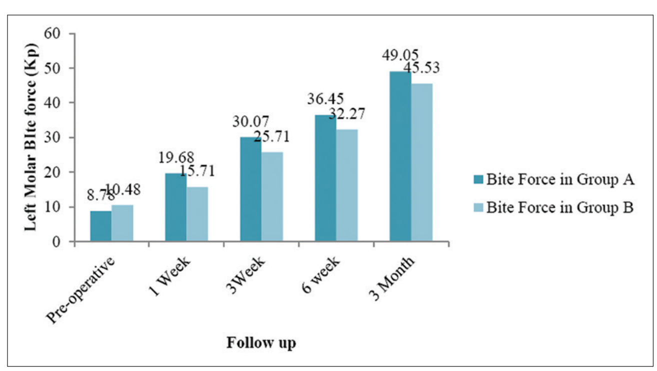
With the growth in the Indian economy in the recent past, the traffic density on the roads has increased much more than earlier. According to the estimates of Association of Automobile Manufacturers of India the number of



Graph 1: Incisor bite force in Groups A and B



Graph 2: Right molar bite force (kp) in Groups A and B



Graph 3: Left molar bite force (kp) in Groups A and B

Table 5: Right molar bite force (kp) in Group B

Follow up	Bite force Mean±SD	Change Mean±SD	't'	'P'
Pre-operative	12.15±0.90	–	–	–
1 week	18.10±1.06	5.95±1.68	11.51	<0.001
3 week	26.01±2.06	8.46±2.69	17.12	<0.001
6 week	34.18±1.84	7.83±2.80	42.0	<0.001
8 week	44.53±2.82	10.38±3.58	38.9	<0.001

Table 6: Comparison of changes in right molar bite force (kp) in Group A and B

Follow up	Group A Mean±SD	Group B Mean±SD	't'	'P'
1 week	7.89±1.72	5.95±1.68	2.42	<.05
3 week	15.02±2.0	8.46±2.69	6.32	<0.001
6 week	7.42±2.54	7.83±2.80	0.34	>.05
8 week	13.03±2.05	10.38±3.58	2.09	0.05

Table 7: Left molar bite force (kp) in Group A

Follow up	Bite force Mean±SD	Change Mean±SD	't'	'P'
Pre-operative	8.78±0.87	–	–	–
1 week	19.68±1.09	10.8±1.60	21.3	<0.001
3 week	30.07±1.15	9.49±2.65	42.6	<0.001
6 week	36.45±1.73	6.57±2.0	45.6	<0.001
8 week	49.05±1.97	12.57±2.0	63.7	<0.001

Table 8: Left molar bite force (kp) in Group B

Follow up	Bite force Mean±SD	Change Mean±SD	't'	'P'
Pre-operative	10.48±1.04	–	–	–
1 week	15.71±0.99	5.3±1.34	13.2	<0.001
3 week	25.71±1.79	10.03±2.24	20.9	<0.001
6 week	32.27±1.68	6.49±1.68	34.3	<0.001
8 week	45.53±2.12	13.29±2.02	40.0	<0.001

Table 9: Comparison of changes in left molar bite force (kp) in Group A and B

Follow up	Group A Mean±SD	Group B Mean±SD	't'	'P'
1 week	10.8±1.60	5.3±1.34	8.5	<0.001
3 week	9.49±2.65	10.03±2.24	0.5	>.05
6 week	6.57±2.0	6.49±1.68	0.03	>.05
8 week	12.57±2.0	13.29±2.02	0.7	>.05

automobiles on the road has grown more than tenfold during the last 10 years. This growing number of automobiles on the road has result in an increase in number of road traffic accidents and maxillofacial injuries. That is why in this study majority of patients had trauma due to road traffic accidents (65%) which also correlate with the study of Rowe and Killey conducted in 1968.[4] The incidence of mandibular fractures was more commonly in age group 20–30 years (60%). The period between injury and definitive management seems to be important because the delay in seeking treatment increases the possibility of infection. In the present study, the majority of patients (45%) were given definitive management within the period of 8–11 days after the injury. Infection was not present in any of these cases preoperatively. This finding correlates with findings of Smith in 1991[5] who effectively used miniplates in delayed treatment of mandibular fractures.

Three-dimensional miniplates

The 3D titanium miniplate is then positioned in such a way that the horizontal arms are perpendicular and the vertical arms are parallel to the fracture line. This technique follows the principle of 3D fixation given by Farmand and Dupoirieux in 1995. Champy *et al*. in 1978,[6] Kuriakose *et al*. in 1996,[7] Renton TF, Wiesenfeld in 1996[8] used miniplate for patients with mandibular fracture and found uneventful healing. The same finding was reported in the present study. IMF was done preoperatively in all the patients to achieve the optimum habitual occlusion which was in correlation with study conducted by Schilli *et al*.[9] Intra-oral approach was used in all the cases of monocortical plating. A minimum of two screws, on each side of fracture were used to prevent rotational movement of the fractured segment which was in correlation with the study of conducted by Spiessl in 1972[10] and Champy *et al*. in 1978. Postoperative IMF with elastics was done for 7–10 days in all patients, following the principles of delayed osteosynthesis given by Nakamura in 1994.[11]

Recommendation for the amount of fixation hardware necessary to treat fracture of mandibular corpus varies widely. Different clinicians use different size of plates (thickness, length, the number of holes), diameter and length of screws and number of plates for mandibular fracture.

Tate and Ellis in 1994[12] stated that sufficient internal fixation material has to be fixed to resist the maximum force produced by mastication. By doing so, they hypothesized that stability of fracture segments are assured even under the full function of the masticatory system.

The forces that must be countered in mandibular body fracture have been derived from maximum voluntary bite force measurement, which in a healthy adult may be in the order of 15.3 kp in the incisor region, 48.3 kpand 49.3 kp in left and right molar regions, respectively. Patient with fracture can generate the force is usually much less. Hence, the fixation requirements, based on maximum voluntary bite force in normal subjects may be inflated, and this is perhaps semi-rigid form of fixation like monocortical fixation has been used successfully.[13]

In the present study, bite force was recorded at incisor, left molar and right molar region in a population of 50 healthy adult male of age group 20–40, weighing 55–75 kg, to calculate the average bite force in normal individuals at these regions. The values were in the order of 13.3 ± 7.5 kp in the incisor, 47.3 ± 9.2 kp and 48.3 ± 7.4 kp in left and right molar regions, respectively. These findings correlate with the finding of Ellis and Throckmorton. Gerlach and Schwarz in 2002[14] stated that maximum bite force in a patient with mandibular fracture treated with miniplate osteosynthesis reaches only 31% at 1 week postoperatively. These value increase to 58% at the 6th week postoperatively.

This statistically significant relation value was found in the postoperative week between the bite force of anterior and posterior region. Value of incisor bite force increased significantly at progressive follow-ups compared to that recorded preoperatively. These findings correlate with the findings reported by Agarwal *et al*. 2011.[15] In Groups A and B, a statistically significant low incisor bite force was found at 1 week postoperatively when compared with that at 3 weeks. At 1st week (follow up I) incisor bite force was only 5.60 kp (in Group A) and 4.58 kp (in Group B) compared with 7.3kp (in Group A) and 6.9 kp (in Group B) in the 3rd week (follow up II) after surgery. Our these findings relates with Ellis and Throckmorton study where average incisor bite force of 6.4 kp in 1st week postoperatively and 12.3 kp after 6 weeks. There were no statistically significant difference between the incisor bite force at follow-up III (11.87 and 9.45kp) and follow up IV (20.49 and 12.03 kp) when compared to that in healthy individual (13.3 kp).

At follow up I, II, III, and IV, significant difference was observed in change in incisor bite force of Group A and Group B, i.e. the change in bite force at incisor was significantly greater in Group A than Group B. In the current study, bite force at left molar increased significantly at progressive follow-ups compared to that recorded preoperatively. These findings correlate with the findings reported by Agarwal *et al*. 2011. A statistically significant reduction in left molar bite force was found at 1st week (follow up I) after surgery when compared with 3rd week (follow up II) after surgery. At 1st week (follow up I), left molar bite force was only 19.68 and 15.71 kp compared with 30.07 and 25.71 kp at 3rd week (follow up II) after surgery. These findings correlate with the findings of Ellis and Throckmorton who reported average left molar bite force of 12.8 kp in weeks one through six and 26.0 kp after 6 weeks, and Gerlach and Schwarz, 2002 who reported a significant increase in maximum bite force from 1st to 6th week postoperatively. There was no significant difference between the left molar bite force at 6 week, i.e., follow-up III (36.45 and 32.27 kp) and 8 weeks, i.e. follow up IV (49.05 and 45.53 kp), when compared to that of healthy individuals (47.3 kp). At follow up I, significant difference was observed in change in left molar bite force of Group A and Group B. At follow-ups II, III, and IV, the change in left molar bite force between Group A and Group B was not found to be significant. In the present study, bite force at left molar increased significantly at progressive follow ups compared to that recorded preoperatively. These findings also correlate with the findings reported by Agarwal *et al*. 2011. A statistically significant low right molar bite force was found at 1 week postoperatively compared with the right molar bite force at 3 weeks after surgery. Right molar force was only 16.0 and 18.10 kp at first follow-up, compared with 31.13 and 26.01 kp at second follow-up after surgery. Our findings is similar with the Ellis and Throckmorto study of average right molar bite force of 13.8 kp at 1st week and 25.3 kp after sixth week, and Gerlach and Schwarz who reported a significant increase in maximum bite force from 1st to 6th week postoperatively.

Right molar bite force at 6 week, i.e. (follow up III) 37.43 and 34.18 kp and 8 week i.e. (follow up IV) 50.04 and 45.53 kp when compared to that in healthy individual (48.3 kp).

Showed no significant difference. At follow up I, II, and IV, significant difference was observed in change in right molar bite force of Group A and Group B. At follow-up III, no significant difference was observed in change in right molar bite force of Group A and Group B.

Neuromuscular protective mechanism occurs throughout the body. The first protective mechanisms when a fracture occurs is "muscle splinting," where a few components of the neuromuscular system are activated or deactivated to remove forces from the damaged bone.

Bite force is the cumulative effect of number of factors such as number of residual teeth, tactile impulses, pressure and pain perception in periodontal ligament. There is a reduction in bite force with age due to age-dependent deterioration of dentition. The above finding shows that the use of 3D miniplates in mandibular fracture was efficient enough to withstand masticatory forces during the healing of the fracture. Although results obtained in the present study do not show a major difference in clinical outcome between the two techniques, yet 3D miniplates could be considered better of the two as its low profile design provides larger space between the plate holes thus permitting excellent revascularization. 3D miniplate utilizes optimal instruments and implant design to avoid complications during handling. Technically too, use of 3D miniplate could be considered better as it requires minimal tissue dissection near the fracture site. Due to its superior design, maximum number of screws lie near the fracture site thus providing better stability, increased bite force and thus open up doors for its satisfactory use even in the management of displaced fractures. On the economic point of view too, 3D miniplate could be adjudged better due to its low cost owing to the fewer number of plates and screws used in the technique.

CONCLUSION

Due to the specially designed mechanical and geometric shape and the ease with which it can be contoured and adapted to the bony segments, the 3D titanium miniplates provide better stabilization of fractured segments in three dimensions. 3D miniplates can be used satisfactorily in cases of unstable fractures of the mandible. Use of 3D titanium miniplates is comparatively more cost-effective than two-dimensional titanium miniplates as lesser number of plates and screws are needed for fixation. With the 3D titanium miniplate osteosynthesis technique, less surgical exposure of the underlying fracture site is required, with a minimal traction of the surrounding soft tissue. Bite force recordings showed increasing values at next follow-ups, corresponding to the healing of the fracture in both groups. At follow-up III and IV, bite force values reached near to those in healthy individuals. The most common cause of mandibular fracture was found to be road traffic accidents (65%). Patients in the 20–30 years of age group were the predominant age group presenting with mandibular fractures (60%). The implant was able to counteract forces along the fracture site, thus precluding hardware failure. No postoperative mobility was found in either group at various follow-ups. Therefore, it has been concluded that the 3D miniplates in mandibular fractures are efficacious enough to bear masticatory loads during the osteosynthesis of fractures. It gives the advantage of greater stability, increased bite force, reduced implant material and 3D stability. In the end, it was found that 3D miniplate was superior to two-dimensional miniplate in respect of stability, increased bite force, economy and surgical technique. However, due to less number of cases the superiority of 3D miniplate could not be established statistically. For this use of 3D miniplate in place of two-dimensional miniplate with larger sample size at different locations is recommended.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil

Conflicts of interest

There are no conflicts of interest.

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