

Comparative Study Evaluating Stability of Fracture Segments after Treatment of Mandibular Angle Fracture with 3D Strut Plate in Two Groups One with IMMF and Another without IMMF; Randomized Clinical Trial

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ABSTRACT

Objective: The aim of this work is to evaluate the stability of fracture segments after treatment of mandibular angle fracture with 3D strut plate and comparison of the two groups: one with IMMF and another without IMMF.

Patients and Methods: Sixteen patients with mandibular angle with or without other fractures indicated for Open reduction internal fixation in the mandible. They were divided randomly into two groups: Group (1): included 8 patients who were treated by 3D strut plate without IMMF. Group (2): included 8 patients who were treated by 3D strut plate with IMMF.

Results: This is a randomized clinical trial including 16 patients with mandibular angle fracture. They were classified into two equal groups; group (1) included 8 patients who were treated by 3D strut plate without IMMF and group (2) included 8 patients who were treated by 3D strut plate with IMMF. The patients in both groups were age and sex matched, p value was statistically insignificant ($P > 0.05$) between the two groups.

Conclusion: 3D strut plate for fixation of fractured mandibular angle has relatively less or no post-operative complications compared with other techniques. Also, they provide adequate stability and resist the torsional forces in mandibular angle fractures especially reduction with IMMF. In addition, there exists an added advantage of minimal manipulation and adaptation that may hasten overall operating time. The simplicity, ease of application, shortened procedural times, and reduced risk of infection is the primary advantages of the 3D strut plate over the superior border technique.

INTRODUCTION

Mandibular fractures are frequent in facial trauma and represent between 35.54% and 44.2% of all facial fractures. This high incidence is a result of the mandibular anatomy and characteristics. The mandibular bone includes fragile areas due to the presence of third molars in the mandibular angle and bone narrowing in the subcondylar region. It constitutes the lower third of the face, and possesses certain mobility due to the presence of the temporomandibular joints. These fractures result in functional problems (speech, chewing, and swallowing), as well as social problems due to aesthetic discrepancies. The ideal treatment for mandibular fractures should aim at a perfect anatomical reduction, stable fixation, and satisfactory future function of the mandible with the least possible repercussions for the joints [1].

Management of mandibular angle fractures is one of the most widely discussed topics in maxillofacial literature. The aim of the treatment is to restore the anatomical form and function as well as establishing the pre-operative occlusion. With ease of application and low complication rates, Champy's 2 mm miniplate is

the widely used treatment modality for management of mandibular angle fractures. This semi-rigid fixation utilizes a single miniplate placed along the superior border which acts as a tension zone. However, the superior border tension zone is seen only if load is applied along the incisal edge. Biomechanical studies have shown that ipsilateral molar loading causes lower border splaying with Champy's technique [2].

Although there have been a number of studies on linear and curvilinear plates for mandibular fracture fixation, there have been only a few reports on the use of low profile 3-dimensional (3D) strut or mesh plates. In fact, the majority of studies on strut plates were in vitro biomechanical studies, some of which were using a sagittal ramus split osteotomy rather than a fracture model [3].

The aim of this work is to evaluate the stability of fracture segments after treatment of mandibular angle fracture with 3D strut plate and comparison of the two group's one with IMMF and another without IMMF.

PATIENTS AND METHODS

This is a randomized clinical trial including 16 patients with mandibular angle fracture carried out in Faculty of Dentistry, Cairo University, Egypt. Comparing between treatment strategies for mandibular angle fracture using 3D strut plate; with or without IMMF. Post-operative fracture stability and alignment and their different outcomes were assessed and compared between the patients' groups. Patients were classified into two groups: Group (1): included 8 patients who were treated by 3D strut plate without IMMF, and group (2): included 8 patients who were treatment by 3D strut plate with IMMF.

Patients with mandibular angle fractures indicated for open reduction internal fixation in the mandible were included in the study, while patients less than 15 years, patients with comminuted fractures, patients with high-risk systemic diseases, and old and/or mal-union fractures were excluded from the study.

Patients of both groups were subjected to:

1. History including personal data, medical, surgical history and family history.
2. Clinical examination: All patients were examined clinically by inspection and palpation both extra orally and intraorally, to detect any associated maxillofacial fractures as mobile fractured maxilla, depressed zygomatic complex fracture, or fracture of zygomatic arch and confirmed by the other examination tools, to reveal the selection criteria.
3. Radiographic examination in the form of Computed tomography (CT): (Axial cuts, DICOM file, Gantry tilt zero and minimal thickness of 1 mm) and panoramic view.
4. Preoperative laboratory tests (complete blood cell count, Hemoglobin count, coagulation profile, liver function, kidney function and blood glucose level).
5. Preoperative anesthesia assessment for fitness for general anesthesia.
6. Surgical simulation of the fracture reduction.

A-3D strut plate without IMMF:

- All cases underwent surgery under general anesthesia.
- Exposure of the fractured segments using vestibular incision.
- Inter-maxillary fixation
- The fractured segments were reduced to normal anatomic position guided by occlusion.
- Fracture fragments were fixed using 3D strut plate.

B-3D strut plate with IMMF:

- All cases underwent surgery under general anesthesia.

- Exposure of the fractured segments using vestibular incision.
- Inter-maxillary fixation done.
- The fractured segments were reduced to normal anatomic position guided by occlusion.
- The fracture fragments were fixed using 3D strut plate.

Immediate Postoperative instructions:

- Ice packs were placed for 10 minutes every 20 minutes for 12 hours.
- A liquid diet was initiated on the first postoperative day, followed by instructions for a soft diet for the next 4 weeks.
- Strict oral hygiene measures including brushing and rinsing.

Criteria for discontinuing or modifying intervention:

- If the study group showed marked destructive side effects and poor cosmetics outcome the procedures were modified to avoid these drawbacks.
- No protocol for discontinuation of the procedure.

Strategies to improve adherence to intervention protocol:

- Face-to-Face adherence reminder session will take place in the initial visit. This session were including: the patient should be informed about the study steps and maintain oral hygiene. Subsequent sessions will occur at the follow-up visits. Participants asked about any problems they had experienced such as pain, swelling and oral hygiene. Patients recalled for clinical evaluation every week for one month and three months postoperative.

Surgical preparation:

All the patients were admitted to the oral and maxillofacial surgery department, faculty of Dentistry, Cairo University. Full laboratory investigation and medical consultation were requested to reveal patient fitness to undergo surgery under general anesthesia with nasotracheal intubation.

All the surgical instruments were prepared and sterilized including the special instruments for application of the plates and screws according to the standard sterilization protocol.

The patients were prepared before going to the operating room, and wear gowns of the operating room. All patients were treated by open reduction and internal fixation through an intraoral approach.

Surgical technique:

Intraoperatively Antibiotic ointment was applied in both eyes and sterile eye pads were placed covering the eyes. The operative site was prepared by removing any foreign material as infected crust, then the patient was scrubbed with a solution of betadine surgical scrub and draped in a standard fashion.

After standard preparation of patient for surgery and disinfection of the oral cavity, Erich type arch bars were applied to the upper and lower teeth, the arch bar was segmented at the site of the fracture line. Surgical site was infiltrated with local anesthetic solution containing Mepivacaine hydrochloride 2% local anesthesia with levonordefrin 1:20000 vasoconstrictor along the proposed incision line for hemostasis.

An intraoral incision was made extending over the external oblique ridge, 3 mm or 5 mm below the mucogingival junction extending to 1st molar region was made by using Bard-Parker blade no. 15. The fracture was exposed by elevating a mucoperiosteal flap down to the inferior border of the mandible. The fractured segments were mobilized and aligned to obtain proper reduction and maxillo mandibular fixation was applied to obtain appropriate occlusion.

In few cases, an extended third molar crevicular incision was used wherever third molars were to be extracted. Third molars with gross caries, periodontal involvement, crown/root fracture, excessive mobility and those interfering with reduction of the fracture segments were extracted.

Any hematoma or fibrous tissue present between the fractured segments was removed by curettage of the bony edges. Then the segments were manipulated and reduced and the occlusion was reestablished.

Fixation with strut 4-hole 3D plate:

The mandible was placed into maxillo mandibular fixation and the reduced fracture was stabilized and further alignment of the segments was performed maintaining satisfactory occlusion. The additional mandibular fractures were exposed through a suitable approach and fixed in a standard manner.

A small extraoral stab incision was given to permit the insertion of the transbuccal cannula. The location of the extraoral stab incision was guided by the location of the fracture line and the position of the facial vessels. The trocar was advanced into the operative site with blunt dissection through the stab incision, perforating the periosteum in the area planned for plate fixation. The cheek retractor was applied to stabilize the trocar assembly during movement towards and away from the fracture site. The plate was seated over the fracture site and adapted along the outer cortex of the mandible. The interconnecting cross struts of 3D miniplate were placed nearly parallel to the fracture line.

A drill bit 11.5 cm in length and 1.6 mm in diameter was inserted through the drill guide to drill the holes under copious irrigation with normal saline as a coolant. Then, the 3D miniplate was secured with monocortical screws (5-7 mm). The occlusion was checked in all patients by releasing MMF after fixation of the fractured fragments. Then patients of group (1) were left without IMMF, while patients of group (2) were maintained on IMMF for 2 weeks.



Fig. (1): Malocclusion before open reduction for case with left mandibular angle fracture (a), mandibular angle fracture and the surgical approach used (b).



Fig. (2): The 4-hole 3D strut plate for open reduction and internal fixation of mandibular angle fracture with the patient in IMMF (a) and without IMMF (b).

The operated site was closed with 3-0 vicryl and an extra-oral pressure dressing was applied. Post-operatively, the same antibiotic was continued for 3 days (2 dosages in a day). Analgesics and chlorhexidine 0.2% mouthwash were also prescribed. Strict oral hygiene instructions were given and patients were kept on fluid diet for 2 weeks in both the groups.

Postoperative instructions

As all patients treated were under general anesthesia, nothing was to be taken orally until the patient was fully recovered from the anesthetic effect and observed two hours after operation. The diet was supplemented with vitamins and high calorie protein mixed with flavoring agents and blenderized food for two weeks. The patients were instructed to use betadine or antiseptic mouth wash and soft tooth brush after every meal to preserve good oral hygiene. Sutures were removed after 10 days and the arch bar was removed after 2 weeks under the effect of local anesthesia after checking proper occlusion.

The actual inter-ramus distance on the cone beam CT was measured for each case using lingula as reference point at first week and third month follow up visits and the difference between the measurements at both visits was recorded:

- Excellent: no difference radiographically between both visits.
- Very good: difference between both visits less than 1 mm.
- Good: difference is 1-2 mm.
- Poor: difference between both visits more than 2 mm.

Follow-up

Patients were evaluated after 1 day, 1 week, 2 weeks, 1 month and 3 months post-operatively for the following parameters:

- 1- Proper reduction and fixation.
- 2- Occlusal discrepancies.
- 3- Fracture stability.
- 4- Mouth opening.
- 5- Bone union at 3 months postoperatively.
- 6- Incidence of infection.

Statistical analysis

Analyzed was performed by using IBM SPSS advanced statistics (Statistical Package for Social Sciences), version 24 (SPSS Inc., Chicago, IL). Numerical data were described as mean and standard deviation or median and range. Categorical data were described as numbers and percentages. Data were explored for normality using Kolmogorov-Smirnov test and Shapiro-Wilk test. Comparisons between two groups for normally distributed numeric variables were done using the student's t-test while for non-normally distributed numeric variables were done by Mann-Whitney test. Comparisons between categorical variables was performed using the chi-square test. A p-value less than or equal to 0.05 is considered statistically significant.

RESULTS

This is a randomized clinical trial including 16 patients with mandibular angle fracture. They were classified into two equal groups; group (1) included 8 patients who were treated by 3D strut plate without IMMF and group (2) included 8 patients who were treated by 3D strut plate with IMMF. The patients in both groups were age and sex matched, p value was statistically insignificant ($P > 0.05$) between the two groups. The common etiologies were road accidents, motor cycles, car accidents, interpersonal violence, and

animal attacks. Fracture displacements were mild, moderate and severe, all were statistically non-significant comparing both groups (table 1).

Maximum displacement of inner ramus distance (IRD) in mm were classified into mild, moderate and severe, they were ranged from 0.514 – 12.857 and 0.778 – 11.281 with means of 5.329 ± 4.296 and 6.272 ± 3.658 in groups (1&2), respectively (table 2).

The degree of reduction on the postoperative first week in panoramic radiographs ranged from 0 – 1.8 and 0 – 1.0 with means of 0.52 ± 0.48 and 0.34 ± 0.37 in groups (1&2), respectively. They had a statistically non-significant difference in comparison between the two groups (table 3).

The means of IRD in mm were 85.09 ± 0.818 and 85.23 ± 0.865 in the first postoperative week and 84.63 ± 0.966 and 84.84 ± 0.729 in the third postoperative month in groups (1&2), respectively. They showed a statistically insignificant difference ($P > 0.05$), table (4).

Postoperative outcome of groups (1 & 2) during the follow-up period showed statistically non-significant difference ($P > 0.05$) as regard fracture stability, mouth opening, and infection (table 5).

DISCUSSION

Despite many advances in internal fixation, angle fracture remains among the most difficult and unpredictable fracture to treat compared with those of other areas of the mandible. The treatment of mandibular angle fractures remains conceptually controversial, with a bothersome complication rate. Mandibular angle fractures can be treated in a closed or open fashion. Closed treatment requires the patient to be in MMF for 4 to 6 weeks or even longer in older patients or patients with comminuted fractures. This prolonged MMF can be problematic in patients with psychiatric disorders or patients at risk of aspiration or patients with altered mental status. Prolonged MMF can also lead to atrophy of masticatory muscles. Open reduction and internal fixation (ORIF) can eliminate or reduce the period of MMF and facilitate an early return of jaw function [4].

In this randomized clinical trial, we tried to compare the stability of fracture segments after treatment of mandibular angle fracture with 3D strut plate in two groups one with IMMF and the other without IMMF. In this study, 16 patients with unilateral isolated mandibular angle fracture were selected for by this trial. They were classified into two equal groups of 8 patients each; group (1) treated by 3D strut plate without IMMF and group (2) by 3D strut plate with IMMF. To the best of our knowledge, this is the first study to compare between 3D Strut plate with and without IMMF in treatment of mandibular angle fracture. The patients in both groups were age and sex matched ($p = 0.224$). The mean age was 23.8 ± 2.03 years and 23.5 ± 1.46 years in groups 1 & 2, respectively. Most of the patients were males (62.5%) compared to (37.5%) females in group (1) and males in group (2) were (75%) and females were (25%).

Although the number selected patients (16 patients) for our trial, there were it corresponded to the previous studies of **Chhabaria et al. [4]** and **Vineeth et al. [5]** study that include 20 patients, 18 males (90%) and 2 females (10%). Only one case had bilateral fracture in their study. Also, the mean age of patients was comparable to our study with mean of 29 years and range of 21 to 50 years old. However, a large coherent retrospective study by **Sawatari et al. [6]** included 263 patients with mandibular angle fractures treated with 3D strut plates at a university hospital in Miami, Florida, USA. Patient age ranged from 16 to 63 years, with a mean age of 30 years.

In our study 3 patients (37.5%) had right sided fracture and 5 patients (62.5%) had left sided fracture in group (1), while have of the patients in each side were found in group (2). The total right sided fractures were 7 patients (43.75%) and 9 patients (56.25%) to the left sided trauma. In of **Chhabaria et al. [4]** study 7 patients (35%) had right sided fractures and 13 patients (65%) had left sided fractures.

As regard to the cause of trauma; the most common etiology was the road traffic accident (RTA) in the two groups (37.5% in group 1 and 50% in group 2). Other causes of group (1) fractures; motor cycle (25%),

animal kicks (25%) and car accident (12.5%), while in group 2 fractures; (12.5%) in each of motor cycles, car accident, interpersonal violence (altercations) and animal kicks.

In accordance into our current finding are the study of **Chhabaria et al. [4]** where they found the causes of mandibular angle fractures in their cases (20 patients) were road traffic accidents in 14 cases (70%), fall in 3 cases (15%), assault in 2 cases (10%), and industrial accident in 1 case (5%). Another study by **Vineeth et al. [5]** had the most common etiology was road traffic accident in 90% (n = 18) followed by altercations in 10% (n = 2). All patients presented with horizontally unfavorable fractures and only 20% (n = 4) of patients presented with a vertically unfavorable fracture. 20% (n = 4) of patients had fracture displacement with ipsilateral premature posterior bite. Also, **Al-Tairi et al. [7]** found that the vast majority of fractures in this study were due to RTA (69%). Similar results were reported by **Singh et al. [8]** in their retrospective study on Indians with mandibular angle fractures and found 74% of all etiological factors due to RTA.

However, in contrast, **Sawatari et al. [6]** found that the most common cause of the angle fracture was assault and interpersonal violence. This was followed by motor vehicle collision and falls. Other studies reported assaults are the major cause of mandibular angle fracture (69-90%) such as **Potter & Ellis [9]** and **Wan et al. [10]**. Thus; the most cause of mandibular angle fractures was the road traffic accidents and the differences in causes in different literatures may be due to the community and environmental status of the studied groups in addition to bad roads, poor implementation of traffic rules and not using safety measures in developing countries.

Regarding maximum fracture displacement, it was assessed as mild (< 1 mm), moderate (>1-5 mm), severe (> 5 mm). It ranged between 0.514 – 12.827 mm with a mean $\pm$ SD of 5.329 ± 4.296 mm in group (1), while in group (2) the average displacement was 6.272 ± 3.658 mm that was ranged between 0.778 – 11.281 mm. Comparison between both groups showed a statistically insignificant difference (P = 0.0984), i.e., both groups were comparable. Mild displacement was 12.5% & 12.5% in both groups, the moderate displacement was 25% and 37.5% in group 1 & 2, respectively, while severe displacement was 62.5% and 50% in group 1 & 2, respectively.

Compared to previous studies **Chhabaria et al. [4]**, in 15 cases (75%), the mandibular angle fractures were grossly displaced and in 5 cases (25%), the mandibular angle fractures were minimally displaced.

The extent of reduction, in this study, by measuring the mean gap at the fracture line on the cone beam CT at the first week follow up visit for group (1) that revealed one case with excellent reduction, 4 cases with very good reduction, and 3 cases with good reduction. In group (2), 3 cases had excellent reduction, 3 cases with very good reduction and 2 cases with good reduction. The mean gap width for group (1) was 0.52 ± 0.48 mm and for group (2) was 0.34 ± 0.37 mm with a statistically non-significant difference between both groups (p-value = 0.096). So, satisfactory occlusion was noted in most of our cases.

In agreement to these results **Al-Tairi et al. [7]** achieved satisfactory occlusion in all cases of 3D strut plate group. Also, these results were in agreement with **Guimond et al. [11]** and **Höfer et al. [12]**.

In contrast to this result **Zix et al. [13]** used guiding elastics postoperatively in 20% of patients in order to adjust the occlusion. **Hochuli-Vieira et al. [14]** reported 6.6% of cases with minor occlusal changes, and **Pal et al. [15]** reported 11% of malocclusion.

This variation could be due to presence of concomitant condylar/ subcondylar fractures in some cases of their studies or the variation due to incidence of complications.

A published meta-analysis of six studies comparing the 3D strut plate to Champy's technique to repair mandible angle fractures revealed a 58% reduction in postoperative complications when the 3D strut plate was used [16].

In the authors' experience, **Sawatari et al. [6]** stated that the 3D strut plate provides rigid stability of the fracture segments with almost no mobility at either the superior or inferior border. With better reduction and stability, there is a presumed reduction of infection, malunion, nonunion, and malocclusion.

Clinical outcome in our study, in group (1): 5 patients (62.5%) had excellent fixation, 2 patients (25%) had very good fixation, and only one patient (12.5%) had good fixation. In group (2): 6 patients (75%) had excellent fixation, and the other 2 patients (25%) had very good fixation.

Radiographic outcome in our study, by measuring the actual IRD on the cone beam CT and/or computerized tomography (CT) in group (1); the mean distance was 85.09 ± 0.818 mm, and 84.63 ± 0.966 mm at 1 week, and 3 months follow up visits, respectively, with a mean difference of 0.46 ± 0.39 mm. The difference when comparing between the IRD at 1 week and 3 months using the paired t-test was statistically non-significant for group (1), p value = 0.3182. For group (2); the mean IRDs were 85.23 ± 0.865 mm and 84.84 ± 0.729 mm at 1 week and 3 months follow up visits, respectively with a mean difference of 0.41 ± 0.67 mm. The difference when comparing between the IRD at 1 week and 3 months using the paired t-test was statistically non-significant for group (2), p-value = 0.2122. There was statistically non-significant difference, when comparing the mean differences of the IRD for group (1 & 2), p-values = 0.674 and 0.624 at one week and 3 months postoperatively, respectively.

Similar to these results was the study of **Al-Tairi et al. [7]** who found no statistical differences as regard the mean IRD during the follow up periods in both study and control groups as compared to immediate postoperative measurements. The fixation system was stable enough to hold the bony segments and resist the muscle pull and occlusal forces. There are no published studies using this measure on trauma patients, so comparison was not possible.

Many studies measured inter-ramus distance on 3D CT to assess stability of the proximal bony segments after BSSO [7, 17,18]. We took the advantage of those measures and applied the same principle for assessment of the stability of the fixated bony segments in mandibular angle fracture.

As regard occlusal discrepancies at the first week postoperatively; group (1) showed 5 patients maintained normal occlusion, 2 patients complained from mild occlusal derangement managed by spot grinding and one patient complained from moderate occlusal derangement managed by spot grinding. However, patients of group (2) showed 6 patients maintained normal occlusion and 2 had mild occlusal derangement managed by spot grinding. After 3 months of follow-up; 7 patients had normal occlusion while only one still had mild occlusal derangement. On the other hand, all patients in group (2) showed normal occlusion.

Based on both clinical and biomechanical studies, a single plate has the propensity to allow the fracture line to open at the inferior border. This subtle displacement can lead to subsequent lateral displacement and posterior open bite malocclusion [19].

A study done using sheep mandibles and a class III cantilever model found that the degree of displacement and gap formation of the 3D strut plate is comparable to that of a reconstruction Plate [20].

Champy's technique, which involves placing one plate at the superior border to repair fractures of the mandibular angle, has been the most commonly used method of fixation to date. However, the stability of the single plate at the superior border has recently been called into question [16]. So, the 3D strut plate introduced a very good stability along the whole period of treatment and follow-up.

In this study, fracture stability was assessed in patients of both the groups by simple digital palpation on either side of the fracture line and checked for the fracture fragments mobility. At day one postoperatively 4 patients (50%) in each group had stable fracture, at the first week postoperatively; 5 patients (62.5%) in each group had stable fracture, by the first month postoperatively 6 patients (75%) and 8 patients (100%) were stable fractures in group (1) and (2), respectively. However, all patients in the two groups were stable at the end of the follow-up period. They showed a statistically non-significant difference between the two groups ($P > 0.05$) in each follow-up visit.

Authors agree with this fact such as **Vineeth et al. [5]** who compared the stability of strut plate with the miniplate and found 40% of patients had unstable fracture in miniplate group on the immediate postoperative day as compared with only 10% of patients in strut plate group were unstable in the immediate

postoperative day. Later after the first month postoperatively, all patients showed stable fracture fragments. They added that although there was no statistical difference between the two groups, the 3-D titanium miniplates showed better initial interfragmentary stability over single non compression titanium miniplates.

Many surgeons felt that miniplate fixation did not provide adequate stability and required maxillo mandibular fixation for additional stability, but in one study it was found that the application of maxillo mandibular fixation did not significantly alter the complication rates [21].

Several studies have reported that a single miniplate does not provide sufficient stability to mandible angle fractures and that the addition of IMF is required [12, 21, 22]. All patients in **Sawatari et al. [6]** study had their arch-bars and IMF removed at the conclusion of the case. Patients were allowed to consume a nonchewing soft diet post-surgery for 6 weeks.

Regarding mouth opening at one day postoperatively none of the two groups were able to open their mouths, at the first week postoperatively; group (1) showed 5 patients (62.5%) were able to open their mouth adequately, the other 3 patients could open their mouth adequately after the first month postoperatively. However, patients of group (2) showed 4 patients (50%) could open their mouth adequately in the first week post-operatively increased to 7 (87.5%) in the first month, then 8 (100%) by the third month. They showed a statistically non-significant difference between the two groups ($P > 0.05$) in each follow-up visit.

Coincides with these results was the results of **Al-Tairi et al. [7]** who measured mouth opening and found that the mean immediate post-operative mouth opening was 17.62 ± 3.62 mm, increased after one month to 41.12 ± 2.41 mm, then after 3 months 43.25 ± 3.1 mm and become stable at 6 months at a mean of 43.37 ± 2.26 mm.

Similar results were reported by **Vineeth et al. [5]** who compared between miniplate and 3D strut plate and found that all patients in both the groups had inadequate mouth opening on immediate post-operative day, 40% of patients had inadequate mouth opening in miniplate group and none in 3D strut group at the first month of follow-up. All the patients in both groups resumed adequate mouth opening after the third month of follow up. **Sawatari et al. [6]** considered the inability to open the mouth postoperatively is a minor complication and found only nine patients (4%) had limited mouth opening.

As regard bone union at 3 months postoperatively represented four cases (50%) with

As regard the incidence of postoperative infection; none of both groups had infection at first postoperative day, two patients had infection in the first postoperative week in group (1), while one patient had infection during the first month. Only one patient had infection in the first month in group (2), while no infection observed at the end of the follow-up period (third month). They showed a statistically non-significant difference between the two groups ($P > 0.05$) in each follow-up visit except the first week that showed week significant value ($P = 0.044$).

In agreement to these results **Al-Tairi et al. [7]** who found none of the cases of 3D strut plate group experienced postoperative infection. This was confirmed by other studies who found infection rate was ranged from 0 to 5.4% [11, 13, 14,23,24].

In contrast to these results, **Chhabaria et al. [4]** encountered two cases (10%) with surgical wound infection, which resolved with appropriate course of antibiotics and wound care. In comparison, the infection rate is found to be much higher with the use of two miniplates in the treatment of the angle fractures (29%) [25].

Vineeth et al. [5] compared infection between miniplate and 3D strut plate and found 20% of patients developed infection in the miniplate group, 10% at 30th (1st month) post-operative day and other 10% at 90th (3rd month) post-operative day follow up, both were managed with incision and drainage intraorally and antibiotics, one patient required plate removal. In those patients a 3rd molar in the line of fracture was left in situ at the time of surgery; later on, the third molar was extracted in one patient. However, none of the patients in 3D strut group developed infection.

Variation in the rate of postoperative infection could be related to the status of a molar in the fracture line, the time delay between trauma and the operation, or improper adaptation of the upper border miniplate. Decreased infection rate in 3D miniplate studies versus two miniplates studies could be attributed to low plate profile, which means less hardware; and to decreased operative time because of 3D plate malleability and simultaneous application of the upper and lower struts of the 3D plate [7].

Conclusion

3D strut plate for fixation of fractured mandibular angle provide adequate stability and resist the torsional forces in mandibular angle fractures especially reduction with IMMF. In addition, it exists an added advantage of minimal manipulation and adaptation that may hasten overall operating time with less complications than other techniques. The simplicity, ease of application, shortened procedural times, and reduced risk of infection is the primary advantages of the 3D strut plate.

REFERENCES

1. de Oliveira JCS, Moura LB, de Menezes JDS, Gabrielli MAC, Pereira Filho VA, Hochuli-Vieira E. Three-dimensional strut plate for the treatment of mandibular fractures: a systematic review. *Int J Oral Maxillofac Surg*. 2018; 47(3):330-338.
2. Pandey V, Bhutia O, Nagori SA, Seith A, Roychoudhury A. Management of mandibular angle fractures using a 1.7 mm 3-dimensional strut plate. *J Oral BiolCraniofac Res*. 2016; 6(1): 35 – 40.
3. Bui P, Demian N, Beetar P. Infection Rate in Mandibular Angle Fractures Treated with a 2.0-mm 8-Hole Curved Strut Plate. *J Oral Maxillofac Surg*. 2009; 67(4): 804-808.
4. Chhabaria G, Halli R, Chandan S, Joshi S, Setiya S, Shah A. Evaluation of 2.0-mm Titanium Three-Dimensional Curved Angle Strut Plate in the Fixation of Mandibular Angle Fractures-A Prospective Clinical and Radiological Analysis. *Cranio-maxillofac Trauma Reconstr*. 2014; 7(2):119-925.
5. Vineeth K, Lalitha RM, Prasad K, Ranganath K, Shwetha V, Singh J. "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*. 2013; 41(2): 103-109.
6. Sawatari Y, Marwan H, Alotaibi F, Christensen J, Gannon J, Peleg M. The Use of Three-Dimensional Strut Plates for the Management of Mandibular Angle Fractures: A Retrospective Analysis of 222 Patients. *Int J Oral MaxillofacSurg* 2016; 45(11): 1410 – 1417.
7. Al-Tairi NH, Shoushan MM, SaadKhedr MM, Abd-alal SE. Comparison of three-dimensional plate versus double miniplate osteosynthesis for treatment of unfavorable mandibular angle fractures. *Tanta Dental Journal* 2015; (12) 89-98.
8. Singh S, Fry RR, Joshi A, Sharma G, Singh S. Fractures of angle of mandible e a retrospective study. *J Oral Biol Craniofacial Res* 2013; 2(3): 154e8.
9. Potter J, Ellis 3rd E. Treatment of mandibular angle fractures with a malleable noncompressionminiplate. *J Oral MaxillofacSurg* 1999; 57(3): 288e92.
10. Wan K, Williamson RA, Gebauer D, Hird K. Open reduction and internal fixation of mandibular angle fractures: does the transbuccal technique produce fewer complications after treatment than the transoral technique? *J Oral MaxillofacSurg* 2012; 70(11): 2620 – 2628.
11. Guimond C, Johnson JV, Marchena JM. Fixation of mandibular angle fractures with a 2.0-mm 3-dimensional curved angle strut plate. *J Oral Maxillofac Surg*. 2005; 63(2): 209 – 214.
12. Höfer SH, Ha L, Ballon A, Sader R, Landes C. Treatment of mandibular angle fractures—lineaobliqua plate versus grid plate. *J CraniomaxillofacSurg* 2012; 40:807 – 811.
13. Zix J, Lieger O, Iizuka T. Use of straight and curved 3-dimensional titanium miniplates for fracture fixation at the mandibular angle. *J Oral MaxillofacSurg* 2007; 65(9): 1758 – 1763.
14. Hochuli-Vieira E, Ha TK, Pereira-Filho VA, Landes CA. Use of rectangular grid miniplates for fracture fixation at the mandibular angle. *J Oral MaxillofacSurg* 2011; 69(5):1436 – 1441.
15. Pal US, Singh RK, Dhasmana S, Das S, Das SK. Use of 3-D plate in displaced angle fracture of mandible. *Cranial Maxillofac Trauma Reconstr* 2013; 6(1): 25 – 30.

16. Al-Moraissi EA, El-Sharkawy TM, ElGhareeb TI, Chrcanovic BR. Three-dimensional versus standard miniplate fixation in the management of mandibular angle fractures: a systematic review and meta-analysis. *Int J Oral Maxillofac Surg* 2014; 43: 708–716.
17. Bayat M, Badri A, Momen-Heravi F, Garajei A, Asgarian A. Transverse displacement and angulation of the proximal segment after mandibular setback by means of bilateral intraoral vertico-sagittal ramus osteotomy. *J Oral Maxillofac Surg* 2011; 69(3): 906 – 910.
18. Yoo JY, Kwon YD, Suh JH, Ko SJ, Lee B, Lee JW, et al. Transverse stability of the proximal segment after bilateral sagittal split ramus osteotomy for mandibular setback surgery. *Int J Oral Maxillofac Surg* 2013; 42(8): 994 – 1000.
19. Chrcanovic BR. Open versus closed reduction: comminuted mandibular fractures. *Oral Maxillofac Surg*. 2013; 17(2): 95 – 104.
20. Wittenberg JM, Mukherjee DP, Smith BR, Kruse RN. Biomechanical evaluation of new fixation devices for mandibular angle fractures. *Int J Oral Maxillofac Surg* 1997; 26: 68 – 73.
21. Gear AJL, Apasova E, Schmitz JP, Schubert W. Treatment modalities for mandibular angle fractures. *J Oral Maxillofac Surg* 2005; 63: 655 – 663.
22. Sadhwani BS, Anchlia S. Conventional 2.0-mm miniplates versus 3-D plates in mandibular fractures. *Ann Maxillofac Surg* 2013; 3: 154 – 159.
23. de Melo WM, Antunes AA, Sonoda CK, Hochuli-Vieira E, Gabrielli MA, Gabrielli MF. Mandibular angle fracture treated with new three-dimensional grid miniplate. *J Craniofac Surg* 2012; 23(5): 416 – 417.
24. Wolfswinkel EM, Kelley BP, Chike-Obi CJ, Weathers WM, Qashqai SM, Bullocks JM, Hollier Jr LH. Treatment of mandibular angle fractures with a matrix strut miniplate. *J Craniofac Surg* 2013; 24: e149 – e152.
25. Siddiqui A, Markose G, Moos KF, McMahon J, Ayoub AF. One miniplate versus two in the management of mandibular angle fractures: a prospective randomized study. *Br J Oral Maxillofac Surg*. 2007; 45: 223 – 225.

Table (1): Characteristics of the studied groups

Age (years)	Group (1)		Group (2)		F-test	P value
Mean ± SD	23.8 ± 2.03		23.5 ± 1.46		0.068	0.224
Range	19 – 42		18 – 41			
Gender	No.	%	No.	%	χ^2	P value
Males	5	62.5	6	75.0	0.034	0.525
Females	3	37.5	2	25.0	0.162	0.065
Total	8	100	8	100		
Laterality	No.	%	No.	%	χ^2	P value
Right	3	37.5	4	50.0	7	43.75
Left	5	62.5	4	50.0	9	56.25
Etiology	Without IMMF		With IMMF		Total	
	No.	%	No.	%	No.	%
Road accidents	3	37.5	4	50.0	7	43.75
Motor cycles	2	25.0	1	12.5	3	18.75
Car accident	1	12.5	1	12.5	2	12.50
Interpersonal violence	0	0.00	1	12.5	1	6.25
Animal kicks	2	25.0	1	12.5	3	18.75
Total	8	100	8	100	16	100
Fracture displacement	No.	%	No.	%	χ^2	P value
Mild	1	12.5	1	12.5	0.000	1.000
Moderate	2	25.0	3	37.5	0.017	0.088
Severe	5	62.5	4	50.0	0.019	0.076

χ^2 = Chi square test, P >0.05= non-significant.

Table (2): Maximum displacement of inner ramus distance in mm of patients in both groups.

IRD	Group (1)		Group (2)	
Case 1	9.065	Severe	7.325	Severe
Case 2	6.253	Severe	10.285	Severe
Case 3	0.514	Mild	3.657	Moderate
Case 4	12.827	Severe	4.382	Moderate
Case 5	0.677	Severe	11.281	Severe
Case 6	3.652	Moderate	0.778	Mild
Case 7	7.058	Severe	8.557	Severe
Case 8	2.583	Moderate	3.912	Moderate
Range	0.514 – 12.827		0.778 – 11.281	
Mean ± SD	5.329 ± 4.296		6.272 ± 3.658	
t-test	0.1825			
P value	0.0984			

IRD: Inner ramus distance. $P > 0.05$ = non-significant.

Table (3): Degree of reduction on the postoperative first week in panoramic radiographs of the two studied groups.

	Group (1)	Group (2)	t-test	P value
Mean $\pm$ SD (mm)	0.52 $\pm$ 0.48	0.34 $\pm$ 0.37	0.0869	0.096
Range	0 – 1.8	0 – 1.0		

$P > 0.05$ = non-significant.

Table (4): Comparison of the mean inner ramus distance (IRD) of both groups.

IRD	Group (1)	Group (2)	t-test	P value
1 week	85.09 $\pm$ 0.818	85.23 $\pm$ 0.865	0.0235	0.674
3 months	84.63 $\pm$ 0.966	84.84 $\pm$ 0.729	0.03192	0.624

Table (5): Comparison of postoperative outcome of the patients of groups (1 & 2) during the follow-up period.

Postoperative fracture stability	Group (1)		Group (2)		Significance	
	No.	%	No.	%	χ^2	P value
1 st day postoperatively	4	50.0	4	50.0	0.00	1.000
1 st week	5	62.5	5	62.5	0.00	1.000
1 st month	6	75.0	8	87.5	0.495	0.059
3 months	8	100	8	100	0.00	1.000
Adequate mouth opening						
1 st day postoperatively	0	0.0	0	0.0	0.00	1.000
1 st week	5	62.5	4	50.0	0.022	0.931
1 st month	8	100	7	87.5	0.027	0.0902
3 months	8	100	8	100	0.00	1.000
Infection						
1 st day postoperatively	0	0.00	0	0.00	0.00	1.000
1 st week	2	25.0	0	0.00	3.02	0.044*
1 st month	1	12.5	1	12.5	0.00	1.000
3 months	0	0.00	0	0.00	0.00	1.000

$P > 0.05$ = non-significant.