



Comparison of bite force evaluation for mandibular angle fracture fixation by conventional miniplates versus new design miniplates: a clinical study

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Abstract

Purpose To evaluate postoperative masticatory efficacy of a new design non-compression titanium miniplate compared to conventional non-compression titanium miniplate on the basis of bite force for treatment of mandibular angle fractures.

Methodology The prospective study included 20 patients with mandibular angle fractures randomly categorized into 2 groups: Group I, fixation of angle fractures by conventional miniplates, and Group II, fixation of angle fractures by new design miniplates. Evaluation was done for clinical outcome, primarily bite force; radiological outcome; and associated postoperative morbidities at different time intervals.

Results The results showed to be highly significant in terms of mean operating time for plate adaptation and fixation and bite force adaptation ($p = 0.003$ at follow-up of 6 months) for the newer miniplate compared to the conventional miniplate. No statistically significant difference was seen for postoperative paresthesia, malunion, non-union, occlusal discrepancy, or hardware failure.

Conclusion Within the limits of the study, it appears that the single, monocortical, non-compression, superior border new design miniplate proved to be a successful procedure for treating non-comminuted mandibular angle fractures specifically in terms of enhanced postoperative masticatory efficiency as compared to conventional miniplates. Further clinical studies with larger sample size can derive a more comprehensive conclusion.

Keywords Mandibular angle fractures · Conventional miniplates · New design miniplates · Bite force · Masticatory efficiency

Introduction

With a rise in incidences of maxillofacial injuries, injury to mandible accounts for 36–70% [1] because of its prominent position on face, with complications ranging from 0 to 32% [2].

Mandibular angle fractures account for 23 to 42% of all mandibular fractures; several inherent anatomical vulnerabilities, thinner cross-section relative to the ramus and body, and a complex convergence of torsional and shear forces

along with its direct proximity to the third molar make it more vulnerable to traumatic injuries [3].

The traditional concept by Michelet involves semirigid functionally stable fixation by incorporating a single 4-hole or 6-hole monocortical osteosynthesis plate on the tension zone intraorally. Authors have argued that internal fixation with a passive miniplate along the external oblique line, in accordance with Champy's ideal osteosynthesis line principle, produces a tension effect that might yield a failed osteosynthesis or a compromised stability [4]. Also, biomechanical studies have found fixing one miniplate along the superior border not being functionally stable as distraction of lower border of mandible was seen when vertical loading forces were applied close to the fracture line [5].

Mandibular fractures adversely affect masticatory apparatus in the form of masticatory muscle tear or injury. Even after achieving satisfactory occlusal position surgically, it is uncertain whether the patient can withstand occlusal loads,

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secondary to the changes in hard and soft tissue components of the masticatory apparatus either due to the fracture and/or its surgical treatment [6, 7]. Bite forces are a significant parameter of masticatory function and are also relatively easy to measure and analyze. Thus, when used in patients treated surgically for mandibular fractures, records of maximum occlusal forces act as excellent assessment criteria for restoration of skeletal architecture and repair and healing of masticatory soft tissues [8–10].

Thus, a continuing quest for a simple, but effective technique drove us to use this new design miniplate for mandibular angle fractures to utilize bite force as an assessment tool for postoperative masticatory efficiency, also overcoming the disadvantages of the other plating techniques but utilizing the benefits and simplicity of the Champy technique.

Materials and method

This study included 20 patients with mandibular angle fractures treated in the Department of Oral and Maxillofacial Surgery, Ahmedabad Municipal Dental College & Hospital, Ahmedabad.

Patients having noncomminuted angle fracture of the mandible were included irrespective of age and sex. Patients having (1) comminuted or infected fracture, (2) malunited or non-united fracture, (3) medically compromised patients, and (4) not committed to follow-ups were excluded. Attempt was made to equally distribute all the types of fractures in terms of location and pattern between both the groups.

After obtaining their informed consent, stratified randomization of the patients was done by creating strata based on fracture location into 2 groups of 10 patients each. Group A underwent open reduction and internal fixation of mandible with conventional 2.0-mm titanium non-compression plates at the superior border of external oblique ridge via transoral approach (Figure 1). Group B was treated with open reduction and internal fixation of the mandible with new design 2.0-mm titanium plates at the superior border of external oblique ridge via transbuccal approach (Figure 2).

A standardized surgical protocol was followed in all the patients. All patients were operated under general anesthesia. Following strict aseptic precautions, a transoral approach was used to access the fracture site. If indicated, the third molar in the line of fracture was extracted.

The fracture site was identified and reduced to obtain satisfactory occlusion by maxillo-mandibular fixation (MMF). The associated fractures were treated using standardized site specific surgical protocols (ORIF) in both the groups.

Fixation for angle fracture was done using either conventional or new design miniplates after adapting it intraoperatively over the site following Champy's principles.

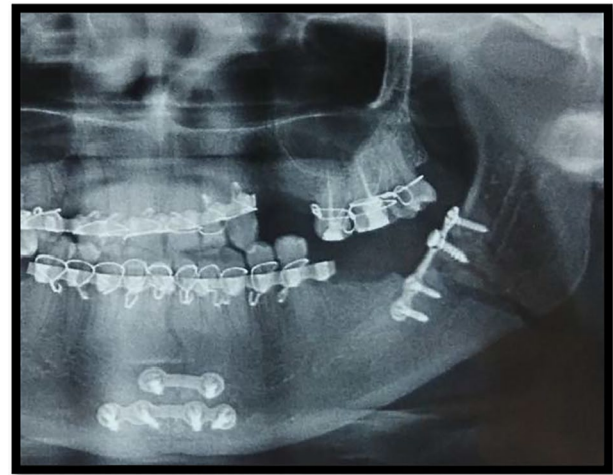


Fig. 1 Postoperative panoramic radiograph: treated with conventional miniplate system.

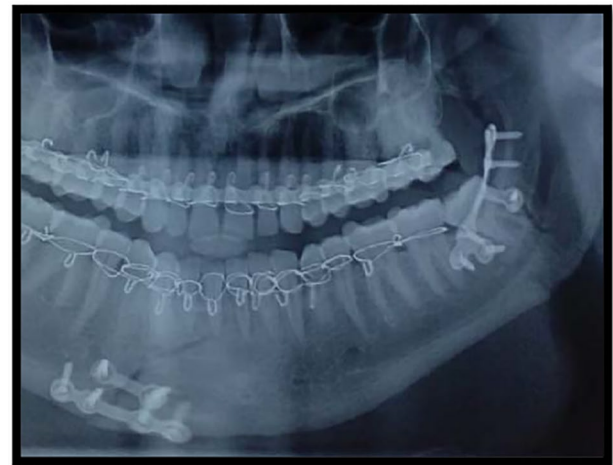


Fig. 2 Postoperative panoramic radiograph: treated with new design miniplate system.

Dimensions of plates and screws (manufacturer: Orthomax)

Control group: 2.0-mm conventional titanium miniplate with total 4 holes with gap and 1.5 mm thickness.

Study group: 2.0-mm new design titanium miniplate with total 6 holes and 1.5 mm thickness:

- A straight 4-hole bar
- Two lateral extension vertical bars with 1 hole each
- Longer lateral arm extends towards the proximal segment of the mandible

Screw dimensions for both the groups: self-tapping titanium screws with diameter 2 mm and length 8 mm.

Intimate passive adaptation of the conventional plate was done over the superior border of external oblique ridge. Drill bit was inserted transorally and holes were drilled perpendicular to the cortex under copious saline irrigation after which fixation was done using 4 monocortical screws. New design titanium plate was also adapted by placing horizontal bar perpendicular to fracture line over external oblique ridge and vertical arms parallel and equidistant to it over the buccal cortical plate. Using drill bit transorally, 4 holes were drilled on the horizontal bar of new design miniplate and fixation was done using 4 monocortical screws, after which trocar was used to drill 2 holes transbuccally for both the lateral arms of the plate and fixation was done (Figure 3). All the screw holes were drilled by ideal technique of being perpendicular to the bone. After confirming occlusion and achieving proper hemostasis, wound closure was done with 3-0 Vicryl sutures intraorally and 4-0 Ethilon suture extraorally.

The comparison between Group A and Group B was based on evaluation of clinical and radiological outcome and associated postoperative morbidities at different time intervals. Suture removal was done on the 7th postoperative day and on the 10th day, IML elastics were removed. Subsequent follow-up was done at the 12th day, 1 month, 3 months, and 6 months.

Parameters evaluated were as follows:

1. Duration of surgery—recorded from the time incision was placed till the closure of wound
2. Postoperative infection if discharge had positive culture test
3. Malunion or non-union—based on clinical examination and radiographical evaluation
4. Hardware failure—based on screw loosening and plate fracture by clinical examination and radiographical evaluation



Fig. 3 New design miniplate: adaptation and fixation over mandibular angle fracture.

5. Paresthesia—based on clinical examination and information obtained from the patients
6. Occlusal status—pre-operative and postoperative occlusion, intact/deranged, after asking patient to occlude in maximal intercuspation
7. Wound dehiscence—based on clinical examination
8. Bite force measured at the molar area on the fractured site and contralateral side, as well as incisal area pre-operatively before arch bar wiring and postoperatively at the 12th day, 1 month, 3 months, and 6 months

Bite force measurements were made using an indigenous bite force recorder. The recorder consisted of strain gauges mounted on steel bars. Load changes in the steel bar produced a measurable voltage change across the strain gauges. Readings were displayed on the digital monitor in kilogram unit. All measurements were taken with the patient seated upright with an unsupported natural head position and looking in forward direction. The patients were instructed to bite as forcefully as possible on the pads of bite force gauge to the maximum level and bite force values were recorded.

Radiographic evaluation via orthopantomogram was done at the 12th day, 1 month, 3 months, and 6 months to assess any postoperative complications.

All results were tabulated and statistical analysis was done by percentage, Pearson chi-square test, Fisher’s exact test, and independent sample *T*-test as per the indication. The significance level was set at $p < 0.05$.

Results

The study included a total of 20 patients (16 males and 4 females); 8 males and 2 females were randomly distributed into control (group A) and test groups (group B) with the mean age of the participants ranging from 34.6 ± 14.91 years in the control group and 28.1 ± 5.06 years in the test group (Table 1).

Accidental fall (50%) was found to be the major cause for mandibular angle fracture, followed by road traffic accident

Table 1 Age and gender.

Age group (in years)	Control group		Study group	
	Male	Female	Male	Female
11–20	1		1	
21–30	4	2	3	
31–40	3		2	2
41–50	0	0	0	0
51–60			1	
61–70			1	
Total	8	2	8	2

(35%) and physical assault (15%). The Pearson chi-square test analysis found no statistical significance.

Seventy percent of the fractures occurred at two sites (14 patients), 20% with isolated fracture site (4 patients), and 10% with 3 fractured sites (2 patients).

Twelve cases of (60%) mandibular angle + parasymphysis fracture, 4 cases (20%) of isolated angle fracture, 2 cases (10%) of angle + condyle, and 2 cases (10%) of angle + parasymphysis + condyle fracture were present.

Both groups had a case of vertical fracture in the associated third molar teeth which were extracted intraoperatively according to the standard protocol.

Mean operating time was more in the study group (58.50 ± 2.64 minutes) than the control group (45.60 ± 2.57 min). Statistical analysis using independent sample *T*-test showed highly significant (HS) difference of operating time for plate adaptation to fixation between two groups ($p < 0.003$).

Mean comparative difference was analyzed using independent sample *T*-test in relation to the baseline values of the control group and study group for interincisal distance on pre-operative day, postoperative 12th day, 1st month, 3rd month, and 6th month. At the end of 6 months, the study group had mouth opening (MO) 40.3 ± 1.69 mm while the control group had MO 36.6 ± 4.66 mm although there was slight improvement in the study group than the control group mathematically and clinically; the difference was not statistically significant ($p = 0.465$).

Bite force was evaluated for all patients of the study, standardly on the incisal area, molar area on the mandibular angle fractured side, and molar area on the contralateral side of the angle fracture.

Using independent sample *T*-test, mean comparative difference was analyzed in relation to the baseline values of the control group and study group for bite force on

pre-operative day, postoperative 12th day, 1st month, 3rd month, and 6th month (Table 2).

1. Bite force on the incisal area → no statistically significant difference (at the 6th month, study group: 11.81 ± 1.09 kg, control group: 9.38 ± 1.31 kg, $p = 0.172$).
2. Bite force on the molar area on the fractured angle side → highly statistically significant difference on the 1st month ($p = 0.023$) (study group: 10.72 ± 0.77 kg, control group: 7.34 ± 1.12 kg) and 6th month ($p = 0.003$) (study group: 14.13 ± 0.38 kg, control group: 9.38 ± 1.35 kg); there was marked increase in bite force of the study group when compared to the control group.
3. Bite force on molar area on the contralateral side of fractured angle → highly statistically significant difference on the 6th month ($p = 0.013$) (study group: 13.47 ± 0.50 kg, control group: 9.84 ± 1.22 kg); there was marked increase in bite force of the study group when compared to the control group.

Using independent sample *T*-test, mean comparative difference was analyzed in relation to bite force between the control group and study group by calculating the difference in bite force between the 12th postoperative day and 6th month findings (Table 3).

1. Incisal area → no statistically significant difference (study group: 7.90 ± 1.013 kg, control group: 3.95 ± 1.608 kg).
2. Molar area on the fractured angle side → statistically significant difference ($p = 0.003$) (study group: 8.50 ± 0.845 kg, control group: 3.61 ± 1.181 kg); there was marked increase in bite force of the study group when compared to the control group.

Table 2 Bite force measured at different intervals in kilogram (NS non-significant, HS highly significant)

Site	Day	Control group	Study group	<i>p</i> value	Significance
Incisal area	Pre-op	3.31 ± 0.43	2.33 ± 0.30	0.077	NS
	12th day	5.55 ± 1.22	3.91 ± 0.73	0.265	NS
	1st month	5.87 ± 1.07	7.09 ± 1.17	0.453	NS
	3rd month	8.73 ± 1.32	10.34 ± 1.34	0.404	NS
	6th month	9.38 ± 1.31	11.81 ± 1.09	0.172	NS
Angle fracture molar side	Pre-op	2.09 ± 0.39	2.46 ± 0.33	0.479	NS
	12th day	6.41 ± 1.19	5.63 ± 0.63	0.570	NS
	1st month	7.34 ± 1.12	10.72 ± 0.77	0.023	HS
	3rd month	8.68 ± 1.49	11.97 ± 1.27	0.111	NS
	6th month	9.38 ± 1.35	14.13 ± 0.38	0.003	HS
Contralateral molar side	Pre-op	5.36 ± 0.76	4.69 ± 0.64	0.507	NS
	12th day	8.11 ± 1.06	6.12 ± 0.62	0.124	NS
	1st month	10.17 ± 0.85	11.30 ± 0.69	0.315	NS
	3rd month	9.58 ± 1.32	11.80 ± 1.19	0.227	NS
	6th month	9.84 ± 1.22	13.47 ± 0.50	0.013	HS

Table 3 Difference in bite force between the 12th post-operative day and 6th month in kilogram (*NS* non-significant, *HS* highly significant)

Group		Mean	Std. deviation	Mean difference	<i>p</i> value	Significance
Incisal area	Control group	3.95 ± 1.608	5.09	− 3.95	0.052	NS
	Study group	7.90 ± 1.013	3.20			
Molar fractured side	Control group	3.61 ± 1.181	3.74	− 4.89	0.003	HS
	Study group	8.50 ± 0.845	2.67			
Molar contralateral side	Control group	2.69 ± 1.403	4.44	− 4.65	0.011	HS
	Study group	7.35 ± 0.829	2.62			

3. Molar area on the contralateral side of fractured angle → statistically significant difference (*p* = 0.011) (study group: 7.35 ± 0.829 kg, control group: 2.69 ± 1.403 kg); there was marked increase in bite force of the study group when compared to the control group.

Postoperative assessment for complications was done for the following parameters at an interval of 12 days, 1 month, 3 months, and 6 months using Fisher’s exact test:

- Postoperative paresthesia, malunion, non-union, occlusal discrepancy, or hardware failure → no case reported in either of the groups.
- No lateral displacement of lower border of mandible was seen in either of the groups clinically or radiographically.
- Wound dehiscence → 1 patient of the control group reported with infection and wound dehiscence on the 3rd month follow-up due to poor oral hygiene. Plates were removed after 6 months as recurrent pus discharge was found. One patient of the control group came with an infection in the angle region on postoperative 1 month. Oral antibiotics were given for 5 days and oral hygiene maintenance was advised.

Discussion

One of the most common mandibular fractures, mandibular angle fracture, occurs either isolated or in association with other fractures, mainly because of the presence of third molars, a thinner cross-sectional area than the tooth bearing region, and biomechanical angle being a “lever” area [11].

Numerous studies evaluating fixation of mandibular angle fractures have been done over decades, but to the best of our knowledge, very few studies have evaluated the bite force while treating mandibular angle fractures.

The most useful techniques evaluated were either an extraoral open reduction and internal fixation with the AO/ASIF reconstruction plate or intraoral open reduction [12] and internal fixation using a single miniplate [13]. However, studies have shown that these findings are not universal

and rather, two miniplates perform better than one [14–16]. Function of the masticatory system depends on the occlusion, number of muscle fibers, and the force created by these fibers. Injury to this system due to mandibular angle fractures highly distorts the chewing efficiency. Gradual healing with restoration of optimum bite forces is a necessary criterion for successful treatment outcome. Utilization of bite force as an objective assessment tool to regain masticatory efficiency following surgical management of mandibular fractures has been stated by Patel et al. [9].

Also, in vitro studies have reported that a gap appeared at the lower border under functional loading when a single plate was used as it did not resist the torsional forces [17–19]. The second miniplate theoretically establishes a second line of osteosynthesis, which protects the fracture site against torsion and bending, and provides increased stability [5]. Henceforth, we used new design miniplate functioning as 2 plates fixed in biplanar manner.

Our study evaluated enhanced postoperative masticatory efficiency along with resistance to lateral displacement of this new design miniplate by comparing the results with the cases treated with a conventional miniplate via transoral approach in cases of mandibular angle fractures.

In this study, prevalence of mandibular fractures was higher in males (80%). This is in conformity with the studies of Saikrishna et al. (92.5%)[20], Singh et al. (92%)[21], Motamedi (89%)[22], Rashid et al. (87%) [23], and Ogunbare et al. (86%) [24] with majority of patients between the age group 20 and 68 years as in studies by Rashid et al. [23], Saikrishna et al. [120], and Motamedi [22].

The main cause of mandibular fractures was fall (50%) followed by RTA (35%) and then by assault (15%). This is in correlation with the studies by Yildirgan et al. [25] and Tatsumi et al. [26] and in contrast to studies of Singh et al. [21], Saikrishna et al. [20], and Paul et al. [27].

Here, we treated 38 mandibular fractures in 20 patients out of which there were 12 cases of (60%) mandibular angle + parasymphysis fracture, 4 cases (20%) of isolated angle fracture, 2 cases (10%) of angle + condyle, and 2 cases (10%) of angle + parasymphysis + condyle fracture. All the associated fractures (which were confounding factors) were treated with titanium 2.5-mm miniplate system. The

unilateral non-displaced angle fractures were treated after randomization by open reduction and internal fixation using conventional miniplates or newer design miniplates.

The control group was treated by intraoral approach using the conventional miniplates. The study group was treated via intraoral and transbuccal approach using a trocar cannula by a new design miniplate. The design was in accordance with a study done by Khiabani et al. [28] in which through finite element analysis, he concluded that in order to biomechanically rebuild optimal mastication force in patients with fracture of the lower angle of the jaw, it is recommended to use two miniplates in two different planes.

In both the groups, fixation was done by principles advocated by Champy et al. [18].

Kale et al. advocated that placement of screws was easier through the transbuccal approach using a trocar cannula, in accordance with the study conducted that cheek retractor incorporated in the trocar retracted the cheek tissue thereby exposing the fracture site completely and providing excellent visibility and accessibility. The main advantage here was to get a perpendicular access for drilling holes and screw fixation [29].

Teeth in the fracture line were extracted only if they were carious/fractured/pathologically involved. In one out of ten patients in each group, vertically fractured tooth was present in the fracture line which was extracted intraoperatively.

Mean duration of surgery was more in the study group (58.50 ± 2.64 min) as compared to the control group (45.60 ± 2.57 min) because lateral arms of the new design plate required a precise adaptation of plate to the bone across the fracture line for superior stability. Placement of trocar system also demanded for some more amount of time.

Using a custom-made gnathodynamometer, bite force was measured at the incisor and molar regions pre-operatively and on postoperative 12th day, 1st month, 3rd month, and 6th month. Bite force generated by patients treated with new design plates at the incisal region during all follow-ups did not show any significance but the bite force measured at the molar area on the fractured side and contralateral side showed significantly higher values on follow-up of 6 months. Encouraging results were seen similar to a study done by Yadav et al. [30] and Saxena et al. [31] wherein increase in bite force was seen after treating mandibular angle fractures using 3D miniplates.

This was also aligning with data provided by Suer et al. [3] from their study in which they did a biomechanical evaluation of this plate *in vitro* and concluded that new miniplate provided more biomechanical stability than the conventional Champy technique. It provided greater stability when subjected to lateral displacing forces leading to undisturbed healing and thus superior reduction of fractured mandible. This new design also offered a plating technique

with very few major complications, such as facial nerve injury or visible scar tissue.

In the present study, there was no occlusion discrepancy in any of the groups in accordance with the studies of Koshy et al. [32] and Thapliyal et al. [33].

There was no significant difference for interincisal distance on pre-operative day, post-operative 12th day, 1st month, 3rd month, and 6th month follow-up. Though the mean interincisal distance was slightly higher in the study group, the difference was not statistically significant as in studies by Vineeth et al. [34] and Al-Moraissi and Ellis [2].

There were no associated complications encountered for any of the cases in the study group. While there were two cases of infection and wound dehiscence in the control group, both were treated without any further major complications. Clinical and radiographic assessment for healing was done in both the groups at the end of 12 days, 1 month, 3 months, and 6 months. At the end of 6 months, both groups had completely satisfactory bone healing.

Patients were followed up at the 12th day and 1st-, 3rd-, and 6th-month interval and orthopantomograms (OPG) were taken to assess reduction and stability of the fractures. All cases showed well united fracture fragments with complete obliteration of the fracture line and absence of any radiolucency at fracture site.

Considering the financial aspect, because the study group system requires use of transbuccal trocar, cost of plate was more compared to the conventional one. However, the difference in the cost can be counted negligible considering the proven advantages of the plate.

Conclusion

From our study, it can be concluded that bite force is a reliable parameter for assessing postoperative masticatory efficiency. Results imply towards the use of new design miniplate as it exceeded conventional miniplates in terms of withstanding masticatory load efficiency during osteosynthesis which leads to early restoration of chewing efficiency. It imparted better resistance to masticatory load, superior biomechanical stability, precise anatomical reduction, and uneventful healing at a cost-effective rate. Additionally, being biplanar, one plate itself compensates for the need of 2 conventional miniplates for treating the same fracture. It also has associated drawbacks such as need for transbuccal approach and increased operating time. The small sample size can be considered the limitation of this study. Henceforth, it is recommended to have a multicentric study with a larger sample size, long-term follow-up, additional electromyography (Bither et al. [35]), and correlation among these studies to authenticate our claims.

Author contributions All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by Dr. MG, Dr RS, and Dr. YP. The first draft of the manuscript was written by Dr. YP, Dr KS, and Dr ZB. Data tabulation was done by Dr YP. Critical revision of manuscript was done by Dr. HV and Dr. RS All authors read, reviewed, and approved the final manuscript.

Data availability All data generated or analyzed during this study are included in this published article.

Declarations

Ethical approval This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of AMC Dental College, Khokhra, Ahmedabad (Ref. No. AMC/IEC /OS/PG20/17).

Consent to participate Informed consent was obtained from all individual participants included in the study.

Consent for publication The authors affirm that human research participants provided informed consent for publication of the images in Figures 1, 2, and 3.

Competing interests The authors declare no competing interests.

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