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An analysis of postoperative complications and efficacy of 3-D miniplates in fixation of mandibular fractures

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ABSTRACT

Background: Recently, various modifications in transorally placed miniplates for direct fixation of the mandibular fracture are gaining popularity. The modifications have various advantages like more rigidity, less foreign material, less time in application, etc. Among the various modifications of miniplates, three-dimensional (3-D) plating system is also gaining popularity. Thus, in the present study, we tried to evaluate the efficacy and postoperative complications of 3-D titanium miniplates in the treatment of mandibular fractures.

Materials and Methods: A prospective study was conducted on 40 patients with non-comminuted mandibular fractures. They were treated using a 2-mm 3-D titanium miniplate through intraoral approach. All patients were systematically monitored 6 months postoperatively. Outcome parameters like infection, hardware failure, wound dehiscence, sensory disturbance of the inferior alveolar nerve, occlusion, and 3-D plate stability were recorded. The statistical tests used in study were mean, standard deviation, and Chi-square test. *P* values less than 0.05 were considered significant and values less than 0.001 were considered very highly significant.

Results: Two patients had a postoperative infection with no consequences. All patients had normal sensory function 3 months after surgery. Plate fracture had not occurred in any patient. Occlusal was normal and wound dehiscence was not reported. 3-D plate was stable in all the patients.

Conclusions: It was seen that 3-D titanium miniplates were effective in the treatment of mandibular fractures and overall complication rates were lesser. In symphysis and parasymphysis regions, 3-D plating system uses lesser foreign material than the conventional miniplates using Champy's principle.

Key Words: 3-D plate, complications, fracture, internal fixation, mandible, miniplates, occlusion

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INTRODUCTION

In the past four decades, there has been an increasing interest in obtaining more immediate return to normal function by using different methods of direct fixation with an open approach and allowing anatomical reduction of the fragments.[1] Surgical treatment of mandibular fractures involves intraoral or extraoral opening of the fracture site and direct osteosynthesis with transosseous wires, lag screws, or bone plates.[2] A number of fixation methods have been advocated for the treatment of mandibular fractures.[3]

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Through the decades, various plate and screw osteosynthesis have been introduced like AO plating system, miniplating system, resorbable plates and screws.[4] Transorally placed miniplates have gained wide acceptance for the treatment of mandibular fractures as described by Champy *et al*. Non-comminuted symphyseal and parasymphyseal fractures, as well as condylar fractures, can be treated with two miniplates, and at times, favorable, undisplaced angle fractures can be treated with an upper border.

Recently, modifications in miniplates like titanium three-dimensional (3-D) plating system have been developed to meet the requirements of semi-rigid fixation with lesser complications.

3-D miniplating system, first introduced by Mustafa Farmand in 1992, has the advantage of creating three-dimensional stability of the fractured and ostetomized bony segment.[5]

The newly introduced 3-D plating system provides definite advantages over conventional miniplates. The 3-D plating system uses fewer plates and screws as compared to conventional miniplates to stabilize the bone fragments. In case of conventional miniplates, two plates are recommended in symphysis and parasymphysis region, while only one 3-D plate is necessary for the same. Thus, it uses lesser foreign material, and reduces the operation time and overall cost of the treatment.[5-8]

MATERIALS AND METHODS

This is a prospective study conducted on patients visiting Department of Oral and Maxillofacial Surgery, Kothiwal Dental College and Research Centre, Moradabad, with diagnosis of mandibular fractures between 2009 and 2011. All the patients were treated on in-patient basis.

Forty patients with insignificant medical history were involved in the study. The selected cases were treated by open reduction and internal fixation using 3-D titanium miniplate. The study was designed to evaluate the efficacy and postoperative complications of titanium 3-D plate. The patients were selected based on the following inclusion criteria: (a) non-comminuted, non-infected mandibular fractures in symphysis, parasymphysis, body, and angle region and (b) fractures indicated for open reduction. The exclusion criteria were: (a) comminuted, infected mandibular fracture and (b) pediatric patients below 12 years of age and geriatric patients with complete edentulous mouth.

Method of study

The study was approved by local ethical committee, and informed consent was obtained from the patients before their inclusion in the study. Detailed case history was recorded and all patients were treated and observed by the same surgeon. Routine clinical, radiological, and hematological examination was carried out and recorded. Oral prophylaxis was carried out and Erich arch bar was applied preoperatively.

Procedure

The 3-D 2.0 mm titanium miniplate system

A 4-holed rectangular or square titanium 3-D plate designed by AO or Orthomax was used in this study. A single plate was used in fracture of symphysis, parasymphysis, body, as well as angle region. It was fixed with 6.0 mm and 8.0 mm screws. In the parasymphysis and body region, 3-D plate was fixed above the level of mandibular canal. The lower border screws were fixed first, followed by upper border screws. Local or general anesthesia was used for the patient as dictated by the case [Figures 1 and 2]. After adequate exposure of fracture fragments, debridement and curettage was done. The fracture fragments were reduced to their anatomical form and jaws were placed into intermaxillary fixation (IMF). The 3-D miniplate was adapted adequately and placed over surface [Figure 3]. The 3-D plate was placed in such a way that horizontal cross bars were perpendicular to the fracture line and vertical cross bars were parallel to the fracture line [Figure 4]. After the procedure was completed, IMF was removed, leaving the arch bars in place and occlusion was checked [Figure 5]. The fixed fracture fragments were checked manually for adequate reduction and fixation. Postoperative IMF was not used in any patient. After achieving hemostasis, incision was closed. All patients received postoperative antibiotics and analgesics for 7 days and were instructed to maintain a soft diet for 30 days. Oral hygiene maintenance using 0.2% chlorhexidine mouthwash was advised to all the patients.

The patients were followed up for a period of 4 weeks initially for every week and later at 8^{th} and 12^{th} weeks. All the parameters used were assessed at various recall visits and recorded. Postoperative orthopantomogram (OPG) was taken in all the cases as early as possible after surgery and at 8^{th} [Figure 6] and 12^{th} weeks [Figure 7]. Additional OPG was taken if required.

Assessment of patients

The patients were evaluated for the location, type, and number of fractures; presence of tooth in the fracture line, time elapsed in the presentation of the patient after trauma, operating time, clinical assessment of mobility after fixation, pre- and post-surgical occlusal relationship, adequacy of reduction on postoperative radiograph, and any post-surgical complications.

Figure 1: Preoperative occlusion

Figure 2: Preoperative OPG

Figure 3: Titanium miniplate in parasymphysis region

Figure 4: Titanium miniplate in angle region

Figure 5: Postoperative occlusion

Figure 6: Postoperative OPG (8th week)

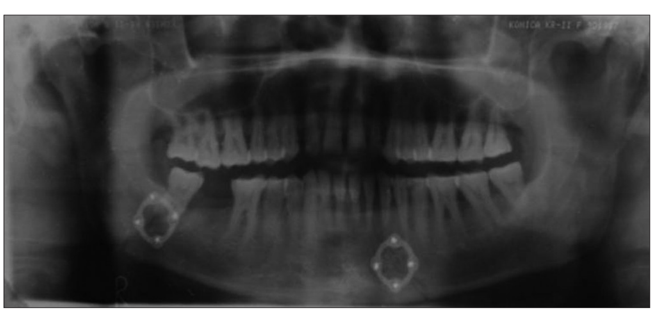

Figure 7: Postoperative OPG (12th week)

Evaluation criteria

Intraoperative

Adequacy of fracture fixation: Adequacy of fracture fixation was checked immediately after fixation by clinical manipulations in three dimensions. In case of adequate fixation, no further treatment was given, while in fractures found to be inadequately fixed, further intervention was done.

Postoperative

a. *Radiological assessment*: Immediate postoperative radiographs were taken within hours after the procedure, followed by at 8th and 12th weeks as normal fracture healing process takes approximately 3 months.

b. *Complications*: Assessed up to 12th week were:

1. Infections: Case to be considered infected if having discharge with positive culture test.
2. Wound dehiscence: Based on clinical examination.
3. Occlusal discrepancies: Based on clinical examination and information obtained from the patient.
4. Paresthesia: Based on clinical examination and information obtained from the patients.
5. Hardware failure: Based on clinical and radiographical evaluation.
6. 3-D plate stability: Based on clinical evaluation.

All the complications when occurred were managed accordingly. The above-described findings were recorded for each patient and the final data thus obtained were compared to those of the other group.

The statistical analysis was done using Statistical Package for Social Sciences (SPSS) Version 15.0 statistical analysis software. The values were represented as number (%) and Mean ± SD. The following statistical formulas were used: *Mean:* To obtain the mean, the individual observations were first added together and then divided by the number of observations. The operation of adding together or summation is denoted by the sign Σ. The individual observation is denoted by the sign X, number of observations denoted by n, and the mean by $\overline{X}$. *Chi-square test:* $\chi^2 = \frac{\Sigma(O-E)^2}{E}$, where O = observed frequency and E = expected frequency.

Level of significance: "P" is the level of significance: $P >$ .05 not significant, $P < 0.05$, significant, $P < 0.01$ highly significant, $P < 0.001$ very highly significant.

RESULTS

Forty patients with mandibular fracture were enrolled. The age of patients ranged from 17 to 60 years. Maximum number of subjects (35%) was in the age group of 31–40 years, followed by 30% subjects in the age group ≤20 years. There were only 6 (15%) subjects above 40 years of age [Figure 8]. Mean age of patients was 30.95 ± 12.37 years.

Left parasymphysis with right-angle fracture and left parasymphysis alone were the most common types and sites of fracture observed in six patients each. Left angle with right parasymphysis, left condyle with right parasymphysis, and left parasymphysis with left condyle were involved in four subjects each. Bilateral involvement of angle, left angle, left body, left angle right body, right body, right parasymphysis, and right condyle and right parasymphysis were involved in two subject each [Figure 9].

Baseline assessment

Preoperatively, none of the sites had infection or paresthesia. There were 36 (90%) subjects with occlusal defects [Table 1].

Postoperative assessment

Postoperative assessment was done for the presence of infection, paresthesia, malocclusion, wound dehiscence, and hardware failure. The assessment was done on 3rd day, 1st week, 2nd week, 4th week, 8th week, and 16th week time intervals.

No case with infection, paresthesia, occlusal defects, wound dehiscence, hardware failure, or 3-D plate instability was noticed at the first follow-up on 3rd postoperative day [Table 2].

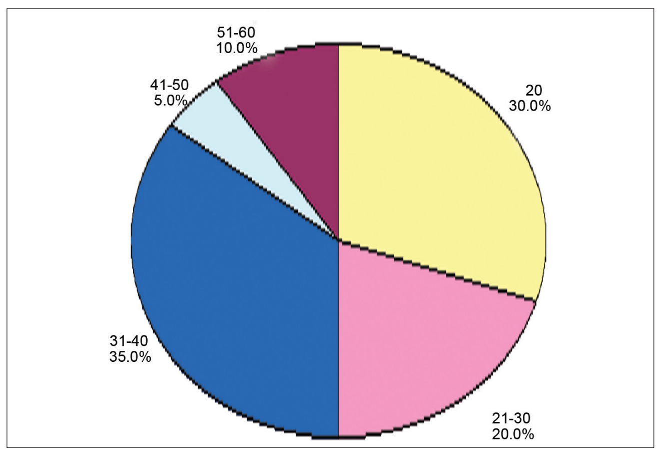

Figure 8: Age wise distribution

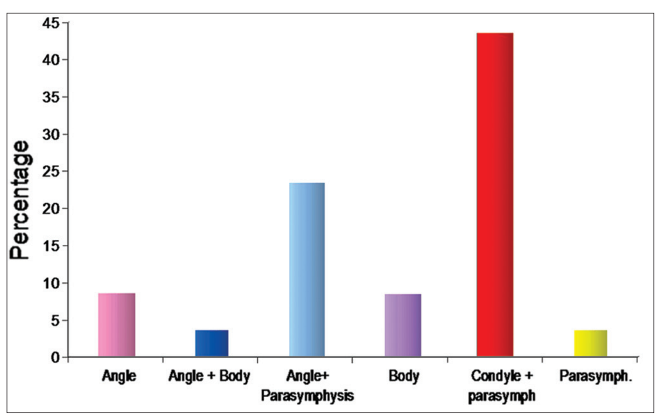

Figure 9: Type of fracture

No case with paresthesia, occlusal defects, wound dehiscence, hardware failure or 3-D plate instability was noticed at the second follow-up in 1 week postoperative interval. However, at this time, infection was observed in 2 (5%) subjects [Table 3].

Infection in the form of swelling and pus drainage continued to persist in 2 (5%) patients even during the third follow-up at the end of 2 weeks postoperatively. However, due to antibiotic coverage, pus drainage had considerably reduced. No other case reported with paresthesia, occlusal defects, wound dehiscence, hardware failure, or 3-D plate instability [Table 4].

At the end of 1st, 2nd, and 4th month postoperative intervals, there were no untoward sequelae, and healing and postoperative results were uneventful [Tables 5 and 6].

Inter-visit analysis of results

Paresthesia, wound dehiscence, and hardware failure were not noticed at any time interval. The events of occlusal defects and infection were noticed during the course of study. Thus, the analysis will be limited to evaluation of change in occlusion and infection status only.

At baseline there was no case with infection. The situation remained unchanged at first follow-up too. However, at the second and third follow-up intervals, there were 2 (5%) cases with evidence of infection. But from the fourth follow-up onward, none of the cases had evidence of infection. On comparing the data statistically, no significant change was observed as compared to the baseline [Table 7].

As compared to the baseline where the occlusion was not disturbed only in 4 (10%) cases, postoperatively the evidence of occlusion was present in all the cases at all follow-up intervals. On comparing the data statistically, a significant difference from baseline was observed ($P < 0.001$).

The 3-D plate was observed to be stable at all follow-up intervals, showing no change from baseline status at the first follow up.

DISCUSSION

The objectives in the treatment of mandibular fracture are to re-establish normal occlusion and masticatory function with minimal disability and complications.

Conservative treatment to achieve this is performed by immobilizing the mandible for the healing period by intermaxillary fixation which is achieved by dental wiring, arch bars, cap splints, and gunning splints. Surgical treatment of mandibular fractures involves intraoral or extraoral opening of the fracture site and direct osteosynthesis with transosseous wires (Schwenzes 1982), lag screws (Niederdellmann 1982), or bone plates (Schilli 1975; Spiessel 1976).[1,2] A number of fixation methods have been advocated for the treatment of mandibular fractures.[3]

Now-a-days, open reduction with internal fixation is the norm and tiny titanium plates are used to

Table 1: Outcome of baseline evaluation ($N = 40$)

Variable	Present		Absent	
	No.	%	No.	%
Infection	0	0	40	100
Occlusal defects	36	90	4	10
Paresthesia	0	0	40	100

Table 2: Outcome of 3rd day postoperative assessment ($N = 40$)

Variable	Present		Absent	
	No.	%	No.	%
Infection	0	0	40	100
Malocclusion	0	0	40	100
Paresthesia	0	0	40	100
Wound dehiscence	0	0	40	100
Hardware failure	0	0	40	100
3-D plate instability	0	0	40	100

Table 3: Outcome of 1 week postoperative assessment ($N = 40$)

Variable	Present		Absent	
	No.	%	No.	%
Infection	2	5	38	95
Occlusal defects	0	0	40	100
Paresthesia	0	0	40	100
Wound dehiscence	0	0	40	100
Hardware failure	0	0	40	100
3-D plate instability	0	0	40	100

Table 4: Outcome of 2 weeks postoperative assessment ($N = 40$)

Variable	Present		Absent	
	No.	%	No.	%
Infection	2	5	38	95
Occlusal defects	0	0	40	100
Paresthesia	0	0	40	100
Wound dehiscence	0	0	40	100
Hardware failure	0	0	40	100
3-D plate instability	0	0	40	100

Table 5: Outcome of 1 month postoperative assessment (*N* = 40)

Variable	Present		Absent	
	No.	%	No.	%
Infection	0	0	40	100
Occlusal defects	0	0	40	100
Paresthesia	0	0	40	100
Wound dehiscence	0	0	40	100
Hardware failure	0	0	40	100
3-D plate instability	0	0	40	100

Table 6: Outcome of 2 months postoperative assessment (*N* = 40)

Variable	Present		Absent	
	No.	%	No.	%
Infection	0	0	40	100
Occlusal defects	0	0	40	100
Paresthesia	0	0	40	100
Wound dehiscence	0	0	40	100
Hardware failure	0	0	40	100
3-D plate instability	0	0	40	100

Table 7: Change in infection status at different follow-up intervals as compared to baseline evaluation (*N* = 20)

Variable	Infection		Significance of change	
	No.	%	χ^2	*P*
Baseline	0	0	–	–
First follow-up	0	0	–	–
Second follow-up	2	5	1.026	0.311
Third follow-up	2	5	1.026	0.311
Fourth follow-up	0	0	–	–
Fifth follow-up	0	0	–	–
Final follow-up	0	0	–	–

immobilize fragments of the jaw. Morbidity of the procedure is low with the advantage that the patient returns to normal function within days of treatment.[2] Intraoral approach is preferred unless indicated otherwise, as it is esthetically accepted, time saving, and less traumatic. Miniplate osteosynthesis was first introduced by Michelet *et al*. in 1973 and further developed by Champy and Lodde in 1975.[9] According to them, physiologically coordinated muscle function produces tension force at the upper border of the mandible and compressive forces at the lower border. The plates are applied close to the tension zone of the mandible. The screws are monocortical to prevent injury to dentition and alveolar nerve.[9,10]

Titanium is the metal of choice for fixation plates, mainly because of its high biocompatibility and ease of manipulation.[11,12] Modification of miniplates like titanium 3-D plating system was developed by Farmand[5,13] to meet the requirements of semi-rigid fixation with lesser complications.

The 3-D miniplate is a misnomer as the plates are not three dimensional, but hold the fracture fragments rigidly by resisting the forces in three dimensions, namely, shearing, bending, and torsional forces.[5,14,15] The basic concept of 3-D fixation as explained by Farmand[5] is that a geometrically closed quadrangular plate secured with bone screws creates stability in three dimensions. The stability is gained over a defined surface area and is achieved by its configuration and not by its thickness or length.[16] The large free areas between the plate arms and minimal dissection permit good blood supply to the bone.[5,8]

The newly introduced 3-D plating system provides definite advantages over the conventional miniplates. The 3-D plating system uses fewer plates and screws as compared to the conventional miniplates, to stabilize the bone fragments. Thus, it uses lesser foreign material, and reduces the operation time and overall cost of the treatment as described by Zix *et al.*, Lieger and Iizuka, and Farmand.[8,16-18]

The 3-D plating system has a compact design and is easy to use. The 1.0-mm-thick 3-D plate is as stable as the much thicker 2.0 mm miniplate. This offers better bending stability and more resistance to out-of-plane movement or torque.[14]

In our study, 46 fractures were treated with 3-D plate in 40 patients. Patients' age ranged from 17 to 60 years, with maximum number of subjects (35%) within the age group of 31–40 years, followed by £20 years (30%). There were only 6 (15%) patients above 40 years of age. Mean age of patients was 30.95 ± 12.37 years. Mean age of the patients in other studies were as follows: 28.6 years in the study of Guimond *et al.*,[19] 26 years in Bui *et al.*'s[17] study, and 33.9 years in the study of Zix *et al.*[8]

Parasymphysis alone or in combination with any other site (angle or condyle) was the most common fracture in our study (30 patients) and similar findings were observed in other studies by Parmar *et al.*[7] and Jain *et al.*[18]

Road traffic accidents was the most common etiology of fracture as was also observed in other studies by Parmar *et al.*[7] and Jain *et al.*[18] However, in some other studies of 3-D plating system, the common etiology of fracture was interpersonal violence as reported by Guimond *et al.*,[19] Bui *et al.*,[17] and Zix *et al.*[8]

The infection rate in our series was 5% at the second follow-up, whereas in other studies, the infection rates were: 5.4% in the study of Guimond *et al.*,[19] 0% in Zix *et al.*,[8] 8.2% in Bui *et al.*,[17] 10% in Jain *et al.*,[18] and 6.6% in Parmar *et al.*[7]

Paresthesia of inferior alveolar nerve was 0% in our study and is similar to that reported by Jain *et al.*[18] and Parmar *et al.*,[7] whereas in other studies like those of Guimond *et al.*[19] and Zix *et al.*,[8] it was considerably high, i.e. 60% and 25%, respectively. When our results were compared to those of Feller *et al.*[2] on miniplate fixation using Champy's principle, it was found that paresthesia rate was 6% in that study. Similar study by Moreno *et al.*[10] on Champy's principle showed paresthesia rate of 2.2%. Study by Moreno *et al.*[10] using 2.7-mm AO plate for mandibular fracture fixation had paresthesia rate of 3.1%. Incidence of low paresthesia in our study is due to the use of monocortical plate as compared to other types of plating system in which chances of inferior alveolar nerve injury are more due to bicortical screws.

In this study, malocclusion was not observed in any case and was similar to the studies by Bui *et al.*[17] and Jain *et al.*[18] However, malocclusion recorded was 6% in a study by Sebastian Sauerbier (2010) in which 2-mm locking plating system was used, 4.4% in a study by Moreno *et al.*[10] which was based on Champy's principle, and 2.7% in a study by Moreno *et al.*[10] using 2.7-mm AO plate. Based on these studies it is evident that in 3-D plating system, chances of achieving good occlusion are relatively high, which is evident in our study.

Wound dehiscence was 0% in a study by Jain *et al.*,[18] whereas 6.6% was reported by Parmar *et al.*[7] and 2.7% by Guimond *et al.*[19] using 3-D plates. Sebastian Sauerbier (2010)[10] reported wound dehiscence of 7.5% in 2-mm locking plate system. All these studies including ours prove that while using 3-D plating system, wound dehiscence is usually less or nil as compared to other plating systems.

Hardware failure was observed radiographically till 12th week postoperatively. Hardware failure in our study was 0% and is similar to the findings of other studies, i.e. 0% by Bui *et al.*[17] and Jain *et al.*,[18] whereas Zix *et al.*[8] reported a hardware failure of 5.8%. Plate fracture was the most important complication in the study by Zix *et al.*[8] The reason for the hardware failure most likely lies in the reduced inter-fragmentary cross-sectional bone surface at the fracture site. A significant amount of contact surface was lost by removal of tooth from the fracture line itself, and this contact was additionally reduced by associated removal of bone around the third molar to be extracted. In our study, out of 46 fracture sites that were treated by 3-D plating system, 6 were in the angle region and third molar was not removed in any of the cases.

Postoperative segmental mobility was not evident in any of our cases, whereas segmental mobility was reported in 10% cases in a study series of 20 patients by Jain *et al.*[18] In a biomechanical comparison study by Alkan *et al.*,[20] it was concluded that stability is better with 3-D plating system. Minor mobility was present when single miniplate was used in the angle region with Champy's principle according to Feller *et al.*[2] All biomechanical tests in which a second miniplate had been fixed to the mandibular margin revealed less mobility according to Ellis and Walker (1994). Ellis also found that adding a second plate at the angle region had a disadvantage as it increased the implant load in the angle region, but in case of 3-D plating system, implant load was reduced and better stability was achieved.[21]

In the present study, it is seen that 3-D titanium miniplates were effective in the treatment of mandibular fractures and overall complication rates were lesser. In the symphysis and parasymphysis regions, 3-D plating system uses lesser foreign material, as only one plate and four screws are used as compared to two plates and eight screws in case of conventional miniplates using Champy's principle. This also reduces the operating time and overall cost of the treatment.[8,15] However, in other areas of the mandible, hardware used is the same with comparable cost of both the systems.

Thus, 3-D plate can be used as an alternative to the conventional miniplates. The system is a reliable and effective treatment modality for mandibular fractures as compared to traditional miniplates. Further, the use of 3-D plating system in various procedures of maxillofacial region needs to be explored.

CONCLUSION

Forty-six mandibular fractures were treated with 3-D plate in 40 patients. The findings of this prospective analysis indicate that 3-D titanium miniplates are effective in the treatment of mandibular fractures and overall complication rates are lesser. Fracture mobility is the main cause of infection postoperatively; however, 3-D plating systems have adequate stability after fixation of fracture. The stability of 3-D plate is gained over a defined surface area and is achieved by its configuration and not by its thickness or length. Wound dehiscence and paresthesia are minimal with this plating system because thickness of plate is less and also monocortical screw is used. The 3-D system is easy to use and cost effective. Further, it uses lesser hardware as compared to the conventional miniplates. Operative time is shorter because of simultaneous stabilization at both superior and inferior borders. The system is a reliable and effective treatment modality for mandibular fractures.

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