EGYPTIAN
DENTAL JOURNAL

Vol. 64, 3179:3193, October, 2018

I.S.S.N 0070-9484

Oral Surgery

www.eda-egypt.org • Codex : 140/1810

MANAGEMENT OF ANTERIOR MANDIBULAR FRACTURES USING FOUR FIXATION METHODS: A CLINICAL COMPARATIVE STUDY

Fatma Ibrahim Mohamed *

ABSTRACT

Purpose: To compare the surgical outcomes of three-dimensional (3D) mini-plates for fixation of anterior mandibular fractures (AMFs) and those of bone plates and lag screws.

Materials and methods: Patients with AMFs, who met the inclusion criteria, were equally distributed into 4 groups. Those in Group I were treated with double 2.0 mm mini-plates, patients in Group II were treated with double lag screws, 2.3mm locking plates were used in group III, while in Group IV 2.0 mm 3D mini-plates were used. Prior to the surgical intervention, MMF was performed to verify the centric occlusion in all patients. After hardware fixation, the MMF was intraoperatively released, and the adequacy of fixation and occlusion was verified. The operation time and postoperative outcomes were also analyzed.

Results: Sixty patients (41 males and 19 females) were included in this prospective study. There were no significant differences in demographic data. The clinical examination showed stable fixation with no mobility in all cases. None of the patients in the 3D mini-plates group showed clinical manifestations of infection or dehiscence. The incidence of malocclusion was the highest in the mini-plates group. There was no statistically significant difference among the groups in all parameters, except for infection and paresthesia. They were significantly greater in double mini-plates and 2.3 mm locking plate groups respectively.

Conclusion: The use of 3D mini-plates is a viable option for fixation of AMFs. It has advantages of both lag screws and bone plates. A 3D mini-plate provided sufficient inter-fragmentary stability with a relatively low rate of complications when compared with other conventional fixation techniques.

KEY WORDS: Three-dimensional plates, Anterior mandibular fractures

* Associate Professor of Oral and Maxillofacial Surgery, Faculty of Dental Medicine for Girls, Al Azhar University.

INTRODUCTION

Anterior mandibular fractures (AMFs) are defined as fractures that occur in the region between the lateral incisor and the second premolar (parasymphyseal region), or fractures that occur in the region between the lateral incisors (symphyseal region).[1] Although there is a wide variance in the recorded percentage of mandibular fractures that occur in the anterior region, the aggregate analysis places them at approximately 17% of all mandibular fractures.[2,3] Various types of plating systems have been evolved during the past decades to provide a stable anatomic reduction for AMFs, so the risk of the postoperative displacement of the fractured segments could be reduced and the early return to normal function is allowed. [4]

One of the most practical fixation methods for AMFs is 2.0mm Mini-plate system. It was first introduced by Michelet[5], and then there was a further development by Champy et al.[6] Since then, this system has become the standard method for surgical treatment of mandibular fractures.[7,8] In 1978, Champy et al[7] advised the use of double mini-plates in the anterior region of the mandible. They had advocated the placement of one mini-plate at the inferior border of the symphysis and another plate is placed 5 mm above the first one. This is to counteract the effect of torsional forces on the anterior mandible that developed during the static biting and chewing. For the same reason, double lag screws have been used for the treatment of AMFs.[9]

The philosophies related to the treatment of mandibular fractures have been altered all over the time, therefore a periodic review of the different fixation systems is necessary to refine techniques and eliminate the unnecessary one to provide an optimum treatment. The three-dimensional (3D) titanium plating systems are relatively new devices, and they were introduced by Farmand and Dupoirieux[10,11] for maxillofacial fractures treatment. The use of 3D plates has been considered one of the fixation methods that challenge Champy's technique for mandibular fractures fixations.[12-14] The 3D mini-plates are considered as 2-plates which are joined together by inter connecting cross-struts, providing a 3D stability.[15]

The ideal fixation method for AMFs is still being debated. Many fixation methods have been mentioned in the literature. The choice between the different hardware for the fixation of AMFs is still challenging. Therefore, this prospective cohort comparative study was done to answer the following questions: 1) Does the 3D plating system provide advantages over the most commonly used hardware? 2) Is there a significant difference in the clinical outcomes of 3D mini-plates and those of double 2.0 mm mini-plates, double lag screws, and 2.3 mm locking plates for the treatment of AMFs? The authors hypothesized that the 3D mini-plates are more able to resist the torsional forces in the anterior mandible than other alternative devices. They also minimize the operation's time, so they provide better surgical and clinical outcomes for patients who have AMFs. Thereby, the aim of this study was to evaluate the use of 3D mini-plates for fixation of AMFs and compare their surgical and clinical outcomes with those of the double 2.0 mm mini-plates, double lag screws, and 2.3 mm locking plates.

PATIENTS AND METHOD

Study design and population

To address the purpose of the study, the investigators designed and achieved a prospective cohort clinical comparative study. Sixty patients (41 males and 19 females) with AMFs were selected and presented at the Department of Oral and Maxillofacial Surgery, Faculty of Dental Medicine Girls branch, Al Azhar University. The study was implemented from January 2011 to September 2017. Informed written consent was taken prior to surgery from all the patients. The local ethics review committee of the Faculty of Dental Medicine for Girls, Al Azhar University, had approved the study.

The inclusion criteria of the study were as follow: 1) AMFs, (either symphyseal or unilateral and bilateral para symphyseal fractures), that were indicated for open reduction and internal rigid fixation, 2) the patient's age is elder than 16 years, 3) the time interval between the trauma and surgical intervention is less than 4 weeks, and 4) the patients have to attend a regular follow-up for 6 months. The patients were excluded from the study if they had one of the following conditions: 1) mandibular pathological fractures, 2) a preoperative infection at the fracture sites, 3) an insufficient dentition to reproduce occlusion, 4) medical conditions that could interfere with the healing process such as nutritional deficiency, diabetes, chemotherapy, radiotherapy... etc., 5) Conditions which are eligible for prevented general anesthesia. Additionally, the patients were excluded if they had concomitant condylar fractures.

Study variables

The patients were divided into four groups. The AMFs, in Group I (12 males and 3 females), were fixed by using double 2.0 mm mini-plates and screws. In Group II (10 males and 5 females), the fractures were fixed by using double lag screws. In group III (9 males and 6 females), a 2.3mm locking plate at the inferior border of the mandible and one standard mini-plate at the tension zone were applied to fix the AMFs. Whereas, in group IV (10 males and 5 females), all AMFs were fixed by employing 3D mini-plates and screws. The choice of the hardware was based on surgeon preference.

The primary outcome variables were the rates of individual and total complications, as infection, wound dehiscence, malocclusion, hardware exposure, mal-union, non-union, paresthesia, and tooth root injury. The additional outcome variables, that could affect the study results, were also analyzed such as patients' demographic variables and surgical variables. The patients' variables included demographic data (age, gender, and cause of the trauma), the time interval between the day of trauma and surgery, and the maximum mouth opening (MMO). The surgical variables were as follow; the fracture site (symphyseal or parasymphyseal), the displacement degree of fractured segments, and the duration of the operative time. Additionally, the postoperative variables included the fractures' healing, the mobility of the fractured fragments, the need for postoperative maxilla and mandibular fixation (MMF), MMO, the accuracy of reduction, and occlusal stability.

Surgical procedures

Prior to the surgical intervention, MMF was performed to verify the centric occlusion in all patients. Under general anesthesia, the fractured sites were exposed through vestibular incisions. The bone reduction clamps were used to achieve anatomical reduction. The time taken from the adaptation of the fixation systems to the time of the last screw placement was measured in minutes. For each patient in Group I, double 2.0 mm mini-plates (Leibinger Stryker, Freiburg, Germany) were adapted on the fracture sites; the lower plate was secured via bicortical screws at the inferior border and the superior plate was fixed and secured by using monocortical screws 5 mm underneath the roots of the teeth (Figure 1).

In group II, 2 self-tapping titanium lag screws (2.0 mm outer thread diameter and 28- 40 mm long, Synthesis Maxillofacial GmbH, Switzerland) were used. A drill with a diameter of 1.5mm was inserted buccally, approximately 1 cm away from the fracture line, to provide an adequate amount of bone between the head of the screw and the fracture line after drilling and countersinking. The drill was perpendicularly crossed the fracture line to prepare the traction hole in the distal segment and the gliding hole in the proximal segment. The countersinking was then made to accommodate the screw head in the proximal segment. The lag screw of appropriate length was placed in the drill hole, and then it was screwed into its place to compress the segments together. The first screw was placed several millimeters above the inferior border of the mandible, and the other was placed approximately 5 mm below the tooth apices (Figure 2).

In group III, the technique for application of the 2.3 mm locking plates at the inferior border did not differ from that of any other non-compression type of plate fixation. The only difference was that the drill guide was used to ensure the perpendicular nature of the drill hole with the plate, thereby allowing the screws to be precisely locked into the threads of the plate holes. Another 2.0 mm mini-plate was also fixed and secured via monocortical screws, 5 mm above the locking plate as a tension band (Figures 3). In Group IV, a single 3D mini-plate was used (2mm x 6 or 2mm x 8 holes). The selection was done according to the extent and severity of the fracture. It was adapted to the bone in such a way that the horizontal bars were perpendicular to the fracture line and vertical bars (cross struts) were parallel to it. Diagonally opposite screws were placed first, followed by the remaining screws (Figure 4). Concomitant fractures were fixed by the same hardware which used to fix the AMFs. The MMF was intraoperatively released, and the adequacy of fixation and occlusion was also verified.

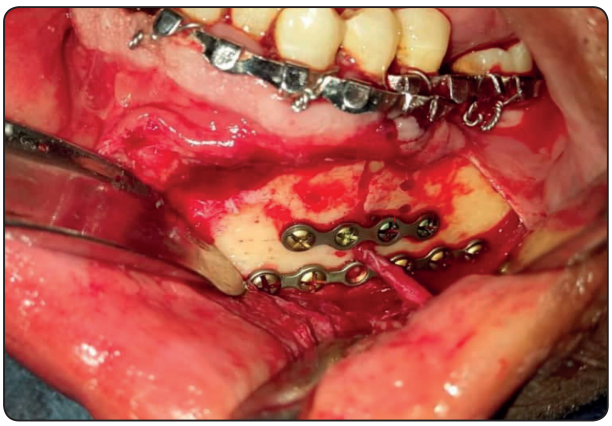

Fig. (1) Intra-operative photograph showing fixation of the left parasymphyseal fracture with double min-plates (Group I)

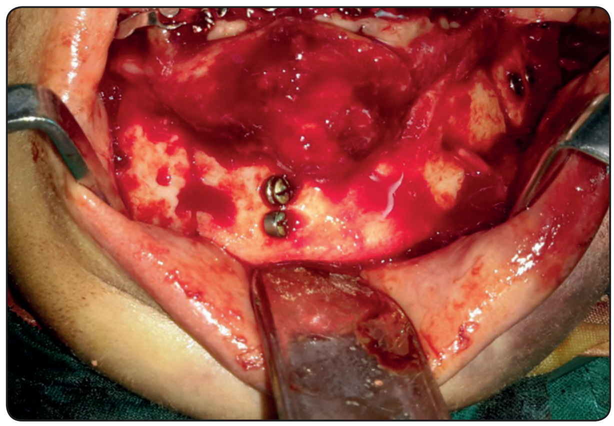

Fig. (2) Intraoperative photograph showing 2 lag screws inserted across the right parasymphyseal fracture. A "washer" was used to provide a larger diameter of its head to overcome the over countersinking (Group II).

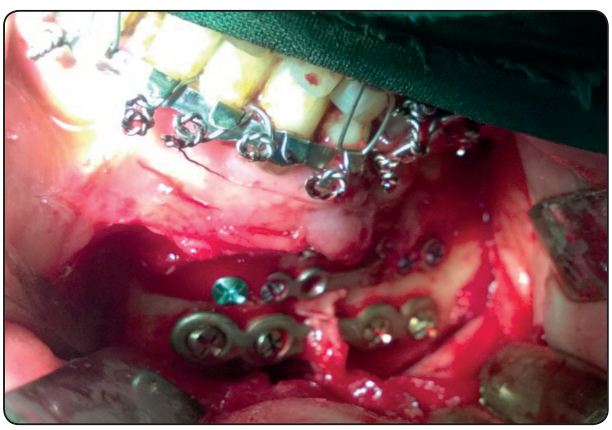

Fig. (3) Intraoperative photograph showing the fixation of the left parasymphyseal fracture via 2.3 mm locking plate at the inferior border of the mandible and 2.0mm mini-plate at the superior border (Group III).

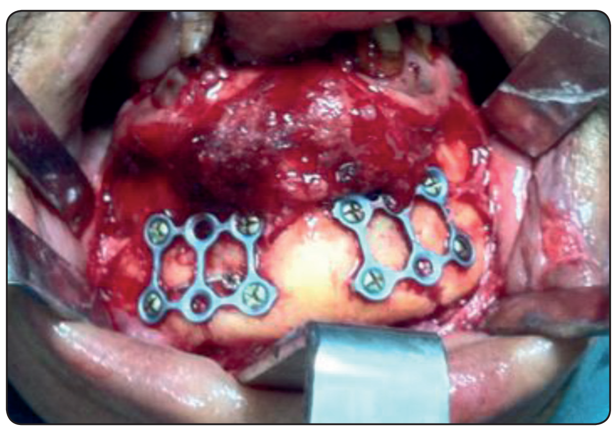

Fig. (4) Intraoperative photographs showing the application of 3D mini-plates to fix bilateral parasymphyseal fractures(Group IV).

Postoperative follow-up

All the patients were evaluated every other day for the first week, and then each subsequent week for the first month and at 3 and 6 months postoperatively for certain clinical and radiographic parameters. The intra-operative and postoperative assessment was performed as follow: a) First: the stability of the occlusion was evaluated according to a scale ranged from 0 to 2, b) Second: the mobility of the fracture fragments was checked by a single operator via digital palpation using thumb and index fingers of both surgeon's hands, c) Third: the need for postoperative MMF with guidance elastics for 1 to 4 weeks, indicated if there was postoperative occlusal discrepancy, d) Forth: MMO was measured in millimeters by using a Vernier caliper. The occlusion status was evaluated by the surgeon and an orthodontist, and e) Lastly: the postoperative complications that including the presence of wound dehiscence, wound infection, plates' exposure, paresthesia, and injury of teeth roots.

The scale "2" occlusion indicates a stable occlusion with no premature contacts or crossbite. The scale "1" occlusion indicates a mild derangement in which premature contact or crossbite could be corrected by guiding elastics or spot grinding, and the scale "0" denotes a severe derangement that needs a revision surgery. To evaluate the fractures' mobility, each fracture site was categorized into: i) a stable fracture in which there was no movement of fragments and ii) an unstable fracture where the movement of segments was present. The postoperative MMO were recorded at the first week, and then at the first, third, and sixth month postoperatively. The MMO was recognized as trismus if it was less than 35 mm. Furthermore, the postoperative radiographs were also taken within the first 2 days to verify the reduction of the fractures and plates' position.

Statistical analysis

The data collected were recorded, tabulated, and analyzed statistically. The data were analyzed with Microsoft Office XP (Excel) and SPSS version 15.00 software (SPSS Inc., Chicago, IL, USA). Parametric data were expressed as the mean ± standard deviation (SD), and non-parametric data were expressed as the number and percentage of the total. Chi-Square test was used to determine the relation between the treatment methods and the outcome results to speculate the differences between the fixation systems. This analysis was also used to investigate whether the outcome was dependent on the treatment method. The results were considered statistically significant if the p-value is≤ 0.05.

RESULTS

Sixty patients, who met the study's inclusion criteria, were included. They were equally distributed to the study's groups. The analysis of the patients' demographic data was summarized in Table 1. Out of the 60 patients, 41(68.3%) subjects were males and 19 (31.7%) cases were females with a mean of 29.6±11.25 years (ranged between 17 and 54 years). Most of the patients fell in the age group of 17–29 years (n=40 patients, 66.7%). The primary cause of the fractures was interpersonal violence 65% (n = 39 subjects), and the most of them were being in 17–29 age group (n= 29 out of 39 cases, 74.4%). While the secondary cause was motor vehicle accidents (MVAs) 21.7% (n = 13 patients), and this was more observed in 17–22 age group (n= 8 out of 13 subjects, 61.5%). In 7 patients, their fractures were because of accidental falls (11.7%) which were more common in 38-54 age group (n= 5 patients out of 7, 71.4%). Sports activities caused a fracture in 1 case (1.7%). Based on the statistical evaluation, there were no statistically significant differences among the study's groups for any of the demographic variables.

The total number of symphyseal and parasymphyseal fractures in the study's groups was 65 fractures. The group I included 16 fracture sites, 15 fracture sites were included in the group II, and 17 fracture sites were enrolled in the group III and group IV for each. Thirty patients (50%) had associated mandibular fractures (either angle or body fractures). The average time from the day of trauma to the surgical management was 3.5±3.73 days (ranged from 1 day to 21 days). Most of the cases (68.3%) were managed within 1 to 3 days after trauma. The preoperative MMO was restricted in 35 cases (58.3%).With respect to the intraoperative occlusion, the difference among groups was found to be statistically insignificant (Table 2). Additionally, there was no significant statistical difference among groups regarding the degree of the preoperative segments displacement.

TABLE (1) Descriptive statistics of study population

Study variables	Group I	Group II	Group III	Group IV
Gender				
Male/Female	12/3	10/5	9/6	10/5
Age	28.9± 11.47	30.6± 11.42	29.1±11.93	29.9±11.26
Etiology				
Violence	9 (60)	10 (66.7)	13 (86.7)	7 (46.7)
MVA	4 (26.7)	3 (20)	2 (13.3)	4 (26.7)
Falls	2 (13.3)	2 (13.3)	-	3 (20)
Sports	-	-	-	1 (6.7)
Fracture site				
Left parasymphyseal	9 (60)	10 (66.7)	8 (53.3)	9 (60)
Right parasymphyseal	4 (26. 6)	2 (13.3)	4 (26.7)	3 (20)
Bilateral parasymphyseal	1 (6.7)	---	2 (13.3)	2 (13.3)
Symphyseal	1 (6.7)	3 (20)	1 (6.7)	1 (6.7)
Associated injuries				
Body/angle fracture	2/4	3/2	2/2	2/3

Data presented as mean ± SD or numbers, with percentages in parentheses.

****: All p-values were less than 0.05***

TABLE (2) Comparison between the four groups with respect to intraoperative and postoperative occlusion stability during the follow-up period

	Intraoperative			First day		1st week		1 month	3 months	6 months
	Satisfactory	Mild deranged	Severely deranged	Satisfactory	Mild deranged	Satisfactory	Mild deranged	Satisfactory	Satisfactory	Satisfactory
Group I	3(20)	7 (46.7)	5 (33.3)	10 (66.7)	5 (33.3)	12 (80)	3 (20)	15 (10)	15 (100)	15 (100)
Group II	0 (0)	5 (33.3)	10 (66.7)	12 (80)	3 (20)	13(86.7)	2 (13.3)	15 (100)	15 (100)	15 (100)
Group III	1 (6.7)	8 (53.3)	6 (40)	13 (86.7)	2 (13.3)	15(100)	0(0)	15 (100)	15 (100)	15 (100)
Group IV	0 (0)	6 (40)	9 (60)	13 (86.7)	2 (13.3)	15(100)	0(0)	15 (100)	15 (100)	15 (100)
Total	4 (6.7)	26 (43.3)	30 (50)	48 (80)	12 (20)	55 (91.7)	5 (8.3)	60 (100)	60 (100)	60 (100)
p-value	0.093	0.716	0.143	0.475	0.475	0.117	0.117	-	-	-

Data presented as numbers, with percentages in parentheses (p-value ≤ 0.05 is considered significant).

The results also revealed that there were no intra-operative difficulties in all patients except 3. Those patients belonged to group II, where there was an insufficient stability of the fracture segments due to either the over countersinking of the near cortex or accidentally over drilling of the far cortex. This was managed by preparing another lag screw hole, applying a washer under the head of the screw, or using a larger one with a diameter of 2.4 mm. Additionally, the mental nerve was impaled in one patient of the same group during the drilling of the holes. On the other hand, no obvious damage to the mental nerve occurred during the fixation of the bone plates in all patients who were included in groups I, III, and IV.

The average operating time for the adaptation and placement of each fixation system at the AMFs region, was 10 to 22 minutes with a mean time of 16.3±4.39 minutes in the group I. In the group II, it was ranged from 5 to 11 minutes with an average of 6.9±2.12 minutes. In the group III, the locking plates required 5 to 15 minutes; the mean time was 11.6±3.41minutes. While that of the group IV, it was 6 to 11 minutes with a mean of 8.9±1.77 minutes. Statistical analysis using Chi-Square tests showed a significant difference of working time between the four groups (*p*-value = 0.0001).

Regarding the postoperative results, all the patients had a mild edema immediately postoperatively. The edema had started to resolve by the third postoperative day, and it completely resolved by the end of the first postoperative week. The intraoral wounds healed at the end of the first postoperative week, except in 7 cases where the wound infection was developed on the fourth day postoperatively. This was associated with dehiscence of the incisions in 4 cases in the group I, 1 patient in the group II, and 2 cases in the group III. The exposure of the hardware through the dehisced wound was noticed in 2 out of the 4 cases in the group I and in only 1 patient in the group III. Additionally, signs of infection were observed in another patient of group I after 1 month postoperatively, but without the occurrence of wound dehiscence. The difference among groups regarding the infection was found to be statistically significant (*p*-value = 0.044), while the difference was found to be statistically insignificant regarding the wound dehiscence and plate exposure (*p*-value=0.129 and 0.277, respectively) as shown in Table 3. The infections were successfully treated with antibiotics and routine wound care. The wound granulated and the dehiscence secondarily healed without further events. All the hardware did not require surgical removal. None of the patients, in

TABLE (3) Outcome analysis for all postoperative complications

	Bone union	Infection	Dehiscence	Plate exposure	Malocclusion		Paresthesia	Root injury
					First day	1 week		
Group I	10(66.7)	5 (33.3)	4 (26.7)	2 (13.3)	5(33.3)	3 (20)	4 (26.7)	2(13.3)
Group II	6 (40)	1 (6.7)	1 (6.7)	0 (0)	3 (20)	2(13.3)	1 (6.7)	2(13.3)
Group III	11(73.3)	2 (13.3)	2 (13.3)	1 (6.7)	2(13.3)	0 (0)	7 (46.7)	0 (0)
Group IV	8(53.3)	0 (0)	0 (0)	0 (0)	2(13.3)	0 (0)	2 (13.3)	1 (6.7)
Total	35(58.3)	8 (13.3)	7 (11.7)	3 (5)	12 (20)	5 (8.3)	14 (23.3)	5 (8.3)
p-value	0.257	0.044	0.129	0.277	0.475	0.117	0.050	0.494

Data presented as numbers, with percentages in parentheses (p-value ≤ 0.05 is considered significant).

the group IV, showed clinical manifestations of wound infection or dehiscence at the surgical site all over the follow-up.

The most common complication, which had encountered in the study, was the minor occlusal discrepancy during the early postoperative period. On the first postoperative day, 5 patients (33.3%) in the group I, 3 patients (20%) in the group II, 2 patients (13.3%) in the group III, and 2 patients (13.3%) in the group IV showed a mildly deranged occlusion. Nevertheless, this was not statistically significant. At the end of the first postoperative week, 3 patients (20%) in the group I and 2 patients (13.3%) in the group II had mildly deranged occlusion which was not also statistically significant. The value of the Chi-Square test showed that the development of the malocclusion was independent on the treatment method (Table 2 and 3). Deranged occlusion was successfully managed by using postoperative guiding elastics for 1 to 2 weeks. None of the patients needed a revision surgery.

Four patients, in the group I, presented with an immediate postoperative paresthesia of the lower lip, and it was also reported in 1 patient in the group II, 7 patients in the group III, and 2 patients in the group IV. The paresthesia completely resolved by the end of the third month, except in 1 case of the group II where it persisted until the end of the follow up as a result of iatrogenic nerve injury during surgery. The immediate postoperative paresthesia was compared between the 4 groups by using the Chi-Square test, the difference was found to be statistically significant (*p*-value = 0.050), suggesting that the incidence of paresthesia was dependent on the treatment method. The roots injuries occurred in 3 patients in the group I, 2 subjects in the group II, and 2 cases in the group IV without statistical significance (Table 3). Regarding the MMO, it returned to its normal value (45 to 55 mm) by the end of the first month in all the study's groups.

The bimanual examination of the fracture segments revealed that none of the patients showed fracture mobility postoperatively; all the fractures appeared to be well reduced and stable which were confirmed via radiographs. Ten patients (66.7%) in the group I, 6 patients (40%) in the group II, 11 patients (73.7%) in the group III, and 8 patients in the group IV (53.3%) showed the evidence of the bone union after the third month postoperatively with no statistical significance among the study's groups (*p*-value = 0.257). The gradual bone healing and disappearance of the fracture line was noted in all the patients at the end of the sixth month. Additionally, no fracture or displacement of the inserted hardware occurred during the entire postoperative period in all groups.

The patients' variables that could affect the primary outcome variable (postoperative complications) were also analyzed and tabulated by using Pearson Chi-Square test. It was observed that the rate of complications was higher in male than female, but the difference was statistically insignificant. There was also an insignificant difference between the cause of fractures, and the presence of concomitant fractures and the postoperative outcomes between the 4 groups (Table 4). The relation between patients' age and the postoperative outcome was also studied. It was observed that the bone union was superior with a highly significant difference (in younger patients than the older one (r=-0.64, *p*-value=0.0001). The infection (r=0.272, *p*-value= 0.035) and dehiscence (r=0.287· *p*-value=0.026) were observed more in elder patients (*p*-value≤0.05), while immediate postoperative malocclusion was observed in younger patients (r=0.382, *p*-value=0.003). Additionally, there was a significant relationship between the duration of the operative procedures and the occurrence of wound infection (r=0.313, *p*-value=0.015) and plate exposure (r=0.35, *p*-value=0.006).

TABLE (4) The relation between the patients' variables and the primary outcome variables (postoperative complications)

	Bone union	Infection	Dehiscence	Plate exposure	Malocclusion		Paresthesia	Root injury
					First day	1 week		
Gender								
Male	25(61.6)	6 (14.6)	6 (14.6)	2 (4.9)	8 (19.5)	5(12.2)	11 (26.8)	5 (12.2)
Female	10(52.6)	2 (10.5)	1 (5.3)	1 (5.3)	4 (21.1)	0 (0)	3 (15.8)	0 (0)
p-value	0.542	0.663	0.293	0.949	0.890	0.112	0.347	0.112
Cause of trauma								
MVA	24(61.5)	4 (10.3)	4 (10.3)	1 (2.6)	6 (15.4)	4(10.3)	8 (20.5)	4 (10.3)
Violence	8(61.5)	3 (23.1)	2 (15.4)	1 (7.7)	3(23.1)	0 (0)	4 (30.8)	0 (0)
Sport	4 (100)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (100)	0 (0)
Fall	2 (28.6)	1 (14.3)	1 (14.3)	1 (14.3)	3 (42.9)	1(14.3)	1 (14.3)	1 (14.3)
p-value	0.323	0.671	0.934	0.571	0.372	0.618	0.243	0.618
Associated fractures								
AMFs	23(57.5)	5 (12.5)	4 (10)	1 (2.5)	7 (17.5)	5(12.5)	10 (25)	4 (10)
Body/angle fractures	12 (60)	3 (15)	3 (15)	2 (10)	5 (25)	0 (0)	4 (20)	1 (5)
p-value	0.853	0.788	0.570	0.209	0.494	0.099	0.666	0.509

Data presented as numbers, with percentages in parentheses(p-value ≤ 0.05 is considered significant).

DISCUSSION

Many studies reported that the torsional forces on the anterior part of the mandible are considerable, and their magnitude increased as they come closer to the symphyseal area.[16-18] For this reason, the biomechanics of the anterior mandible required the use of more rigid internal fixation to resist these torsional forces.[19,20] In this study, the parasymphyseal fractures were categorized if the fractures located in the region between the mandibular lateral incisor and the second premolar. This was also reported by many authors[1], but it does not coincide with an old study[21], which suggested that the parasymphyseal fractures are those fractures which involve a region that is bilaterally bounded by vertical lines just distal to the canines.

The results of our study revealed that the age of the patients ranged from 17 to 54 years with a mean age of 29.6 ±11.25years, the highest incidence was noted in the age group of 17-29 years (66.7%). These results are in agreement with the results of many studies,which reported that the second and third decades of the personal life showed the highest incidence of the mandibular fractures.[4,22] A male predominance (68.3%) was also noticed as reported in the literature.[4,22-24] The causes of fractures were extremely variable, the interpersonal violence accounted for the majority of the patients (65%); this finding is in agreement with many studies.[25,26] On the other hand, many authors showed that the main cause of AMFs was RTA.[4,22,27] These differences may be due to the socioeconomic status of the population involved, the unemployment rates, and usage of motor vehicles.

The majority of the study's patients (68.3%) received treatment within 1 to 3 days after injury.

The authors preferred early interventions to avoid complications that may be developed due to delayed intervention. This was proved by Herzberg[28] who noticed a higher rate of complications when the interval between trauma and surgical treatment is delayed for more than 6 days. The rest of the study's cases were treated within 21 days, primarily owing to delays in hospitalization. Even though, there were no signs of infection were observed in those patients. This may be due to the durable blood supply of the head and neck, so the bacterial load is minimized even with delayed intervention and the vascularity of the fracture segments remains adequate to prevent infection. This is in agreement with other reports.[29,30] Additionally, when correlating the postoperative complications with this variable, the delayed treatment had no effect on the wound healing and other postoperative complications. This observation is in agreement with many studies.[31-33]

With respect to the operating time, there were significantly shorter operative times with lag screws and 3D mini-plates in comparison to the placement of 2 mini-plates and locking plates. The lag screws required the least operative time with a significant statistical difference (p-value = 0.0001). This could be attributed to the fact that lag screw fixation does not require the time-consuming task of plates' bending to adapt them on the surface of the bone. Similar results have been described previously by many authors.[34,35] It is not surprising that the placement of the 3D mini-plate required shorter operative time than that of 2 mini-plates and locking plates. This is because the 3D mini-plate required minimal manipulation and adaptation, where it is considered as only one plate instead of 2; they also have a low profile that makes their manipulation simple and easy. The same results are demonstrated by Al-Moraissi and Ellis.[14] In group III, the exact plate adaptation is no longer necessary for locking plate which should shorten the operation time as reported by many authors,[36-40] but the needed time to fix the tension zone mini-plate increased its operating time. Nevertheless, it is still shorter than that of the double mini-plates system. This is also agreed with the results of previous studies.[37,41]

The intra-operative complications were only encountered in the group III, where there was an insufficient stability of the fractures in 3 cases due to over-countersinking of the buccal cortex or over-drilling of the distal cortex. This was also reported by other studies.[9,20,42] Regarding the postoperative complications, the patients were assessed for the presence or absence of postoperative infection, wound dehiscence, and malocclusion. The wound dehiscence usually appeared within 6 to 10 days after surgery as reported by Ellis.[19] This was also observed in this study. The wound dehiscence may be caused due to many factors such as the preoperative soft tissue loss, poor closure during surgery, infection, smoking, trauma……etc. Infections and wound dehiscence were observed in 4 cases in group I at the first postoperative week; the signs of infection were observed in another case in the same group at the first postoperative month but without wound dehiscence. Despite that, the incidence of infection was low and similar to other literature.[17,43-45] In group II, infection and wound dehiscence were observed in 1 patient at the first postoperative week, as also reported by others [9] who observed 2 patients with infection when treating AMFs by using 2 lag screws. In group III, 2 cases (13.3%) of infection and wound dehiscence were reported. This is in accordance with the findings of Ellis and Graham[37] who treated 80 fractures in 59 patients with 102 locking plate systems and reported 6 cases developed infections. Additionally, Sauerbier[41] used locking plates and reported wound dehiscence in 7.5% of his patients.

The second group had a significantly lower incidence of infection than that of the group I and III ($p \leq 0.05$). This may be due to bone plates are often placed just under the soft tissue incision on the buccal cortex, but the lag screws are internally inserted inside the bone. This also was supported by another research.[19] None of the patients, in group IV, showed the clinical manifestations of infection or dehiscence at the surgical site throughout the follow-up period. These results are in agreement with Mittal and Dubbudu results.[13] On the other hand, Jain et al[12] and Meram et al[46] observed, in their studies, the presence of postoperative infection without soft tissue dehiscence in 2 patients. Additionally, 6.6% of wound dehiscence was reported by Parmar et al.[47] All these studies including ours proved that when using the 3D mini-plating system, wound dehiscence and infection are usually less or nil as compared to other plating systems. The decreased infection rate with 3D mini-plates could be attributed to its low profile which means less hardware and to the decreased operative time because of its malleability and simultaneous application of the upper and lower struts.[4] There was a correlation between the patient's age, infection, and dehiscence. These complications were significantly observed more in elder patients (p-value≤0.05). This may be due to decreased vascularity of the tissues, collagen production, and oxygen delivery to the tissues by aging. Odom and Synder-Warwick[30] supported this finding.

The results also revealed that no statistically significant difference among the groups, regarding the postoperative malocclusion on the first postoperative day and at the end of the first postoperative week (p-value = 0.475 and 0.117, respectively). The immediate postoperative malocclusion was observed in younger patients. Its incidence was the highest in the group I as reported by others.[31,43] In group II, the malocclusion may result from the inability to place the second lag screw exactly perpendicular to the fracture line, and this could lead to a minor overriding between the segments. This explanation was also reported by another study.[18] Additionally, when over countersinking occurred, the small head of the 2.0 mm lag screw cannot grip the buccal cortex and then advanced into the medullary bone. This causes a loss of segments stability that produces postoperative malocclusion. In the Locking system, the threads on the screw head lock into the threads in the holes of the plate. This is transforming the screws and plate into a single unit, creating a rigid splint with higher mechanical stability allowing the fracture segments to stay in the reduced position when tightening the screw seven if the plate is not precisely adapted. For this reason, the incidence of malocclusion in group III was low. Many authors supported our findings regarding this variable.[39,40,41,48]

Another possible explanation for the postoperative malocclusion is the presence of concomitant fractures at the contralateral side. This may contribute to the instability of the segments, leading to impaired bone healing and malocclusion, suggesting that there could be several factors contributing towards the development of complications rather than just the biomechanical consideration. In spite of that, the Pearson Chi-square test showed that the associated fractures had no significant effect on the treatment outcomes.

The iatrogenic damage to the tooth roots and the mental nerves are possible if the care is not taken during the application of the fixation hardware. The study' results revealed that these complications are less likely with plating techniques because the roots of the teeth are often visible by the undulations of the alveolar bone which surrounding them, so the plates are positioned apical to the roots to avoid their injuries. Similarly, the mental nerve is clearly visible as it exits from the mental foramen and could be avoided. These findings also reported by Ellis.[19] There was a statistically significant difference regarding the incidence of paresthesia (p-value =0.050); the highest incidence occurred with the locking plate in the group III. The main reason for postoperative paresthesia (7 cases) was the need of more tissue retraction to accommodate the drill guide and subsequent placement of perpendicular screws, Saikrishnaetal[49] supported this explanation.

In group IV, 2 cases of postoperative numbness and 1 patient with root injury were reported. The root injury may be occurred due to the improper size of 3D mini-plate and insufficient vertical height of the anterior mandible in this case. Patients with paresthesia in this group had fracture lines too close to the mental foramen. This may explain why this complication was encountered. Despite that, the postoperative paresthesia was transient in all groups and showed full recovery at the end of the follow-up period, except in 1 case of lag screw group which showed a permanent paresthesia in the chin region. The resolution of paresthesia could be explained by the absence of the actual nerve injury and maybe only due to the presence of edema around the nerve, because of the tissue dissection and prolonged tissue retraction. But in the case of permanent paresthesia with lag screws, there was an iatrogenic nerve injury. This is because the lag screw is a blind and sensitive technique that needs great experience as reported in another study.[50]

It was reported that the lag screws provide the greatest fracture stability among all fixation devices as reported by another study.[51] The results of our study showed that the 3D mini-plates also provide great stability for AMFs as much as that is provided with lag screws, which reduces the risk of the postoperative complications. This is because the 3D mini-plates are able to hold the fracture fragments rigidly by resisting the forces in three dimensions. Many authors found that they can resist the shearing, bending, and torsional forces.[11,52] Also, the quadrangle geometry of the 3D mini-plates assures a 3D stability of the fracture sites. Thus, they prevent the bucco-lingual splaying and gap formation at the fracture site that results in a subsequent occlusal discrepancy. Furthermore, the achieved stability is gained by its configuration, not by its thickness or length like other types of plates. Therefore, they have no harmful impact on the covering soft tissues minimizing the risk of wound dehiscence. This is supported by a previous study.[53] Additional advantages of 3D mini-plates include easy application, simple adaptation to the bone without distortion as well as simultaneous stabilization of the tension and compression zones by using one plate. All these advantages make the 3D mini-plates a time-saving alternative to conventional plates, and they also have advantages of lag screws without the need for surgical experience. This is also in agreement with many findings.[11,54,55] On the other hand, a study reported some difficulties that limit their use such as the presence of mental protuberance and if the fracture line passes through the mental foramen, where the injury of the nerve cannot be avoided.[46]

The key findings of this study are that; the 3D mini-plates provide much better fixation to AMFs which is an area subjected to torsional forces with the increased magnitude at its midline. Also, they have the lowest profile among other types of bone plates and the shortest working time that minimize the risk of the postoperative complications. The clinical implement is that they could be used to rigidly fix the fractures, which need a great amount of rigidity like AMFs. Additionally, they are able to reduce the treatment cost by reducing the operation time and the risk of postoperative complications.

CONCLUSION

With regard to this study, it could be concluded that the use of 3 D mini-plates is a viable option for fixation of AMFs that have advantages of both lag screws and plating systems. A 3D mini-plate provided sufficient inter-fragmentary stability with a relatively low rate of complications when compared with other conventional fixation techniques. However, the results were considered statistically insignificant with respect to all evaluated parameters, except for wound infection and postoperative paresthesia. Double mini-plates pose the greatest risk of postoperative complications such as wound infection and dehiscence, exposure of the plate, and malocclusion.

REFERENCES

1. Schenkel JS, Jacobsen C, Rostetter C, Gratz KW, Rücker M, Gander T: Inferior alveolar nerve function after open reduction and internal fixation of mandibular fractures. J Cranio-Maxillofac Surg 44: 743-748, 2016.

2. Brown JS, Grew N, Taylor C, Millar BG: Intermaxillary fixation compared to miniplate osteosynthesis in the management of fractured mandible: An audit. Br J Oral Maxillofac Surg29:308-311, 1991.

3. Subhashraj K, Nandakumar N, Ravindran C: Review of maxillofacial injuries in Chennai, India: a study of 2748 cases. Br J Oral Maxillofac Surg 45:637–639; 2007.

4. Sehgal S, Ramanujam L, Prasad K, Krishnappa R: Three-dimensional v/s standard titanium miniplate fixation in the management of mandibular fractures - A randomized clinical study. J CranioMaxillofac Surg 42: 1292-1299; 2014.

5. Michelet FX, Deymes JB, and Dessus B:Osteosynthesis with miniaturized screwed plates in maxillofacial surgery. J Oral Maxillofac Surg 1: 79-84, 1973.

6. Champy M, Lodde JP, Jaeger JH, Wilk A: Mandibular osteosynthesis according to the Michelet technique. I. Biomechanical bases biomechaniques. Rev Stomatol77: 569-76, 1976. (in French, English abstract).

7. Champy M, Lodde JP, Schmitt R, Jaeger JH, and Muster D: Mandibular osteosynthesis by miniature screwed plates via a buccal approach. J Oral Maxillofac Surg 6: 14-21; 1978.

8. Shetty V, McBrearty D, Fourney M, Caputo AA: Fracture line stability as a function of the internal fixation system: an in vitro comparison using a mandibular angle fracture model. J Oral Maxillofac Surg53:791-801; 1995.

9. Ellis E, Ghali GE: Lag screw fixation of anterior mandibular fractures. J Oral Maxillofac Surg 49:13-21, 1991.

10. Farmand M, Dupoirieux L: Interet des plaques tri-dimensionnelles en chirurgiemaxiIlo-faciale. Rev Stomatol-ChirMaxillofac 93: 353-357, 1992.

11. Farmand M: Three-dimensional plate fixation of fractures and osteotomies. Facial Plast Surg Clin North Am 3:39-56, 1995.

12. Jain MK, Manjunath KS, Bhagwan BK, Shah DK: Comparison of 3-dimensional and standard miniplate fixation in the management of mandibular fractures. J Oral Maxillofac Surg 68: 1568-1572, 2010.

13. Mittal G, Dubbudu RR: Three dimensional titanium miniplates in oral and maxillofacial surgery: a prospective clinical trial. J Maxillofac Oral Surg 1: 152- 159; 2012.

14. Al-Moraissi EA, Ellis E: Surgical Management of Anterior Mandibular Fractures: A Systematic Review and Meta-Analysis. J Oral Maxillofac Surg 72:2507.e1-2507.e11, 2014.

15. 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 fractured randomized prospective study. J Craniomaxillofac Surg41: 103-109, 2013.

16. Khalifa ME, El-Hawary HE, Hussein MM: Titanium three dimensional miniplate versus conventional titanium miniplate in fixation of anterior mandibular fractures. Life Sci J 9:1006, 2012.

17. Madsen MJ, McDaniel CA, Haug RH: A biomechanical evaluation of plating techniques used for reconstructing mandibular symphysis/parasymphysis fractures. J Oral Maxillofac Surg 66: 2012-2019, 2008.

18. Emam HA, Stevens MR: Can an Arch Bar Replace a Second Lag Screw in Management of Anterior Mandibular Fractures? J Oral Maxillofac Surg 70: 378-383, 2012.

19. Ellis E: Is Lag Screw Fixation Superior to Plate Fixation to Treat Fractures of the Mandibular Symphysis? J Oral Maxillofac Surg 70: 875-882; 2012.

20. Oliver R: Lag screw fixation of mandibular symphysis fractures is associated with fewer postoperative complications compared to plates and screws. J Evid Based Dent Pract 13:20-21, 2013.

21. Dingman RO, Natvig P: Surgery of Facial Fractures. Philadelphia, PA, WB Saunders, 1964.

22. Bormann KH, Wild S, Gellrich NC, Kokemuller H, Stuhmer C, Schmelzeisen R, et al.: Five-year retrospective study of mandibular fractures in Freiburg, Germany: incidence, etiology, treatment, and complications. J Oral Maxillofac Surg 67: 1251-1255, 2009.

23. Sojat AJ, Meisami T, Sandor GK, Clokie CM: The epidemiology of mandibular fractures treated at the Toronto general hospital: A review of 246 cases. J Can Dent Assoc 67: 640- 644, 2001.

24. Ellis E: A study of 2 bone plating methods for fractures of the mandibular symphysis/body. J Oral Maxillofac Surg 69: 1978-1987, 2011.

25. Ogundare BA, Bonnick A, Bayley N: Pattern of mandibular fracture in urban major trauma centre. J Oral Maxillofac Surg 61:713-8; 2003.

26. Motamedi MH: An assessment of maxillofacial fractures. A 5- year study of 237 patients. J Oral Maxillofac Surg 61: 61-4, 2003.

27. van den Bergh B, Heymans MW, Duvekot F, Forouzanfar T: Treatment and complications of mandibular fractures: a 10-year analysis. J Craniomaxillofac Surg 40: e108-e111, 2012.

28. Herzberg D: Die Behandlung der Unterkieferfraktur mittels Miniplatten osteosynthese. Dissertation Thesis. Albert-Ludwigs- Unversitat, 2001.

29. Barker DA, Oo KK, Allak A, Park SS: Timing for repair of mandible fractures. Laryngoscope 121:1160–1163; 2011.

30. Odom EB, Snyder-Warwick AK: Mandible Fracture Complications and Infection: The Influence of Demographics and Modifiable Factors. Plast Reconstr Surg. 138:282e-9e; 2016.

31. Tuovinen V, Norholt SE, Pedersen SS, Jensen J: A retrospective analysis of 279 patients with isolated mandibular fractures treated with titanium miniplates. J Oral Maxillofac Surg 52: 931–935; 1994.

32. Zachariades N, Mezitis M, Papdemetriou I: Use of lag screws for the management of mandibular trauma. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 81: 164–167; 1996.

33. Koulocheris P, Sakkas N, Otten JE: Maxillomandibular fixation with Otten mini-hooks. Br J Oral Maxillofac Surg 45: 679-680, 2007.

34. Goyal M, Jhamb A, Chawla S, MaryaK, DuaJS, YadavS: A comparative evaluation of fixation techniques in anterior mandibular fractures using 2.0 mm monocortical titanium miniplates versus 2.4 mm cortical titanium lag screws. J Maxillofac Oral Surg 11: 442-450, 2012.

35. Agnihotri A, Prabhu S, Thomas S: A comparative analysis of the efficacy of cortical screws as lag screws and miniplates for internal fixation of mandibular symphyseal region fractures: A randomized prospective study. Int J Oral Maxillofac Surg 43: 22-28, 2014.

36. Gutwald R, Büscher P, Schramm A, Schmelzeisen R: Biomechanical stability of an internal mini-fixation-system in maxillofacial osteosynthesis. Med BiolEng Comp 37:280–281, 1999.

37. Ellis E, Graham J: Use of a 2.0-mm locking plate/screw system for mandibular fracture surgery. J Oral Maxillofac Surg 60: 642-645, 2002.

38. Gutwald R, Alpert B, Schmelzeisen R: Principle and stability of locking plates. Keio J Med 52: 21-24, 2003.

39. Gbara A, Heiland M, Schmelzle R, Blake F: Mechanical aspects of a multidirectional, angular stable osteosynthesis system and comparison with four conventional systems. J Cranio Maxillofac Surg 36: 152-156, 2008.

40. Gbara A, Heiland M, Schmelzle R, Blake F: Clinical implementation of a multidirectional, angular stable osteosynthesis system in maxillofacial traumatology. J Craniomaxillofac Surg 36: 157-160, 2008.

41. Sauerbier S, Kuenz J, Hauptmann S, Hoogendijk CF, Liebehenschel N, Schon R et al: Clinical aspects of a 2.0-mm locking plate system for mandibular fracture Surgery. J Cranio Maxillofac Surg 38: 501-5049, 2010.

42. Tiwana PS, Kushner GM, Alpert B: Lag screw fixation of anterior mandibular fractures: a retrospective analysis of intraoperative and postoperative complications. J Oral Maxillofac Surg 65:1180-1185, 2007.

43. Cawood JI: Small plate osteosynthesis of mandibular fractures. Br J Oral Surg 23: 77–91, 1985.

44. Nakamura S, Takenoshita Y, Oka M: Complication of miniplate osteosynthesis for mandibular fractures. J Oral Maxillofac Surg 52: 233-238; 1994.

45. Gabrielli MAC, MrFRGabrielli, Marcantonio E, Hochuli-Vieira E: Fixation of mandibular fractures with 2.0-mm miniplates: review of 191 cases. J Oral Maxillofac Surg 61: 430-437, 2003.

46. Meram AT, OlateS, Palmieri CF Jr: Is the Three-Dimensional Strut Plate an Adequate Fixation Technique for Mandibular Symphysis Fractures? J Oral Maxillofac Surg 76:140-145, 2018.

47. Parmar B, Menat S, Raghani M, Kapadia T: Three dimensional miniplate rigid fixation in fracture mandible. J Maxillofac Oral Surg 6: 2-3, 2007.

48. Kumar I, Singh V, Singh A, Arora V, Bajaj A: Comparative evaluation of 2.0-mm locking plate system vs. 2.0-mm nonlocking plate system for mandibular fractures—A retrospective study. Oral Maxillofac Surg 17:287–91, 2013.

49. Saikrishna D, Shetty SK, Marimallappa TR: A comparison between 2.0-mm standard and 2.0-mm locking miniplates

in the management of mandibular fractures. J Maxillofac Oral Surg 8:145–149, 2009.

50. El Sayed SA, Mohamed FI, Khalifa GA: Clinical outcomes of three different types of hardware for the treatment of mandibular angle fractures: a comparative retrospective study. Int J Oral Maxillofac Surg 44:1260-7, 2015.

51. Mittal G, Aggrawal A, Garg R, Sharma S, Rathi A, Sharma V: A clinical prospective randomized comparative study on ostyeosynthesis of mandibular anterior fractures following open reduction using lag screws and miniplates. Natl J Maxillofac Surg 8:110-116, 2017.

52. Boyd N, John DW, Lovald S: Clinical and FEA of low profile 3 D and parallel miniplates in fixation of mandibular symphysis and parasymphysis fracture. J Maxillofac Oral Surg 7:431-437, 2008.

53. Kalfarentzos EF, Deligianni D, Mitros G, Tyllianakis M: Biomechanical evaluation of plating techniques for fixing mandibular angle fractures: the introduction of a new 3D plate approach. Oral Maxillofac Surg 13: 139-44, 2009.

54. Farmand M: Experiences with the 3-D miniplate osteosynthesis in mandibular fractures. Fortschr Kiefer Gesichtschir 1996; 41, 85–87.

55. Sadhwani BS, Anchlia S: Conventional 2.0 mm miniplates versus 3-D plates in mandibular fractures. Ann Maxillofac Surg 3: 154-159, 2013.