

3-D Miniplates Versus Conventional Miniplates in Treatment of Mandible Fractures

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Received: 5 March 2017 / Accepted: 8 December 2017 / Published online: 14 December 2017
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Abstract

Aim To study whether the use of 3-D miniplate, when compared with conventional miniplate, gives better clinical outcomes with fewer complications in patients with fracture mandible.

Materials and Methods A prospective study was conducted in the Department of Oral and Maxillofacial Surgery, Trauma Care Centre, on 40 patients. They were randomly divided into Group-I and Group-II with 20 patients in each group. In Group-I, 3-D miniplate was used and in Group-II, conventional miniplate was used. Parameters such as fracture stability, occlusal status, mouth opening, nerve paresthesia, infection, pain, swelling, and complications were evaluated on 1st, 7th postoperative day, 1st month and 3rd month.

Results Fracture stability and occlusion were clinically better in Group-I than in Group-II on each follow-up; however, it was not statistically significant. Infection rate was lesser in Group-I than in Group-II ($p = 0.003$). Mouth opening was more in Group-II than in Group-I on immediate ($p = 0.001$) and 7th post-op day ($p = 0.002$). Overall complications were lesser in Group-I than in Group-II ($p > 0.005$).

Conclusion There is no major difference observed in clinical outcomes between 3-D miniplate and conventional

miniplate. Either method of fixation can be used successfully in treatment of mandible fractures with comparable rates of complications.

Keywords 3-D miniplate · Conventional miniplate · Mandible fracture

Introduction

With the rise in the number of road traffic accidents (RTA), interpersonal violence, sports activities, there has been a considerable increase in the incidence of fractures of mandible [1]. Rigid internal fixation (RIF) has revolutionized the treatment aiming at anatomic reduction and early immobilization [2]. Out of various methods of RIF, the use of mini plate has emerged as a standard method in treatment of facial bone fractures following discovery by Champy et al. [3–6]. Conventional miniplate provides semirigid fixation which is functionally stable. However, according to Ellis, the complications associated with use of miniplate are significant (29%) [7].

Addition of 3-D miniplate in the year 1992 as a method of rigid internal fixation has made the treatment of fracture mandible more rational for its resistance to torsional forces [8, 9]. The name, 3-D miniplate, is misnomer as the shape of plate is not three dimensional. It resists the forces in three dimensions namely shearing, bending, and torsional forces [9]. Three-dimensional plating system uses fewer plates and screws in comparison with conventional miniplates, reducing the operation time, cost of treatment and foreign material, as described by Zix et al. [3] and Farmand and Dupoirieux [9].

Various studies show that the 3-D miniplate produces more favorable biomechanical behavior than miniplates in

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terms of strain resistance and stability in different parts of mandible [3, 10, 11]. The 1-mm-thick 3-D plate can withstand traction forces up to 690 N which is almost equal to the maximum load capacity of the mandible [9]. The disadvantage of 3-D miniplate as compared to miniplate is difficulty in adaptation to the mandible. It is a geometric plate and has to be bent in three dimensions, whereas a linear plate has to be bent in two dimensions [12].

There are a few studies comparing 3-D miniplate versus conventional miniplate in treatment of mandible fractures. According to survey published in 2005, only 6% of the North American and European surgeons have used 3-D miniplate in treatment of mandible fracture [4]. Thus, there is a need to compare 3-D miniplate versus conventional miniplate mandibular fracture treatment. The purpose of this study is to address them following; among the patients with fracture mandible, does the use of 3-D miniplate, when compared with conventional miniplate give better clinical outcomes with lesser complications.

Materials and Methods

This prospective randomized comparative study was conducted in the Department of Oral and Maxillofacial Surgery and Trauma Care Centre from January 2015 to December 2016. Ethical clearance was taken from institutional ethics committee prior to the study. Study population consisted of patients with mandible fractures reported to our department and trauma care center. Informed consent was obtained prior to inclusion in the study. Patients of both genders in the age group of 10–50 years with displaced mandibular fractures involving symphysis, parasymphysis, body, and angle region were included. Patients with infected comminuted fracture, condyle and coronoid fractures, gun-shot injuries, edentulous fractures, and pathological fractures were excluded. Patients with any type of comorbidities were also excluded.

A total of 40 patients were selected from study population and randomly divided by computer-generated randomizer into Group-I and Group-II of 20 patients each. In Group-I, 3-D miniplate and in Group-II, conventional miniplate were used.

Personal details, any drug addiction, cause of injury, fracture sites, inferior alveolar nerve paresthesia were recorded. Orthopantomogram (OPG) and postero-anterior (PA) mandible views were taken.

Surgical Procedure

The procedure was performed under general anesthesia by the same surgeon to eliminate interoperator bias. The fracture site was exposed through intra-oral vestibular

incision or existing extra-oral laceration. Following reduction in fractured segments, fixation was done using 3-D miniplate or conventional miniplate.

In Group-I, a single rectangular 2.0-mm 4-hole/6-hole 3-D titanium miniplate was fixed with 2×6 mm, 2×8 mm screws according to the extent and severity of fracture. Diagonally opposite screws were placed first, followed by the remaining two screws. Three-dimensional plate was contoured across the fracture line in such a way that the horizontal crossbars were perpendicular to the fracture line and vertical struts were parallel to fracture line. In symphysis and parasymphysis fractures, the upper crossbar was placed subapically. To preserve the mental nerve while placing 3-D plates, proper adaptation and subapical placement of plate with monocortical screw fixation were done. In angle region, plate was placed on the lateral cortex or on external oblique ridge and fixed using transbuccal trocar (Fig. 1).

In Group-II, single/double 2.0-mm 4-hole miniplates were contoured to the surface of mandible and secured with monocortical 2×6 mm, 2×8 mm titanium screws according to Champy's principle (Fig. 2).

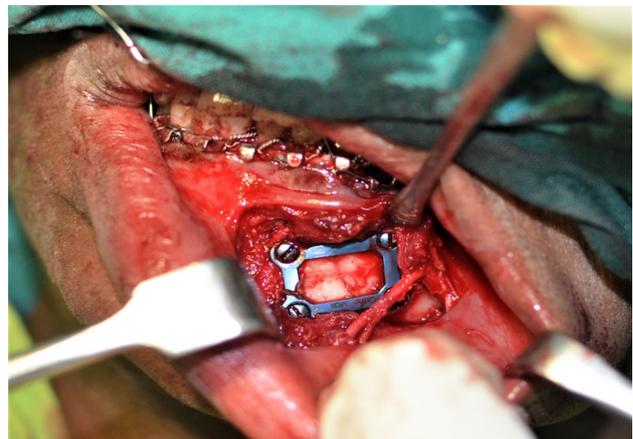


Fig. 1 3-D plate fixation



Fig. 2 Miniplate fixation

Drains were not placed in any of the patients. An extra-oral pressure bandage was applied. Occlusion discrepancy noted, if any, was subjected to MMF for 7–10 days in both groups. They were instructed to be on a soft diet for 4 weeks.

Cefoperazone with sulbactam 1.5 g IV 12 hourly was administered for 5 days postoperative period. Diclofenac sodium 75 mg IM 12 hourly for first 2 days followed by diclofenac dispersible tablet (50 mg) orally SOS was prescribed. Maintenance of oral hygiene using 0.12% chlorhexidine mouthwash was advised.

Outcome Measures

Following parameters were evaluated on the 1st post-op day, 7th post-op day, 1st month and 3rd month: (1) Occlusion—measured with caliper between first molars and divided into satisfactory (no gap), mild derangement (gap of 1–2 mm), and deranged (gap more than 2 mm); (2) Fracture stability—evaluated by a single surgeon by manual palpation, considered to be stable if interfragmentary mobility was not present and unstable if mobility was present; (3) Mouth opening—interincisal distance measured with scale in millimeters, considered to be adequate if > 30 mm and inadequate if < 30 mm; (4) Complications such as paresthesia, infections, plate fracture, plate loosening, malunion, nonunion, intra- or extra-oral sinus, wound dehiscence were assessed and recorded. Radiological evaluations were done with OPG and PA mandible views postoperatively on 1st day, 1st month and 3rd month (Figs. 3, 4, and 5).

Duration of surgery from the beginning of incision to the surgical closure was recorded in both groups. Pain was measured using VAS scale on 1st, 2nd, and 3rd post-op days, and swelling was measured on 3rd post-op day.

Statistical Analysis

The data were collected into Microsoft Excel worksheet and analyzed using SPSS (version 15.0, Chicago, IL,



Fig. 3 OPG showing 3-D plate fixation



Fig. 4 PA mandible showing 3-D plate fixation

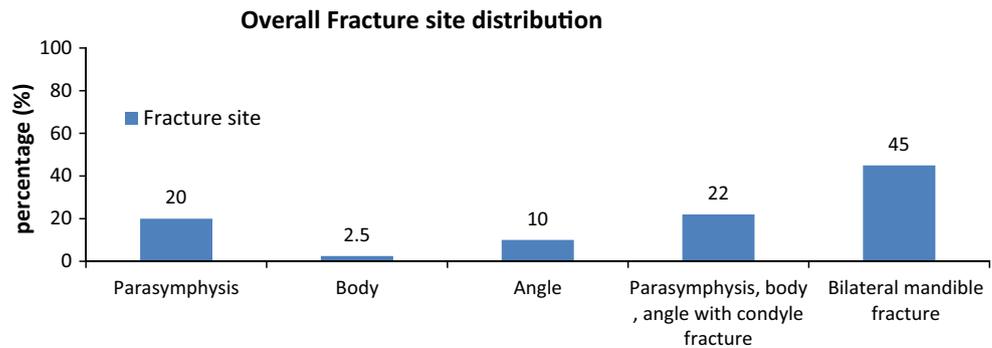


Fig. 5 PA mandible showing miniplate fixation

USA). Proportions were compared by using Chi-square or Fisher's exact test whichever was applicable. Student *t* test (unpaired) and Fisher's exact test were used as test of significance. A *p* value of < 0.05 was considered as significant.

Results

The mean age of the patients in this study was 25.82 ± 7.3 years with a range of 14–48 years. Overall incidence of injury (62.5%) was most common in third decade of life. There was a male predominance (95%) with

Graph 1 Overall fracture site distribution

male to female ratio of 19:1. Road traffic accident (RTA) was the most common etiology in 34 patients (85%), followed by fall in 6 patients (15%). 17.5% patients had trauma under influence of alcohol. The time from injury to the treatment ranged from 2 to 14 days, with a mean of 5.27 ± 2.5 (SD) days. Fracture site distribution is showed in Graph 1.

The average operating time in Group-I was 55.20 ± 20.9 and 54.60 ± 18.4 min in Group-II. For isolated parasymphysis fracture, average operating time in Group-I and Group-II was 38 ± 1.4 and 40.33 ± 1.6 min, respectively. The average operating time for angle fracture in Group-I and Group-II was 45 and 43.33 ± 2.8 min, respectively. Average operating time for parasymphysis, body, and angle fracture associated with condyle fracture in Group-I was 38.42 ± 5.0 and 42.50 ± 3.5 min in Group-II. Average operating time for bilateral mandibular fracture in Group-I was 71.40 ± 18.0 and 74.37 ± 12.93 min in Group-II.

No significant differences in pain and swelling ($p = 0.21$) were noted postoperatively between two groups. Comparison of fracture stability, occlusal status, mouth opening, paresthesia, infection rate and overall complications, and post-op X-ray findings is explained in Tables 1, 2, 3, 4, 5, 6, and 7, respectively.

Discussion

The study purpose was to compare 3-D miniplate with conventional miniplate in treatment of mandible fracture. We hypothesized that 3-D miniplate is better than

conventional miniplate in clinical outcomes in treatment of mandible fractures. Clinical outcomes were evaluated by measuring fracture stability, occlusion, mouth opening, pain, swelling, and postoperative complications like infection, paresthesia, plate loosening or fracture, wound dehiscence, intra-/extra-oral sinus, and scar.

The result of this study is in contradiction with our hypothesis; there are no major differences in clinical outcomes between two plating systems, and both can be effectively used in treatment of mandible fractures. Fracture stability, occlusion, and postoperative complications like paresthesia, wound dehiscence, plate loosening/fracture, delayed union, malunion, nonunion, and intra-/extra-oral sinus were similar in both groups. Mouth opening was more in Group-II than Group-I. Postoperative infection was more in Group-I than Group-II.

In this study, though there was no statistical difference between the two groups in terms of fracture stability at any of the follow-ups, initial interfragmentary stability was better in 3-D miniplate as compared to miniplate. Similar results were obtained by Jain et al. [12] and Vineeth et al. [13].

Considering the occlusal status between the two groups, the difference was not statistically significant on immediate ($p = 0.11$), 7th postoperative day ($p = 0.19$), 1st and 3rd month ($p = 0.14$) follow-up. Similar findings were obtained by Vineeth et al. [13] on immediate postoperative day ($p = 0.235$) and on 7th postoperative day ($p = 0.303$), Malhotra et al. ($p = 0.264$) [14], and Mittal et al. [15]. In other clinical studies with 3-D plates, occlusal change ranged from 0 to 20% [3, 16–19].

Table 1 Comparison of fracture stability between two groups

Fracture stability	1st post-op day		7th post-op day		1st post-op month		3rd post-op month	
	Stable	Unstable	Stable	Unstable	Stable	Unstable	Stable	Unstable
Group-I	17 (85%)	3 (15%)	18 (90%)	2 (10%)	20 (100%)	0 (0%)	20 (100%)	0 (0%)
Group-II	14 (70%)	6 (30%)	16 (80%)	4 (20%)	20 (100%)	0 (0%)	20 (100%)	0 (0%)
Total	31 (77.5%)	9 (22.5%)	34 (85%)	6 (15%)	40 (100%)	0 (0%)	40 (100%)	0 (0%)
<i>p</i> value	0.25		0.37		–		–	

Table 2 Comparison of occlusal status between two groups

Occlusal status	1st post-op day			7th post-op day			1st post-op month			3rd post-op month		
	Satisfactory	Mild deranged	Deranged	Satisfactory	Mild deranged	Deranged	Satisfactory	Mild deranged	Deranged	Satisfactory	Mild deranged	Deranged
Group-I	16 (80%)	4 (20%)	0 (0%)	16 (80%)	4 (20%)	0 (0%)	20 (100%)	0 (0%)	0 (0%)	20 (100%)	0 (0%)	0 (0%)
Group-II	11 (55%)	6 (30%)	3 (15%)	13 (65%)	4 (20%)	3 (15%)	18 (90%)	2 (10%)	0 (0%)	18 (90%)	2 (10%)	0 (0%)
Total	27 (67.5%)	10 (25%)	3 (7.5%)	29 (72.5%)	8 (20%)	3 (7.5%)	38 (95%)	2 (5%)	0 (0%)	38 (95%)	2 (5%)	0 (0%)
<i>p</i> value	0.11			0.19			0.14			0.14		

The mouth opening preoperatively in both the groups was found to be almost equal. On 1st and 7th postoperative day, the mouth opening was less in Group-I which was found to be significant ($p = 0.001, 0.002$, respectively). The reason for this difference might be due to the fact that more periosteal stripping is required in 3-D miniplate placement as compared to miniplate. All the patients had adequate mouth opening at 1st month and 3rd month follow-up. These findings were similar to the study of Vineeth et al. [on immediate postoperative day ($p = 0.656$) and on 7th postoperative day ($p = 0.087$)] [13], Al-Moraissi et al. [20].

Average operating time was less with the 3-D miniplate system in comparison with conventional miniplates in the symphysis/parasymphysis region because placement of one plate makes another plate in place, thus reducing the manipulation for two individual plates. In the angle region, the 3-D miniplate took more time as compared with conventional miniplates. Intra-oral placement of the 3-D miniplate is also more difficult. In bilateral fracture of mandible, operating time for 3-D miniplate was less compared to miniplates. Overall operating time was slightly higher with the 3-D miniplate system as compared with conventional miniplates. These findings were consistent with study done by Jain et al. [12] and Singh et al. [21] who found that the 3-D miniplate system took less operating time in the symphysis/parasymphysis region and more time in the angle region as compared with conventional miniplates. Al-Moraissi et al. [20] found no significant difference in duration of surgery ($p = 0.141$) between two groups.

Three-dimensional miniplate system uses lesser implant material in the symphysis and parasymphysis region, as only one plate and four screws are fixed as compared to miniplates where two plates and eight screws are fixed. Overall cost of the treatment is reduced to half for 3-D miniplate in comparison with miniplates of the same manufacturer. However, cost of the implant used in other areas of mandible is comparable for both the systems [14].

Postoperative infections occur commonly due to mobility of fracture segments. The improvement in plate stability will reduce the postoperative infection [22, 23]. With the use of ORIF, the reported incidence of infection ranges from 3 to 32% [7, 24]. In the present study, no significant difference was noted in infection between two groups on immediate and 7th postoperative day. At 1 and 3 months, 1 patient (5%) in Group-I and 6 patients (30%) in Group-II had developed infection. Plate removal was done in 5% patients in 3-D miniplate group and 15% patients in miniplate group. However, in follow-up period of 1 and 3 months, it was significant ($p = 0.03$). The infections were treated with antibiotics, incision–drainage and resolved uneventfully. These findings were similar to

Table 3 Comparison of mouth opening between two groups

Mouth opening (mm)	Group-I (mean ± SD)	Group-II (mean ± SD)	<i>p</i>
Pre-op	35.75 ± 4.1	33.85 ± 4.4	0.173
Post-op day 1	24.10 ± 1.5	27.85 ± 4.0	0.001
Post-op day 7	27.05 ± 1.5	32.4 ± 6.8	0.002
Post-op 1 month	36.15 ± 2.1	37.60 ± 3.6	0.134
Post-op 3 month	36.75 ± 2.0	38.95 ± 4.0	0.036

Table 4 Comparison of paresthesia between two groups

Paresthesia	1st post-op day		7th post-op day		1st post-op month		3rd post-op month	
	Absent	Present	Absent	Present	Absent	Present	Absent	Present
Group-I	13 (65%)	7 (35%)	13 (65%)	7 (35%)	13 (65%)	7 (35%)	13 (65%)	7 (35%)
Group-II	11 (55%)	9 (45%)	11 (55%)	9 (45%)	16 (80%)	4 (20%)	16 (80%)	4 (20%)
Total	24 (60%)	16 (40%)	24 (60%)	16 (40%)	29 (72.5%)	11 (27.5%)	29 (72.5%)	11 (27.5%)
<i>p</i> value	0.51		0.51		0.28		0.28	

Table 5 Comparison of infection between two groups

Infection	1st post-op day		7th post-op day		1st post-op month		3rd post-op month	
	Absent	Present	Absent	Present	Absent	Present	Absent	Present
Group-I	20 (100%)	0 (0%)	17 (85%)	3 (15%)	19 (95%)	1 (5%)	19 (95%)	1 (5%)
Group-II	20 (100%)	0 (0%)	17 (85%)	3 (15%)	14 (70%)	6 (30%)	14 (70%)	6 (30%)
Total	40 (100%)	0 (0%)	34 (85%)	6 (15%)	33 (82.5%)	7 (17.5%)	33 (82.5%)	7 (17.5%)
<i>p</i> value	–		–		0.03		0.03	

Table 6 Comparison of complications between two groups

Complications	Group-I	Group-II	Overall	<i>p</i> value
Nonunion	0 (0%)	0 (0%)	0 (0%)	–
Malunion	0 (0%)	2 (10%)	2 (5%)	0.14
Plate loosening	1 (5%)	3 (15%)	4 (10%)	0.2
Extra-oral sinus	2 (10%)	3 (15%)	5 (12.5%)	0.6
Intra-oral sinus	0 (0%)	0 (0%)	0 (0%)	–
Wound dehiscence	0 (0%)	0 (0%)	0 (0%)	–
Scar	10 (50%)	9 (45%)	19 (47.5%)	0.7

Table 7 Comparison of post-op X-ray findings between two groups

Immediate post-op X-ray findings	Group-I <i>n</i> (%)	Group-II <i>n</i> (%)	<i>p</i>
Precise anatomic reduction	16 (80.0)	7 (35.0)	0.004
Slightly displaced fracture with satisfactory occlusion	4 (20.0)	13 (65.0)	
Poorly reduced fracture	0 (0.0)	0 (0.0)	
Total	20 (100.0)	20 (100.0)	

studies done by Jain et al. [12], Vineeth et al. ($p = 1.00$) [13], Malhotra et al. [14], Al-Moraissi et al. ($p = 1.00$) [20], and Singh et al. [21]. Infection rates with 3-D mini-plate in other studies have been 9% [16], 8.2% [19], 5.5% [16, 25], and 4.4% [18] for angle fractures and 6.6% [26] and 10% [12] for mandibular fractures.

Totally, 16 patients had preoperative paresthesia. Nine patients in Group-I and 7 patients in Group-II had preoperative paresthesia. In Group-I, 7 patients (35%) and in Group-II, 9 patients (45%) had a complaint of paresthesia postoperatively on day 1 and 7 ($p = 0.51$). At the follow-up of 1st and 3rd month, 7 patients (35%) from Group-I

and 4 patients (20%) from Group-II had paresthesia ($p = 0.28$). Three-dimensional plates were placed in mental region involving isolated body and combined body fracture with other region of mandible fracture in 8 patients. Out of 8 patients, 6 patients had paresthesia in mental region after 3 months. Residual sensory impairment was present at 3 months of follow-up. Whether the sensory impairment was transient or permanent could not be assessed because of limited follow-up period. The sensory disturbance identified after surgery might be due to manipulation of the fracture site during surgery [27], debridement of fracture site, extraction of 3rd molar [28], fixation of screws in the inferior alveolar canal which can be avoided with the use of monocortical screws. However, incidence of sensory impairment in previous reports was about 0–8% with monocortical screws [29]. Guimond et al. [17] and Pal et al. [25] found 60 and 16.7% postoperative persistent sensory deficit, respectively.

No significant difference in pain (VAS) was noted between both groups at any of the follow-ups. These findings were similar to the study done by Singh et al. ($p > 0.005$) [21]. Swelling was compared on postoperative day 3. Difference of swelling between two groups was not significant ($p = 0.21$).

Infection or conditions that decrease blood supply are the usual cause of nonunion and delayed union. Incidences of malunion and nonunion range between 1 and 2% [30]. Potter and Ellis [31] reported 10.8% of plate fracture with 1.3-mm malleable noncompression miniplates which in turn resulted in interfragmentary mobility and nonunion. Farmand and Dupoirieux [8] treated 95 mandibular body fractures using 3-D miniplate and observed infection and plate fracture in 1 patient. Zix et al. [3] also found plate fracture in his study which is mainly due to reduced interfragmental cross-sectional bony surface at the fracture site.

There was no evidence of nonunion, malunion, plate fracture in 3-D miniplate group. Similar results were found by Zix et al. [3] and Malhotra et al. [14]. However, malunion was found in 10% patients in miniplate group only. The incidence of malunion has been reported to occur in a range of 0–4.2% [32]. Malunion results from inadequate fracture reduction or immobilization, poor patient compliance, or improper use of rigid internal fixation [33]. Plate removal was done in 5% patients in 3-D miniplate group and 15% patients in miniplate group due to loosening of plate and screws which resulted because of infection. Poor fixation of screws and plates was chief reason for plate removal in this study. Moore et al. [34] found that the incidence of plate removal was 18.2% when using Champy's technique compared to 8.2% with the use of 3-D strut plates. None of the patients developed wound dehiscence showing similar results as of Jain et al. [12], but contrary to

study by Al-Moraissi et al. ($p = 0.296$) [20], Pal et al. (11% wound dehiscence) [25], and Pandey et al. (33% wound dehiscence) [35].

In postoperative X-ray findings, the difference of fixation between two groups was statistically significant ($p = 0.004$). Possible explanation of this difference is that 3-D miniplate secured with bone screws creates box-like configuration and stabilizes the fracture in three dimensions which is not possible in case of miniplate fixation.

Limitations of this study are inclusion of isolated fractures and bilateral fractures. The treatment protocol, fixation requirements, and forces acting on bilateral fractures are different from that of isolated fractures. Our sample size was small with follow-up of 3 months. Complications with RIF may occur well after 3 months, and these could affect outcome variables. The masticatory forces were not measured in postoperative period. Qualitative assessment of sensory disturbances was not observed in postoperative period.

Conclusion

There is no major difference in clinical outcomes between two plating systems, and both can be effectively used in treatment of mandible fractures. Intra-oral placement of 3-D miniplate is difficult in angle fractures as well as in fractures involving mental nerve. However, it provides superior stability compared to miniplates. Overall complications are lesser in 3-D miniplate as compared to conventional miniplate. Also, less hardware is used in 3-D miniplate as compared to miniplate, making it less time-consuming and more economical in symphysis and parasymphysis region.

Compliance with Ethical Standards

Conflict of interest None.

References

1. Chrcanovic BR (2012) Open versus closed reduction: mandibular condylar fractures in children. *Oral Maxillofac Surg* 16(3):245–255
2. Al-Belasy FA (2005) A short period of maxillomandibular fixation for treatment of fractures of the mandibular tooth-bearing area. *J Oral Maxillofac Surg* 63:953–956
3. Zix J, Lieger O, Iizuka T (2007) Use of straight and curved 3-dimensional titanium miniplates for fracture fixation at the mandibular angle. *J Oral Maxillofac Surg* 65:1758–1763
4. Gear AJ, Apasova E, Schmitz JP, Schubert W (2005) Treatment modalities for mandibular angle fractures. *J Oral Maxillofac Surg* 63:655–663
5. Champy M, Lodde JP, Schmidt R (1978) Mandibular osteosynthesis by miniature screwed plates via a buccal approach. *J Maxillofacial Surg* 6:14

6. Champy M, Pape HD, Gerlach KL, Lodde VP (1986) The Strasbourg miniplate osteosynthesis. In: Krüger E, Schilli W, Worthington P (eds) *Oral and maxillofacial traumatology*, vol II. Quintessence, Chicago
7. Ellis E (1999) Treatment methods for fractures of the mandibular angle. *Int J Oral Maxillofac Surg* 28:243–252
8. Al-Moraissi EA, El-Sharkawy TM, El-Ghareeb TI, Chrcanovic BR (2014) Three dimensional versus standard miniplate fixation in the management of mandibular angle fractures: a systematic review and meta-analysis. *Int J Oral Maxillofac Surg* 43:708–716
9. Farmand M, Dupoirieux L (1992) The value of 3-dimensional plates in maxillofacial surgery. *Maxillofac Surg* 93:353
10. Alkan A, Çelebi N, Özden B, Baş B, İnal S (2007) Biomechanical comparison of different plating techniques in repair of mandibular angle fractures. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 104:752–756
11. Meyer C, Serhir L, Boutemi P (2006) Experimental evaluation of three osteosynthesis devices used for stabilizing condylar fractures of the mandible. *J Craniomaxillofac Surg* 34:173–181
12. Jain MK, Manjunath KS, Bhagwan BK, Shah DK (2010) Comparison of 3-dimensional and standard miniplate fixation in the management of mandibular fractures. *J Oral Maxillofac Surg* 68:1568–1572
13. Vineeth K, Lalitha RM, Prasad K, Ranganath K, Shwetha V, Singh J (2013) A comparative evaluation between single non-compression titanium miniplate and three dimensional titanium miniplate in treatment of mandibular angle fracture-a randomized prospective study. *J Craniomaxillofac Surg* 41:103–109
14. Malhotra K, Sharma A, Giraddi G, Shahi AK (2012) Versatility of titanium 3D plate in comparison with conventional titanium miniplate fixation for the management of mandibular fracture. *J Maxillofac Oral Surg* 11:284–290
15. Mittal G, Reddy R, Cariappa KM (2012) Three dimensional titanium mini plates in oral & maxillofacial surgery: a prospective clinical trial. *J. Maxillofac Oral Surg* 11(2):152–159
16. Feledy J, Caterson EJ, Steger S, Stal S, Hollier L (2004) Treatment of mandibular angle fractures with a matrix miniplate: a preliminary report. *Plast Reconstr Surg* 114:1711–1716
17. Guimond C, Johnson JV, Marchena JM (2005) Fixation of mandibular angle fractures with a 2.0-mm 3-dimensional curved angle strut plate. *J Oral Maxillofac Surg* 63:209–214
18. Hochuli-Vieira E, Ha T, Pereira-Filho V, Landes CA (2011) Use of rectangular grid miniplates for fracture fixation at the mandibular angle. *J Oral Maxillofac Surg* 69:1436–1441
19. Bui P, Demian N, Beetar P (2009) Infection rate in mandibular angle fracture treated with a 2.0-mm 8-hole curved strut plate. *J Oral Maxillofac Surg* 67:804
20. Al-Moraissi EA, Mounair RM, El-Sharkawy TM, El-Ghareeb TI (2014) Comparison between three dimensional and standard miniplates in the management of mandibular angle fractures: a prospective, randomized, double-blind, controlled clinical study. *Int J Oral Maxillofac Surg*
21. Singh V, Puri P, Arya S, Malik S, Bhagol A (2012) Conventional versus 3-dimensional miniplate in management of mandibular fracture: a prospective randomized study. *Otolaryngol Head Neck Surg* 147:450–455
22. Lamphier J, Ziccardi V, Ruvo A, Janel M (2003) Complications of mandibular fractures in an urban teaching center. *J Oral Maxillofac Surg* 61:745–750
23. Maloney PL, Lincoln RE, Coyne CP (2001) A protocol for the management of compound mandibular fractures based on the time from injury to treatment. *J Oral Maxillofac Surg* 59:879–884
24. Levy FE, Smith RW, Odland RM, Marentette LJ (1991) Monocortical miniplate fixation of mandibular angle fractures. *Arch Otolaryngol Head Neck Surg* 117:149–154
25. Pal US, Singh RK, Dhasmana S, Das S, Das SK (2013) Use of 3-D plate in displaced angle fracture of mandible. *Craniofac Trauma Reconstr* 6:25–30
26. Babu S, Parmar S, Menat M et al (2007) Three dimensional miniplate rigid fixation in fracture mandible. *J Maxillofac Oral Surg* 6(2):14–16
27. Fox AJ, Kellman RM (2003) Mandibular angle fracture: two-miniplate fixation and Complications. *Arch Otolaryngol Head Neck Surg* 5:464–469
28. Sawatari Y et al (2016) The use of three-dimensional strut plates for the management of mandibular angle fractures: a retrospective analysis of 222 patients. *Int J Oral Maxillofac Surg*. <https://doi.org/10.1016/j.ijom.2016.05.023>
29. Assael LA (1994) Treatment of mandibular fractures: plate and screw fixation. *J Oral Maxillofac Surg* 52:757–761
30. Siddiqui A, Markose G, Moos KF, McMahon J, Ayoub AF (2007) one miniplate versus two in the management of mandibular angle fractures: a prospective randomised study. *Br J Oral Maxillofac Surg* 45:223–225
31. Potter J, Ellis E 3rd (1999) Treatment of mandibular angle fractures with a malleable noncompression miniplate. *J Oral Maxillofac Surg* 57:288–292 (**discussion 292–293**)
32. Koury ME (1997) Complications in the treatment of mandibular fractures. In: Kaban LB, Pogrell AH, Perrot D (eds) *Complications in oral and maxillofacial surgery*. Saunderspp, Philadelphia, pp 121–146
33. Ellis E (1996) Complications of rigid internal fixation for mandibular fractures. *J Craniomaxillofac Trauma* 2:32
34. Moore E, Bayrak S, Moody M, Key JM, Vural E (2013) Hardware removal rates for mandibular angle fractures: comparing the 8-hole strut and Champy plates. *J Craniofac Surg* 24:163–165
35. Pandey V et al (2015) Management of mandibular angle fractures using a 1.7 mm 3-dimensional strut plate. *J Oral BiolCraniofac Res*. <https://doi.org/10.1016/j.jobcr.2015.11.001>