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A prospective study for the effectiveness of 3-dimensional curved strut plates for the treatment of mandibular angle fractures

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Abstract

Background: The treatment for mandibular angle fractures has evolved over the years, from old methods of bandaging, splinting, extra-oral pin fixation, circum-mandibular wiring, semi rigid fixation with transosseous wiring to various methods of open reduction and internal fixation (ORIF). Open reduction and internal fixation can be performed by intraoral, extraoral or combined intraoral and transbuccal approach. During the last decade, significant attention has been placed on fixation of mandibular angle fractures using a variety and combination of transorally placed small plates secured with monocortical screws. Fixation with these plates has shown to simplify surgery and reduce surgical morbidity. One of the various methods of fixation is using a 3-dimensional strut plate. The 3-D curved angle strut plate is a single plate composed of two 4-hole miniplates with interconnecting crossbars or struts. Its geometry with an increased number of screws allows for stability in 3-dimensions, malleability and also provides increased torsional stability. The fixation of a single miniplate at the superior border, as in Champy technique can cause lower border splaying due to molar loading. This complication is prevented by the 3-D strut plate due to its action like 2 miniplates. The purpose of this study is to evaluate the effectiveness of the 3-dimensional curved strut plate in the management of mandibular angle fractures. Materials and Methods: Patients who reported to the Department of Oral and Maxillofacial Surgery, A.J Institute of Dental Sciences, Mangalore diagnosed clinically and radiographically with mandibular angle fractures were selected for the study with their informed consent. A total of 10 patients were selected after fulfilling the inclusion and exclusion criteria. All patients were operated under general anesthesia for open reduction and internal fixation. The fractures were exposed by an extraoral approach using Risdon's incision. After reducing the fracture anatomically, the 3-D strut plate was placed across the fracture site and secured with monocortical screws. After fixation, the occlusion was assessed and layered suturing was done. Patient was evaluated preoperatively, intraoperatively and postoperatively on various parameters by a prosthodontist and an oral and maxillofacial surgeon. Results: Ten patients fulfilling the inclusion and exclusion criteria were selected for repair using 3-dimensional strut plates in the mandibular angle region. 80% of the cases were found to be caused due to Road traffic accidents while remaining 20% were due to self-fall. Nine of the patients were associated with other fractures. Five patients were found to have minor occlusal disturbances preoperatively and five had severe occlusal disturbances. Intraoperatively, 30% cases were found to be easy for plate fixation. Postoperatively, evaluation was done immediately, at 3 months and months using a panoramic radiograph. Anatomic reduction was excellent in all patients at the end of 6 months. All patients showed stability during each evaluation. No occlusal disturbances were seen in any patient at the end of 6 months. Three patients complained of paresthesia postoperatively, which reduced to one in the second follow-up. One of the patients had to undergo plate removal due to a swelling which did not subside even after a course of antibiotics. Conclusion: Based on our study and its findings, we can conclude that a 3-dimensional curved strut plate is an effective modality of treatment for mandibular angle fractures.

Keywords: Mandibular fractures, Angle fractures, 3-d plates, Strut plates.

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INTRODUCTION

Mandibular fractures can be dated back to 1650 BC where they were initially detailed on an Egyptian papyrus [1]. Although the mandible is considered to be one of the toughest bones of the face, it is commonly a part of facial bone fractures mainly because of its prominence. It is seen to be occurring second only to fractures of the nose. Statistically, 68.8% of the causes were road traffic accidents, 16.8% were self-falls, 11% included interpersonal violence and the remaining smaller percentage were other reasons [2].

The mandibular angle accounts for about 20-36% of all mandibular fractures, because it is considered as the most susceptible anatomic location. This is mainly due to the relatively delicate angular area of the jaw and also due to the third molar being in the same region [3-8].

A number of concepts are involved in the management of angle fractures which includes anatomy of the area, knowledge about the appropriate muscles, occlusal significance as well as tooth present in the line of fracture. Various techniques exist for the treatment of these fractures. The most favorable option for managing mandibular angle fractures is still debatable. Traditionally, treatment for angle fractures was achieved by closed reduction by immobilizing the jaws using different wiring techniques [3,8].

The newer methods include internal fixation with mono cortical non-compression plates, rigid fixation using thick solid plates at the lower border, one miniplate on the upper border, and even using two plates for better stability [3,7,9-11].

Many biomechanical tests done to check for stability of one or two plate fixations, resulted in gaps at the inferior border, causing complications like infections. In spite of these results, the treatment methods continued to progress positively with a noticeable transition from bulky plates to an isolated or double miniplates [3,7,12].

Additionally, all the drawbacks resulted in the formation of three dimensional miniplates. First described by Farmand and Dupoirieux, the 3-D strut plate was fabricated with two titanium miniplates connected to each other with bars [13].

This 3-dimensional design was such that there was a reduced risk to the inferior alveolar nerve and contouring of the plate was avoided. It was sturdy with the ability to withstand torsional forces along with being adaptable. The geometry of the plate is such that there are an increased number of screws – 8 monocortical screws, 4 to be placed on each border, and vertical struts which aid in stability in 3-dimensions. It was suitable for both favorable and unfavorable angle fractures [13-16].

A combination of intraoral and percutaneous approaches using a trocar can also be used for adequate reduction and fixation. An extraoral approach provides sufficient visibility, accessibility and ease in manipulation of the segments [15,17]. This along with the benefit of being able to confirm appropriate reduction is the reason why this approach has been adopted in this study.

The best site for plating a mandibular angle was considered to be at the superior aspect, over the flat osseous surface approximating the third molar. This provided better stability at the tension and compression zone [18,19].

Taking all the above studies and their findings into consideration, 3-dimensional strut plates are being used more frequently for the treatment of mandibular angle fracture treatment. The main purpose of our study was to evaluate the advantage of utilizing 3-D strut plates in mandibular angle fracture management.

MATERIALS AND METHODS

This prospective study was carried out in the Department of Oral and Maxillofacial surgery, A.J. Institute of Dental Sciences, Mangalore, Karnataka, India from December 2017 to June 2019. Ten patients who fulfilled the inclusion and exclusion criteria were chosen. Each patient was selected only after they signed the consent forms.

Inclusion Criteria

- Clinically and radiographically diagnosed angle fractures, either isolated or along with other fractures
- Patients within the age group of 18-60 years.

Exclusion Criteria

- Severely comminuted fractures were not considered
- Medically compromised patients and those not fit to undergo surgery.
- Any pathology/ infection at the site of mandibular angle fracture region

MATERIALS

1. PLATE- 3-DIMENSIONAL STRUT PLATE – 2mm 8 hole 3-D titanium plates were used in this study. (Fig. 1)
2. SCREWS- 2X8mm titanium screws were used in this study. (Fig. 1)
3. MAXILLOFACIAL TRAUMA CASE INSTRUMENTS

METHODOLOGY

A thorough preoperative evaluation was done for each patient comprising of:

1. Thorough history of the trauma
2. Complete clinical evaluation
3. Required Radiographs
4. All mandatory pre-surgical workup

All ten patients included in this study underwent Erich's arch bar fixation preoperatively.

PRE–OPERATIVE EVALUATION

All ten patients were evaluated using a panoramic radiograph (OPG) to know the fracture type, degree of displacement and if a tooth was present in the line of fracture (Fig. 2).

Clinically, the pre-operative occlusion was evaluated using a set of photographs and scored by a prosthodontist and an oral and maxillofacial surgeon. Scores were given based on an occlusion scale as [20]

Good = 1 (If there are no occlusal discrepancies)

Acceptable = 2 (if there are minor occlusal discrepancies)

Poor = 3 (if the occlusal discrepancies are severe).

INTRA-OPERATIVE EVALUATION

All ten surgical procedures were carried out under general anesthesia. An extraoral approach with a Submandibular/ Risdon's incision was decided for all ten patients and fixed with the 2 mm 3-dimensional curved angle strut plate (Fig.3). Intraoperatively, the patient was evaluated using three parameters.

Ease of adaptability and fixation of plate-

This was evaluated based on the amount of time required to fix the plate. It was calculated as the period from the anatomic reduction of the fracture to the fixation of the last screw was noted.

Easy = 0 – when time taken for fixation is within 20 mins

Moderate = 1 – when time taken for fixation is within 20-30 mins

Difficult = 2 – when time taken for fixation is more than 30 mins

Fixation at operation

The stability of the fixation was assessed intraoperatively based on movement of the plate or bony fragment and scored[21] as

Excellent= 0 (If there is no displacement of the plate or bone fragment)

Good=1 (If there is a slight displacement of plate but none in the bone fragment)

Acceptable= 2 (If there is displacement of the bone fragment but other internal fixation was not required)

Poor=3 (If there is displacement of fragment which required further internal fixation)

State of Reduction

After the complete fixation of the plate, the state of the fracture reduction is assessed based on the amount of gap between the fracture fragments. It was scored[21] as –

Excellent= 0 (when there is no gap between bone fragments)

Good= 1 (when the gap between bone fragments is less than 1mm)

Acceptable= 2 (when the gap between bone fragments is more than 1 mm but less than 5mm)

Poor=3 (when there is over 5 mm gap or step between bone fragments)

The surgical wound was closed in layers using 3-0 Vicryl and 4-0 Ethilon. Chlorhexidine mouthwashes along with antibiotic coverage (Inj. Cefotaxime 1gm 12th hourly and Inj. Metronidazole 100 ml 8th hourly) was prescribed preoperatively from the day of admission to the hospital until the fifth postoperative day. Patients were advised to follow up for a minimum of 6 months. Post-operative assessment was done by clinical and radiological parameters.

POST-OPERATIVE EVALUATION

The patient was evaluated postoperatively during three time intervals – immediate postop, at 3 months and at 6 months.

Evaluation of occlusion

Post-operative occlusion was evaluated at immediate postop and at 6 months post op by a prosthodontist and oral and maxillofacial surgeon and compared with the preoperative occlusion. [20]

Good = 1 (If there is no visible occlusal disturbances)

Acceptable = 2 (If there are minor occlusal disturbances)

Poor = 3 (If there are severe occlusal disturbances which require attention).

Reduction by radiograph

Postoperatively, a panoramic radiograph is taken and evaluated for the anatomic reduction based on the amount of radiographic gap between the fracture fragments. It is scored[21] as -

Excellent = 0 (In case of no detectable gap between fracture fragments)

Good =1 (In case of a gap less than 5mm between fracture fragments)

Fair = 2 (When there is gap of more than 5mm between fracture fragments)

This reduction is evaluated at immediate postop, after 3 months and then after 6 months post-operatively.

Stability of the fracture fragment

This is evaluated clinically by examining the mobility of the fracture fragments. It is scored as –

Good = 0 – No movement of fracture fragments

Acceptable = 1- Slight movement of fracture fragments

Poor = 2 – Unstable fracture in need of further fixation

The stability is evaluated during immediate post op, after 3 months and then after 6 months post-operatively.

Evaluation of complications

Presence of Infection, Nonunion, Malunion, Hardware failure, Dehiscence, Paresthesia is evaluated at each follow up. (Immediate, 3 months and 6 months post op). It is scored based on its absence or presence. [20]

ABSENT = 0; PRESENT = 1

RESULTS

Ten mandibular angle fractures which were diagnosed clinically and radiographically and managed surgically by open reduction and internal fixation using 2 mm 3-dimensional curved strut plate. All ten patients in this investigation which was conducted from November 2017 to June 2019 were males. RTA's were the cause in 80% of the cases while 20% were due to self-fall (Table 1). All patients were above the age of consent with a maximum age of 57. The mean age was found to be 31.3 ± 11.605 (Table 2).

Of these 10 patients, 9 were found to be associated with other fractures, while only one was an isolated mandibular angle fracture (Table 3). 4 cases were seen associated with parasymphysis fractures, 2 along with mandibular body fractures, 1 with bilateral condylar fracture, and 1 with a zygomaticomaxillary complex fracture. One case was seen associated with a parasymphysis and condyle fracture along with the angle. Pre-surgical panoramic radiograph was used for evaluating the patient's condition and those suitable as per the inclusion criteria were chosen. There were 8 cases where a tooth was in the line of fracture, in which one was a root stump while the remaining two cases did not have this condition.

Preoperatively, the occlusion was evaluated clinically by a prosthodontist as well as oral surgeon as per the occlusion scale. 5 patients were found to have minor occlusal disturbances and given a score of 2, while 5 had severe occlusal discrepancies with a score of 3. Similar scores were given by both specialists.

The mandibular angle fractures were approached extraorally by a submandibular/ Risdon's incision and fixed using the 3-dimensional curved strut plate with 8 screws of size 2 mm each. The time required for the fixation of the plate was noted in each case and 70% of the cases were scored as moderate and the remaining 30% were scored as easy taking less than 20 minutes for the plate fixation (Table 4).

Intraoperatively, the fixation was assessed in each case and scored accordingly. All ten cases showed excellent results, as there was no movement of the fragments or plate after fixation. (Table 5)

The state of reduction in each case was evaluated intraoperatively by checking the amount of gap between the fracture fragments after reduction and fixation. We found that almost 50% of the cases were

seen to be acceptable, 40% of the cases had good results and 10% of the cases had excellent results (Table 6). The patient was evaluated postoperatively based on a number of criteria.

Occlusion was assessed postoperatively immediately after the surgery and then at 6 months post op. The prosthodontist's evaluation showed that four of the patients had minor occlusal disturbances and four had no occlusal disturbances. Two patients (20% of the cases) were seen to have severe occlusal disturbances. Their evaluation at 6 months post op showed one case as minor occlusal disturbance. This result was determined to be statistically significant with $p<0.001$ (Table 7).

When the same cases were assessed by an oral and maxillofacial surgeon, it was reviewed as six cases with no occlusal disturbances and two cases with mild occlusal disturbances. Two patients which were stated as severe occlusal disturbances by the prosthodontist were considered as minor occlusal disturbances by the oral and maxillofacial surgeon. The occlusion evaluated at 6 months post-operative period was reported as no occlusal disturbances by the oral surgeon. On comparing the occlusal evaluation at all three time intervals it was declared as highly significant with $p<0.001$ (Table 8).

Anatomic reduction was evaluated post-operatively using a panoramic radiograph (OPG) immediately, at 3 months and at 6 months. On immediate postoperative evaluation, anatomic reduction showed 8 cases of good results and only two cases of excellent results. One of the patients became infected post –operatively resulting in a second surgery requiring plate removal under GA. This case was not considered for the remaining postoperative parameters. At three months' follow up, only one case had good results, the remaining 8 cases showed excellent results. At six months follow up, all cases showed excellent outcomes resulting in highly significant statistics (Table 9).

Stability of the fracture fragments were evaluated clinically by checking mobility of the fracture after fixation. It was evaluated at three intervals – postoperatively, first follow up at 3 months and second follow up at 6 months. All ten patients showed excellent results postoperatively. As one patient had to undergo plate removal under general anesthesia after one month, he was eliminated from further evaluation. On the first and second follow up, all nine patients were found to have excellent results. In this evaluation, on comparing the observations at all time intervals, the results were statistically insignificant with $p=1$ (Table 10).

On evaluation of post-operative complications of the ten patients, three patients complained of paresthesia postoperatively. In the first follow up, two out of the three patients continued to have paresthesia. In the second follow up, only one patient had paresthesia. One of the ten patients was noted to have a swelling which did not subside even after one week of antibiotics. There was no active pus discharge. He was later planned for plate removal under general anesthesia, due to which further postoperative assessment could not be done. The comparison of the post-operative complications at the three time periods was calculated to be highly significant with $p<0.001$. (Table 11).

Table 1: Cause of trauma

	Frequency	Percent
RTA	8	80.0
Self fall	2	20.0
Total	10	100.0

Table 2: Age group

	N	Minimum	Maximum	Mean	Std. Deviation
Age	10	18	57	31.30	11.605

Table 3: Association of fractures

	Frequency	Percent
B/L condylar and Right mandibular angle	1	10.0
Left mandibular angle	1	10.0
Left mandibular angle and parasymphysis	1	10.0
Left mandibular angle and right body	1	10.0
Left mandibular angle and right parasymphysis	3	30.0
Left Mandibular body and Right Angle	1	10.0
Left ZMC and left mandibular angle	1	10.0
Right Mandibular angle, parasymphysis and condylar head	1	10.0
Total	10	100.0

Table 4: Ease of plate fixation

	N (%)
Easy	3 (30.0)
Moderate	7 (70.0)
Difficult	0 (0.0)
TOTAL	10 (100.0)

Table 5: Fixation at operation

	N (%)
Excellent	10 (100.0)
Good	0 (0.0)
Acceptable	0 (0.0)
Poor	0 (0.0)
TOTAL	10 (100.0)

Table 6: State of reduction after fixation

	N (%)
Excellent	1 (10.0)
Good	4 (40.0)
Acceptable	5 (50.0)
Poor	0 (0.0)
TOTAL	10 (100.0)

Table 7: Prosthodontist evaluation of occlusion

		Pre-operative	Immediate post-operative	Post-operative-6 months	**Total**
N (%) no. of cases	Good	0 (0.0)	4 (40.0)	9 (90.0)	13 (43.3)
	Acceptable	5 (50.0)	4 (40.0)	1(10.0)	10 (33.3)
	Poor	5 (50.0)	2 (20.0)	0 (0.0)	7 (23.3)
	Total	**10 (100.0)**	**10 (100.0)**	**10 (100.0)**	**30 (100.0)**

Symmetric Measures

Group		Value	Asymptotic Standardized Errors	Approximate T[b]	p
Prosthodontist	Kendall's tau-b	-.667	.079	-8.627	.<0.001 vhs

Table 8: Oral surgeon's evaluation of occlusion

		Pre-operative	Immediate post-operative	Post-operative-6 months	**Total**
N (%) no. of cases	Good	0 (0.0)	8 (80.0)	10 (100.0)	18 (60)
	Acceptable	5 (50.0)	2 (20.0)	0(0.0)	7 (23.3)
	Poor	5 (50.0)	0 (0.0)	0 (0.0)	5 (16.7)
	Total	**10 (100.0)**	**10 (100.0)**	**10 (100.0)**	**30 (100.0)**

Symmetric Measures

Group		Value	Asymptotic Standardized Error	Approximate T	p
Oral surgeon	Kendall's tau-b	-.765	.033	-10.127	.<0.001 vhs

Table 9: State of reduction

		Immediate post-operative	**Follow up 1 (3 months)**	**Follow up 2 (6 months)**
N (%) no. of cases	Excellent	8 (80.0)	8 (88.9)	9 (100.0)
	Good	2 (20.0)	1 (11.1)	0 (0.0)
	Fair	0 (0.0)	0 (0.0)	0 (0.0)
	Total	**10 (100.0)**	**9 (100.0)**	**9 (100.0)**

Symmetric Measures

	Value	Asymp. Std. Error	Approx. T	P
Kendall's tau-b	0.614	.065	4.869	<0.001 vhs

Table 10: Stability of fracture fragments

		Immediate post-operative	**Follow up 1 (3 months)**	**Follow up 2 (6 months)**
N (%) no. of cases	Good	10 (100.0)	9 (100.0)	9 (100.0)
	Acceptable	0 (0.0)	0 (0.0)	0 (0.0)
	Poor	(0.0)	0 (0.0)	0 (0.0)
	Total	**10 (100.0)**	**9 (100.0)**	**9 (100.0)**

Table 11: Post-operative complications

		Immediate post-operative	Follow up 1 (3 months)	Follow up 2 (6 months)
N (%) no. of cases	Absent	6 (60.0)	7 (77.7)	8 (88.8)
	Present	4 (40.0)	2 (22.2)	1 (11.1)
	Total	**10 (100.0)**	**9 (100.0)**	**9 (100.0)**

Symmetric Measures

	Value	Asymp. Std. Error	Approx. T	P
Kendall's tau-b	0.725	.072	3.719	<0.001 vhs

Figure 1: 3-dimensional curved titanium strut plate with 6x8 mm titanium screws

Figure 2: Pre-operative OPG showing left mandibular angle and right parasymphysis fractures

Figure 3: Plate fixation using the 3-dimensional strut plate after fracture reduction (exposed using Risdon's incision)

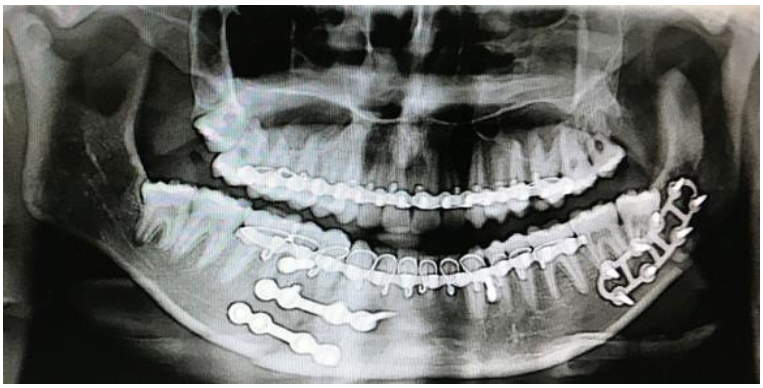

Figure 4: Immediate postoperative OPG

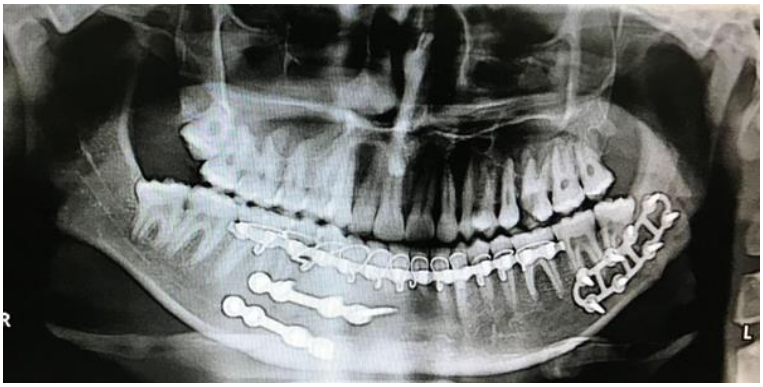

Figure 5: OPG at 6 months follow up

DISCUSSION

The angle of the mandible is one of the most commonly involved segments in mandibular fractures. They account for about 30% of all mandibular fractures. Some of the reasons for the facial fractures include road traffic accidents, self-fall and interpersonal violence [2,3,5].

Barde et al, in their retrospective study established developing nations tend to have more cases of road traffic accidents as compared to developed nations. This was found to be true in our prospective study of 10 cases where we saw that 80% of them were caused due to road traffic accidents [2].

In a study conducted by Ogundare et al, people in the age range of 25-34 years were found to be the most commonly affected group [5]. The highest frequency of the fractures in our study was established to be occurring in the age group of 21-38 years, with a mean age of 31.3 years. This could be due to the increase in the number of two-wheelers, lack of appropriate safety measures and improper road conditions as most of the cases are seen occurring due to road traffic accidents.

Certain vulnerabilities like thin cross-sectional area and third molar presence, weaken the angle of the mandible and are the main reasons for increased incidence of their fractures [3,6,8,16,19]. In our study, we had eight cases comprising of a tooth in the fracture line, of which one was a root stump. Again, whether or not to perform extraction of the tooth during open reduction is controversial. Certain studies reported that removal of the tooth could cause the fracture to be unstable upon fixation, while other studies have reported a higher rate of infection on retaining the third molar [8,16]. In our study, in only two cases the tooth was extracted during the fixation as the fracture line was passing through the tooth and had a higher chance of infection as compared to others.

Mandibular angle fractures can be seen occurring as isolated fractures or along with other facial fractures [17]. In our study, only one of ten cases was an isolated mandibular angle fracture, while others were seen associated with other fractures.

The muscle activity and the tridimensional movements around the mandibular angle causes a higher chance of displacement of the fracture segments [8,22]. In our study, all the cases had displaced fractures of the mandibular angle. The study conducted by Guimond et al on 37 cases of angle fractures showed displacement of the fracture in all except for two cases [16]. These displaced fractures cannot be reduced by simple intermaxillary fixation and require open reduction and fixation [8]. All ten cases in our study were managed surgically under general anesthesia.

The ideal goal of managing fractures includes anatomic reduction, stable fixation and immobilization followed by prevention of complications and restoration of the function [14,21]. The techniques for the repair of these angle fractures by open or closed methods have been described in abundance over the years. Open reduction was first described by Schede in 1888, with the use of steel plates and screws for the fixation. This system was later disposed of due to metal corrosion and fatigue. This was also associated with screw failure causing nonunion [7,8].

Studies done by Luhr, Spiessel and Schmoker derived inspiration from orthopedic biomechanics which showed that compression plates accelerated bone healing. This also resulted in the development of dynamic compression plating (DCP) in the early 1970's by the AO Foundation (AO/ASIF). This type of plating was ideal in the lower border to avoid any root injury. However, this could lead to splaying at the superior border during jaw movements, which could be neutralized by using a second plate in the superior surface of the fracture site. However, this was not ideal in case of oblique or comminuted fractures. Thus, surgeons sought to use a reconstruction plate in such cases as they are thicker and provide better stability [3,7,10].

A study conducted by Balasubramanian et al where they treated five patients with mandibular angle fractures using a solitary lag screw for the fixation. They concluded this method to be successful, however it is technique sensitive and hence surgical expertise is vital. The placement of these lag screws is proven to be difficult which could be why it hasn't gained much popularity [7,19,23].

Around 1973, the application of monocortical non compression miniplates was detailed by Michelet et al. These miniplates are small, easily bendable and used along with monocortical screws for the fixation of lower jaw fractures [7,8,10,19]. About five years after this, the "ideal lines of osteosynthesis" were described by Champy et al after performing a series of experiments with miniplates. As per his findings the superior border of the mandible was subject to tension and splaying while the inferior border was subject to compression. Expecting better fixation and stability, the plates were placed along these lines of osteosynthesis. In case of mandibular angle fractures, the ideal treatment, as described, was a single non-compression miniplate along the superior border of the mandible [3,7,10,11,14,15,19].

Biomechanical tests done on the mandibular angle have shown that use of two plate fixation is more stable when compared to single plate and assumed to reduce the complication rate due to this. Ellis et al in 1994 found a complication rate as high as 28% when using a second plate for fixation. However, Levy et al had no complications when double miniplates were used, but had a 20% complication rate when single plate was used for the fixation. Taking all these studies and their findings into consideration, it can be said that biomechanics is not the only factor to be considered during reduction and fixation [12,19].

In 1992, a new concept of using 3-dimensional plates for fixation of fractures was developed by Farmand et al. The geometric shape of this plate provided increased stability and resistance. It does not require contouring and is said to cause minimal damage to the inferior alveolar nerve. In our study, we used a 2mm 8-hole curved 3-dimensional titanium strut plate with a curved angle which is fixed using 2 x 3 mm titanium monocortical screws. Basically, this plate is composed of 2 mm linear plates connected by vertical struts. This style of the plate allows for greater strength against breach at the inferior border. Because of this configuration, the plates are placed such that the screws will be on both sides of the fracture line creating broad platforms and increasing the resistance against torsional forces [10, 14-16, 24,25].

Alkan et al used twenty sheep hemi mandibles to assess the different outcomes when various plating types are used for mandibular angle fractures. They reached a conclusion where the 3D plates were found to be more effective and had greater resistance when compared to the others [26]. With increasing demand for easier techniques of fixation with lower complication rates, 3-D plates are being used currently at a higher rate. We have taken up this study to assess the capability of the 3D plates and the complications associated with it.

Previously, a significant number of studies took the transoral route and fixed the plate percutaneously using a trocar [15,16,24]. In our study, we approached the fracture extraorally, using a submandibular/ Risdon's incision. Though this approach helped in easy accessibility, a large amount of masseter muscle stripping was needed due to the bulk of the plate. This excessive stripping could have interfered with the post-operative healing which was one of the disadvantages other than the scar that would be left behind.

The time frame for plate fixation was assessed intraoperatively, establishing that 30% of the cases took less than 20 minutes for the

fixation, while 70% were in the range of 20-30 minutes. Zix et al inferred that one of the advantages with these plates was its easy application as the average operating time was much less when compared with other techniques. Similarly, Barde et al and Feledy et al in their analysis have also shown that the use of 3-D plates has reduced the operating time [10,27].

One more advantage of the 3-D strut plates is the stability that it provides [15,16,21,24]. It was seen in our study that after the last screw was placed and fixation was complete, there was no movement of the plate or fracture fragment in any of the cases. It was also observed in previous studies that movement of the plates was one of the causes of postoperative infections. This problem was minimised by the use of 3-dimension strut plates due to its increased stability which prevents movement of the plate or the fracture fragments [27].

In this study, the stability post-operatively was assessed using digital palpation inspecting for any mobility in the area of the fixation. We had good stability in all cases immediately after the surgery. One patient had to undergo plate removal after a month so we did not include this patient in our follow up. But, all remaining cases had good stability even during the second follow up after 6 months. The process of osteosynthesis requires a minimum of hardware with increased stability, which was provided by the 3-D strut plate. Due to its geometric design it provided increased stability and resistance to forces thus preventing any movement to occur [28].

Occlusion was the key to assess results in the management of these fractures. Any discrepancies were noted during each follow up and scored accordingly. The assessment was conducted by a prosthodontist along with an oral surgeon. According to our prosthodontist, there were two cases post-operatively with severe occlusal disturbance while four had minor and remaining four had no occlusal disturbances. The oral surgeon's evaluation showed only 2 of the ten cases had minor occlusal disturbances post-operatively, while the remaining 8 had no occlusal disturbances. These were corrected using guiding elastics and on the second follow up it was seen that all the patients had a stable occlusion. Wusiman et al in their research exhibited a relatively lower incidence of malocclusion when 3-D strut plates were used for fixation as compared to the standard miniplates [21].

Post-operative infection is one of the most common complications seen occurring in mandibular fractures and about 32% cases involve the mandibular angle. Some studies have linked the post-operative infection with the third molar tooth in the line of fracture. A study by Vineeth et al showed that the group that used conventional titanium miniplates had 20% (=2) cases with post-operative infection and both these cases had a tooth in the fracture line which was left undisturbed. The other group that used 3-D strut plates had no cases of infection [14,29].

In our prospective study of 10 patients, one of the patients developed a swelling which did not subside even with antibiotics. The fracture line in this patient's jaw was associated with a tooth which was left behind. There was no pus discharge seen. The plate was removed after a month. After this, the swelling did subside and the patient had no further complications.

Another most commonly seen postoperative complication is paresthesia. This is usually a temporary post-operative deficit. The incidence of nerve injury is linked to the level of damage caused in this region. A considerable number of studies show that the cause of paresthesia is due to the trauma in itself. One of the principal reasons for nerve damage is found to be occurring during the manipulation of the fracture. In our study, there were three cases of paresthesia, which resolved after 6 months in two cases. One of the patients had pre-operative paresthesia which continued until 6 months postoperative period [15,16,27,30].

There was no case of wound dehiscence, implant failure, non-union, malunion or loosening of screws in our study. A study conducted by Farmand in 1993 on the different types of 3-D plating for maxillofacial surgery concluded that they had only one case of plate fracture [14].

Taking into account the results of previous studies as well as the outcome of our study, it can be said that the 3-dimensional strut plate provides adequate stability and can resist the torsional forces. In addition, it is also associated with relatively lower complications. Due to its configuration similar to two miniplates interconnected by vertical bars called struts and a curved design, it did not require contouring. This design requires excessive stripping of the masseter muscle due to the increased area required for the placement of the plate over the mandibular angle region. There may be transient sensory deficit which could also be due to fracture manipulation.

CONCLUSION

Trauma is one of the world's major health burdens despite all the preventive measures being developed. The maxillofacial region is most prone to injury during trauma. In spite of being the strongest and largest of all the facial bones, the mandible is commonly injured in case of trauma to the head and neck region. The mandibular angle accounts for 25-30% of these fractures and its management is one of the most controversial. After looking at the results of our study, we can safely presume the 3 dimensional plate to be effective in mandibular angle fracture treatments. However, a larger sample size and a comparative study is necessary to prove it superior over another.

Conflict of interest

The authors reports no conflicts of interest.

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