Assessment of Bite Force in Patients Treated with 2.0-mm Traditional Miniplates versus 2.0-mm Locking Plates for Mandibular Fracture

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Abstract

The objective of this study is to analyze the difference in bite forces in patients treated for mandibular fractures with 2.0 mm conventional and locking titanium plating system. A randomized study was performed for the treatment of fractures of mandible. In this study, 20 adult patients with isolated mandibular fracture were included. The patients were randomly allocated into two groups, that is, Group I—2.0 mm nonlocking (traditional) and Group II—2.0 mm locking plates. Bite force was evaluated at 1st, 3rd, and 6th weeks. Comparison of all the assessed parameters between both the groups depicted no significant difference in terms of pain, swelling including the incidence of infection, paresthesia, and hardware failure. Although same was true in case of bite force between both the groups at various time intervals, there was statistically significant increase in the bite force within the group comprising patients in whom locking plates was used between 1st and 3rd weeks follow-up period and highly significant increase in bite force between 1st and 6th weeks of follow-up period. The rapid improvement of bite force values when locking plates were used implies that the locking plate can be used in preference to conventional plates to achieve early mobilization with assured stability in the treatment of mandibular fractures.

Keywords

- mandibular fractures
- locking plates
- nonlocking plates
- bite force

Face being the most admired part of the body, disfigurement due to trauma or otherwise would immensely affect an individual physically, physiologically, and psychologically. Hence, any disfiguring trauma or defect to the maxillofacial region needs immediate and skillful management. Therefore, no stones should be left unturned to improve the final outcome of patients with maxillofacial trauma.

With the advancement in automobile technology, increase in the number of vehicles on roads coupled with dynamic

panorama of sporting activity the world over and significant increase in the violence, maxillofacial trauma, and its management loom as a major challenge.

Mandible, despite being the largest and strongest facial bone, by virtue of its position on the face and its prominence, is commonly fractured when maxillofacial trauma is sustained. There are various anatomic and biomechanical reasons for this occurrence.¹ Osteology of mandible, the muscular attachments, and their influence and presence of

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developing or developed dentition play an important role in producing the inherent weakness and making isolated areas of the mandible more susceptible to fractures.

Surgeons began to explore the concept of open reduction and internal fixation. Techniques used in orthopedic fracture management (Arbeitsgemeinschaft für Osteosynthesefragen/Association for Study of Internal Fixation) (AO/ASIF) were borrowed and applied to maxillofacial surgery.²

Various techniques such as intraosseous wires, external pins, intramedullary pins, and plates and screws were tried by various experts—Roberts (1964), Battersby (1967), and Becker (1974) in the United States and Luhr (1960), Spiessl (1970), and Champy in Europe—in an attempt to overcome the disadvantages of intermaxillary fixation.³

From then, the hardware available for the treatment of mandibular fractures has been in a constant state of evolution and recently, designs such as the three-dimensional plates and locking plates have been introduced in maxillofacial surgery as a new treatment modality.^{4,11}

The aim of mandibular fracture treatment is to restore anatomical form and function, with particular care to re-establish the occlusion and thereby the bite force. The relationship of the bite force to the method of fixation has been studied previously by some authors. The pioneering work of Gerlach and Schwarz⁵ revealed that the maximal bite force in patients with mandibular fractures treated with miniplate osteosynthesis had reached only 31% at 1 week postoperatively compared with a healthy control group. This value had increased to 58% at 6 weeks postoperatively. Agarwal et al⁶ further emphasized the role of adequate fixation by reporting a statistically significant increase in the bite force on subsequent visits in patients with locking miniplates than non-locking miniplates. The current study was done with the sole purpose to analyze the variation in the bite force following open reduction and rigid fixation using 2 mm locking plates with 2 mm standard miniplates in fixation of mandibular fractures.

Materials and Methods

A randomized study was conducted at the Department of Oral and Maxillofacial Surgery, performed from August 2012 to August 2014. The institutional reviewer board and local ethical committee had approved the study. The study followed the criteria as declared by Helsinki. In this study, 20 adult patients without any systemic complications, who strictly met the inclusion criteria, were included. The inclusion criteria were noncomminuted fractures of mandible, patients requiring open reduction and internal fixation. The exclusion criteria were mandibular fracture with infection and a history of diabetes, uncontrolled hypertension, prolonged steroid therapy, compromised immunity, or associated bone pathologic features, alcoholics, and fracture older than 7 days.

The diagnosis was made on the basis of the clinical examination findings and radiographic interpretation. Routine investigations were performed. All patients provided informed consent before participating in the present study.

Randomization of consecutive patients was done using slot method, irrespective of age, and gender. To remove the bias, a single surgeon had operated on all the patients under standard aseptic conditions and protocol.

The individuals were randomly allotted to either Group I or Group II. Patients in Group I were treated by open reduction and internal fixation, through an intraoral approach using titanium conventional miniplates and screws, and individuals in Group II were treated by open reduction and internal fixation, through an intraoral approach using titanium locking miniplates and locking screws. Open reduction and internal fixation for all patients were done under general anesthesia with nasoendotracheal intubation.

The cause of trauma, interval from injury to surgery, average age, gender, and site distribution were all assessed. Follow-up was done at the 2nd day of 1st, 3rd, and 6th weeks. The following clinical parameters were assessed for each patient at each follow-up visit: pain (visual analogue scale 1–10), swelling, infection, paresthesia, hardware failure (plate fracture), mobility between fracture fragments, and bite force recording at the incisor, right molar, and left molar regions.

All bite force measurements were made using an indigenous bite force recorder, designed at the Research Designs and Standard Organization. All measurements were made with the subject seated with the head upright, looking forward, and in an unsupported natural head position. The subjects were asked to remain in this position throughout the trial and to refrain from extraneous movement. Bite forces were measured at the incisor and right and left molar regions taken as reference points. The subjects were instructed to bite on the pads of bite force gauge to the maximum level. This was accomplished by instructing the subject to bite as forcefully as possible and bite force values were recorded. Calibrations of the strain gauge unit were done outside the mouth before and after every bite sequence and when calibrations deferred records obtained in the mouth were discarded.

Statistical Analysis

A null hypothesis was proposed that there is no significant difference in the mean bite force (Newtons) of the two groups, that is, $\mu_1 = \mu_2$. Along with alternate hypothesis, it was stated that there is a significant difference in the mean bite force (Newtons) of the two groups, that is, $\mu_1 \neq \mu_2$.

A level of significance of $\alpha = 0.05$ had been put. To compare the mean bite force of the two groups, analysis of variance (ANOVA) is used. A *p*-value is compared with the level of significance. If $p < 0.05$, alternate hypothesis is considered and concluded that there is a significant difference in the mean bite force (Newtons) of the groups. Otherwise, the null hypothesis is accepted.

If there is a significant difference between the groups, multiple comparisons (post hoc tests) using Bonferroni test are performed.

The clinical parameters were assessed and analyzed by using a computer program statistics (SPSS Version 10.0; SPS Inc., Chicago, IL). Moreover, data were analyzed using mean

Table 1 Distribution of cases according to side involved ($n = 20$)

Side involved	No.	Percentage
Unilateral	11	55.00
Bilateral	09	45.00
Total	20	100.00

standard deviation, chi-square test, Student “Y” test, and Student “t” test (paired test).

Results

A total of 20 patients with 31 fractures (► **Tables 1** and **2**) met the inclusion criteria and were included in the present study. In Group I, 10 patients with fracture of mandible underwent osteosynthesis using standard 2.0 mm miniplates. In Group II, 10 patients with mandibular fractures underwent osteosynthesis using the 2.0 mm locking miniplates. The most common cause of injury was road traffic accidents (80% of cases). The age range of the patients was 11 to 40 years. Majority of the patients were male (85%) than female (15%). Parasymphysis was the most commonly involved site followed by the body of the mandible. Although, the preoperative occlusion was deranged in all the patients in both the groups, but functional occlusion was achieved in all patients in both the groups. Average time interval between injury and treatment was 5 days.

No statistically significant difference was found in the clinical parameters such as swelling, pain, paresthesia, and infection between the two groups ($p > 0.05$).

As depicted in ► **Tables 3** and **4**, the mean bite force steadily increased in both Group I and Group II over a period of 6 weeks following the surgery. Upon intragroup analysis of Group I (► **Table 5**), it was observed that there was an increase in bite force during the follow-up period between 1st week

Table 2 Distribution of fracture sites ($n = 31$)

Fracture site	No.	Percentage
Symphysis	01	3.23
Parasymphysis	12	38.71
Body	10	32.26
Angle	04	12.90
Ramus	00	00
Subcondyle	04	12.90
Coronoid	–	–
Dentoalveolar	–	–
Total	31	100.00

and 3rd week. But it was statistically nonsignificant. However, statistically significant increase in bite force was observed only in the incisor region between 3rd and 6th weeks of postoperative period. Increase in bite force was statistically significant in the entire areas, that is, incisor, right molar, and left molar during the time interval between 1st week and 6th week postoperative follow-up period.

Upon intragroup analysis of Group II (► **Table 6**), it was observed that there was an increase in bite force during the follow-up period between 1st week and 3rd weeks, and it was statistically significant. In contrast, a statistically significant increase in bite force was observed only in the right molar region between 3rd and 6th weeks postoperative period. The increase in bite force was statistically highly significant in the entire areas, that is, incisor, right molar, and left molar during the time interval between 1st week and 6th week postoperative follow-up period. The difference between both the groups was that there was a significant increase in bite force between 1st week and 3rd week follow-up period in Group II, whereas there was a nonsignificant improvement in the bite force during the same time period in Group I. Intergroup

Table 3 Measurement of bite force (Newtons) within the Group I

	1st week (mean $\pm$ SD)	3rd week (mean $\pm$ SD)	6th week (mean $\pm$ SD)
Incisor region	5.46 $\pm$ 1.22	6.85 $\pm$ 1.59	8.49 $\pm$ 1.38
Left molar region	15.54 $\pm$ 4.26	18.0 $\pm$ 4.97	21.26 $\pm$ 5.70
Right molar region	16.10 $\pm$ 4.46	19.34 $\pm$ 4.99	23.08 $\pm$ 5.99

Abbreviation: SD, standard deviation.

Table 4 Measurement of bite force (Newtons) within Group II

	1st week (mean $\pm$ SD)	3rd week (mean $\pm$ SD)	6th week (mean $\pm$ SD)
Incisor region	5.54 $\pm$ 1.67	7.26 $\pm$ 1.96	8.83 $\pm$ 1.97
Left molar region	16.92 $\pm$ 2.87	19.83 $\pm$ 2.19	22.69 $\pm$ 2.09
Right molar region	16.60 $\pm$ 3.45	19.50 $\pm$ 2.17	22.79 $\pm$ 3.39

Abbreviation: SD, standard deviation.

Table 5 Intragroup comparison of bite force at different region of mandible of Group I at different time interval

	Incisor region	Left molar region	Right molar region
	<i>p</i> -Value	<i>p</i> -Value	<i>p</i> -Value
1st vs. 3rd week	> 0.05	> 0.05	> 0.5
3rd vs. 6th week	< 0.05	> 0.05	> 0.05
1st vs. 6th week	< 0.001	< 0.05	< 0.01

Note: Level of significance: $p < 0.05$.

Table 6 Intragroup comparison of bite force at different region of mandible of Group II at different time interval

	Incisor region	Left molar region	Right molar region
	<i>p</i> -Value	<i>p</i> -Value	<i>p</i> -Value
1st vs. 3rd weeks	< 0.05	< 0.05	< 0.05
3 vs. 6th weeks	> 0.05	> 0.05	< 0.01
1st vs. 6th weeks	< 0.001	< 0.001	< 0.001

Note: Level of significance: $p < 0.05$ (significant); $p < 0.001$ (highly significant).

comparison of Group I and Group II at various follow-up time intervals (►Tables 7 and 8) did not yield any statistically significant difference in bite force increase.

Furthermore, at 1st week time interval, using ANOVA, it was inferred that there was a significant difference between the two groups with respect to the mean bite force ($p < 0.001$). To verify it, multiple comparisons (post hoc test) using Bonferroni method were done and it has been shown that there is no statistically significant difference between locking plates and conventional plates with respect to the mean bite force ($p > 0.05$). However, mean bite force in locking plate group is higher than that of conventional plates but this difference is not statistically significant (►Tables 9–11). Similarly, at 6th week, there was no statistically significant difference between locking plates and conventional plates with respect to the mean bite force ($p > 0.05$). Nonetheless, mean bite force in locking plate group is higher than that of conventional plates but this difference was not statistically significant (►Tables 12–14).

Discussion

The treatment of mandibular fractures has evolved significantly in the past few decades as rigid internal fixation has become increasingly popular with both patients and surgeons. Two general treatment philosophies emerged for plate and screw fixation of mandibular fractures in the 1970s and 1980s. The AO/ASIF philosophy, which promote sufficient rigidity at the fracture site to prevent interfragmentary mobility during mandibular function, has traditionally been accomplished using large rigid plates and bicortical screws placed through an extraoral approach. A second philosophy, popularized by Champy et al,^{7–10} emphasized “The Ideal Lines of Osteosynthesis” in the mandible. This technique uses noncompression monocortical miniplates placed through transoral incision in the region of optimal stress to neutralize tension. He also emphasizes that at the level of the horizontal ramus, the movement is almost only flexion, the force of which increases from the front to the back. In the anterior part of the mandible, anterior to the first premolar, the movement is

Table 7 Comparison of bite force in Group I and Group II at different time intervals for different teeth

	Bite force	Group I (mean $\pm$ SD)	Group II (mean $\pm$ SD)	<i>p</i> -Value	Significance
1st week	Incisor region	5.46 $\pm$ 1.22	5.54 $\pm$ 1.67	0.90	NS
	Left molar region	15.54 $\pm$ 4.26	16.92 $\pm$ 2.87	0.40	NS
	Right molar region	16.10 $\pm$ 4.46	16.60 $\pm$ 3.45	0.80	NS
3rd week	Incisor region	6.85 $\pm$ 1.59	7.26 $\pm$ 1.96	0.62	NS
	Left molar region	18.0 $\pm$ 4.97	19.83 $\pm$ 2.19	0.30	NS
	Right molar region	19.34 $\pm$ 4.99	19.50 $\pm$ 2.17	0.95	NS
6th week	Incisor region	8.49 $\pm$ 1.39	8.83 $\pm$ 1.97	0.66	NS
	Left molar region	21.20 $\pm$ 5.70	22.69 $\pm$ 2.09	0.46	NS
	Right molar region	23.08 $\pm$ 5.99	23.64 $\pm$ 3.02	0.90	NS

Abbreviations: NS, not significant; SD, standard deviation.

Table 8 Comparison of bite force increase in Group I and Group II

	Group I (mean $\pm$ SD)	Group II (mean $\pm$ SD)	p-Value	Significance
Incisor region	3.03 $\pm$ 0.68	3.29 $\pm$ 0.92	> 0.05	NS
Left molar region	5.72 $\pm$ 1.98	5.77 $\pm$ 1.18	> 0.05	NS
Right molar region	6.98 $\pm$ 2.09	7.04 $\pm$ 1.68	> 0.05	NS

Abbreviations: NS, not significant; SD, standard deviation.

Table 9 Descriptive statistics: at 1st week

Group	N	Mean	Standard deviation	95% confidence interval for mean		Minimum	Maximum
				Lower bound	Upper bound		
Traditional plates	10	140.93	28.58	119.56	162.27	108.10	191.30
Locking plates	10	166.56	34.62	141.23	190.25	100.78	207.57

Table 10 Descriptive statistics: at 1st week: ANOVA; bite force (Newtons)

	Sum of squares	df	Mean square	F	Significance
Between groups	361,988.2	2	180,484.684	110.324	0.000
Within groups	43,877.765	26	1,627.874		

Table 11 Descriptive statistics: at 1st week: dependent variables; bite force (Newtons); Bonferroni

Group I	Group II	Mean difference	Standard error	Significance	95% confidence interval	
					Lower bound	Upper bound
Traditional plates	Locking plates	23.644	18.028286	0.596	-22.224	69.704

Table 12 Descriptive statistics: at 6th week

Group	N	Mean	Standard deviation	95% confidence interval for mean		Minimum	Maximum
				Lower bound	Upper bound		
Traditional plates	10	196.44	35.36	170.55	222.55	131.56	240.95
Locking plates	10	227.86	30.65	205.34	250.48	175.45	274.54

Table 13 Descriptive statistics: at 6th week: ANOVA; bite force (Newtons)

	Sum of square	df	Mean square	F	Significance
Between groups	204,410.4	2	102,154.784	58.876	0.000
Within groups	45,031.848	26	1,703.824		

Abbreviation: ANOVA, analysis of variance.

Table 14 Descriptive statistics: at 6th week: dependent variables; bite force (Newtons); Bonferroni

Group I	Group II	Mean difference	Standard error	Significance	95% confidence interval	
					Lower bound	Upper bound
Traditional plates	Locking plates	31.326500	18.355664	0.303	-15.705	78.450

mainly torsion. The forces become greater as they become nearer to the mandibular symphysis.

Although the Champy principle is clinically well adapted among the surgeons, it is not without complication. Some surgeons believed that the conventional plates based on Champy principle do not offer sufficient resistance.¹¹ Hence they used supplemental maxillomandibular fixation for several weeks following fixation with miniplates.^{5,12-17}

To overcome the problem of fracture displacement and at the same time retain the advantages of Champy conventional miniplates, the locking screw and locking plate system for maxillofacial region were extensively studied by Herford and Ellis III in 1998.¹⁸ This new design of minilocking plate provided locking of both the plate and bone interface, on either side of the fracture. Thus, a frame construct was achieved on either side of the fracture fragments. This provided better stability of the fracture fragments. Sutter and Raveh and Vuillemin et al were the first to develop the concept of locking plates in maxillofacial reconstructive surgeries. They introduced titanium hollow-screw reconstruction plate.^{19,20}

In spite of all the advantages that these locking plates and screw offer surgeon, they are still far from being the perfect treatment modality. Although clinically more efficient than a conventional plate, the locking plate still has the same complication rates.^{21,22}

The main disadvantage of the locking system has been the cost. The extra cost to the patient will be considerable burden. The surgeon should be aware of the cost difference between the two systems before selecting the plates for fixation. The locking system requires only minor additions to the conventional kit. The system requires perpendicular placement of the plate/screw interface; thus, a locking drill guide is required. The technical difficulty associated with this technique is fairly minor. Postoperative intermaxillary fixation with elastics was done for 7 to 10 days in all our patients. Previous investigators have reported excellent results with 2.0-mm miniplate fixation and a short period of maxillomandibular fixation. Follow-up examinations at 1, 3, and 6 weeks are an acceptable follow-up protocol for studying mandible fractures compared with published studies.^{6,22-25}

The knowledge about forces that are countered in mandibular fractures have been derived from maximum voluntary bite force measurement, which in healthy adult may be in the order of 15.3 kPa in the incisor, and 48.3 and 49.3 kPa in left and right molar regions, respectively (Ellis and Throckmorton, 1994).²³ The amount of force the subjects with fractures can generate is much less.⁶ Sufficient internal fixation hardware must be applied to resist the maximum forces of mastication. By doing so, the stability of fracture segment is assured even under full function of the masticatory system.⁶

Gerlach and Erle (2002)¹ stated that maximum bite force in patient with mandibular fractures treated with miniplate osteosynthesis reaches only 31% at 1 week postoperatively, compared with healthy control group. This value increases to 58% at the 6th week postoperatively.

In our study, there was increase in bite force in both the groups at subsequent follow-up, but the increase in bite force at incisor, left molar region, and right molar region was more in

Group II (locking) than Group I (nonlocking), taking at 1st week. Similarly, the bite force at 6th week in comparison to 1st week bite force; there was significant increase in bite force within group I (nonlocking) (►Table 3). Nonetheless, the values were highly significant in group II (locking) (►Table 4) at 6th week. It is supported by the fact that the screws, plate, and bone form a solid framework with higher stability in case of locking miniplate than the traditional miniplate system.^{6,24} Hence patient can generate more bite force with minimum forces across a fracture gap in locking miniplate compared with the conventional nonlocking 2.0 mm miniplate. But bite force achieved in patients of mandibular fracture treated either by locking or nonlocking miniplates failed to meet the reported maximum voluntary bite force of a healthy adult (►Tables 3 and 4). Although the maximum bite force recorded at the incisor, left molar, and right molar regions in Group I were, respectively, 8.49 ± 1.38 , 21.26 ± 5.70 , and 23.08 ± 5.99 kPa and that in Group II were 8.83 ± 1.97 , 22.69 ± 2.09 , and 22.79 ± 3.39 kPa, respectively, in the same regions, these were no match for the baseline values in healthy adult volunteers as reported by Ellis and Throckmorton which were, respectively, 15.3, 48.3, and 49.3 for the Caucasian population.²³ This could be attributed to the fact that neuromuscular protective mechanisms existing throughout the body prevent the subject to bite voluntarily beyond the zone of comfort. For instance, one of the first protective mechanisms called into play when a fracture occurs is "muscle splinting," where selective components of the neuromuscular system are activated or deactivated to take forces off the damaged bone. Moreover, a bite force is related to several factors such as tactile impulses, pain and pressure reception in periodontal ligament, and number of residual teeth thereby limiting the patient's ability to apply pretrauma bite force.²⁵⁻²⁷

Conclusion

The data assimilated from the study indicate that though there is no significant increase in bite force between two systems of plates when compared with each other, there was a highly significant increase in bite force in the group of patients in whom locking plates were used as early as at 3rd weeks. Thereby making a case for the use of locking plates in preference to conventional plates to achieve early mobility with assured stability in the treatment of mandibular fractures. Thereby allowing the patient to return to pretrauma lifestyle in terms of mandibular function in mastication, speech, and aesthetics.

Conflict of Interest

None.

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