

## Original Research Article

# Objective assessment of progressive increase in bite force post surgical correction of mandibular fractures using Nupai bite scan analyser

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### ABSTRACT

**Background:** Fracture of mandible is a common condition which is increasing in incidence in the trauma centers due to increasing motor vehicles and failure to abide by traffic regulations. Patients undergo surgical open reduction and internal fixation where post-operative occlusion and normal masticatory functions are targeted. Bite force can be taken as a guide of normal masticatory function of an individual which is dependent upon craniomandibular biomechanics. The aim of the study was to analyse bite force measurements post-operatively in patients who underwent open reduction and internal fixation for mandible fractures at different sites.

**Methods:** Molar bite force was recorded in 31 post-operative patients who underwent open surgical procedure for fracture mandible in the department of plastic surgery from January 2018 to June 2019 by a pre-scale bite force recorder-Nupai bite force prescale system (Fuji™). Various parameters were recorded pre and post-operatively including age, gender, history, comorbidities, requirement of MMF, site and number of fractures and age of injury. Bite force were compared and improvement of bite force every 2 weeks was noted and analyzed upto 6 weeks postoperatively.

**Results:** Bite force improvement was seen in all types of mandible fractures irrespective of the site and type of fractures over a period of 6 weeks post-operatively. This improvement was however not statistically significant. Decreased time interval from injury to surgery resulted in improved bite force measurements though not statistically significant.

**Conclusions:** Although objective improvement in bite force could be demonstrated but extensive study involving more subjects and more patient variables would have statistical significance.

**Keywords:** Bite force, Mandible fractures, Internal fixation

### INTRODUCTION

Fracture is defined as breach in the continuity of bone. Mandibular fractures are the second most frequent facial injuries treated at a trauma center, accounting for 36% to 70% of all facial fractures.<sup>1,2</sup> Fractures of the mandible not only cause a change in the skeletal architecture but also lead to changes in other components of the

masticatory apparatus in the form of masticatory muscle tear or injury and neurovascular injuries. Surgical treatment of mandibular fractures aims at restoration of skeletal form of the mandible with a hope that normal function and aesthetics would be restored.

Open reduction and internal fixation is the most preferred and popular treatment for fractures of the mandible. The

ultimate target of surgical open reduction and internal fixation for fracture mandible should be to attain post-operative occlusion and normal masticatory functions. Masticatory function refers to the ability of a person to masticate or chew without pain or interference. Forces applied by the masticatory muscles in dental occlusion (bite force) following treatment of mandibular fractures have received little attention. Bite force can be taken as a guide of normal masticatory function of an individual which is dependent upon craniomandibular biomechanics. The concern on the intraoral force has a long history.<sup>3</sup> In the related research, a wide range of methods and devices for the determination of bite force has been reported. These devices vary from simple springs to complex electronic devices. Today, sensitive electronic devices are used which are both accurate and precise enough for common load measuring.

Keeping in view the perceived benefits of bite force measurements on occlusion as well as patient satisfaction during post-operative recovery, it is essential that evidence in support of this should be substantiated and its feasibility and applicability in clinical situations should be validated. Hence, the present study was proposed to evaluate the post-operative bite force in patients who were treated for different types of mandibular fractures.

## METHODS

This prospective study was carried out in department of plastic surgery at Dayanand medical college and hospital, Ludhiana. All who attended the emergency or OPD from January 2018 to June 2019, willing to be a part of the study were included in the study. Ethical committee approval was obtained prior to the commencement of the study and written consent was obtained from all the cases

### *Inclusion criteria*

All patients who underwent open reduction and internal fixation for isolated mandibular fractures in the department of plastic surgery were included in the study.

### *Exclusion criteria*

Patients below 14 and above 45 years of age, with associated mid-face fractures, edentulous patients, neurosurgically compromised patients and patients with history of mental disorders, those who received tranquilizers, opioids for a long period prior to surgery were excluded from the study.

Informed consent was taken from the subjects who met the inclusion criteria prior to their enrollment in the study. The study design included a thorough case history taking in a case sheet which was custom made for the study. Pre-operatively, all patients underwent routine investigations including hemogram, fasting blood sugar, renal function tests and coagulation profile. Additionally

non contrast CT face with 3D reconstruction was done for all.

Open reduction and internal fixation for all patients was done under general anesthesia with nasoendotracheal intubation. Intraoral approach was used in the majority of cases. Sublabial/degloving incision was made, reflection of mucoperiosteal flap was done leading to exposure of fracture fragments. In the others, extraoral approach was used either submental or submandibular incision was made. Blunt dissection was performed, periosteum was incised leading to exposure of fractured fragments. In a few patients, the fractured fragments were exposed, dissecting through the existing extraoral lacerations. Anatomical reduction of fracture fragments was done, followed by intermaxillary fixation with the help of tie wires. Bone plates were placed along the lines of osteosynthesis as described by Champy. Fixation was done by one or two locking miniplates with or without gap (at least 4 hole) with at least 2 holes on either side of fracture.

After completion of surgery all patients were prescribed injection diclofenac sodium intramuscular 75 mg 8 hourly for the post-operative analgesia and injection ondansetron 4 mg intravenous to prevent post-operative vomiting. All the findings were noted including, mode of injury, time from injury to surgery, site and number of fracture lines, need for maxillomandibular fixation. Post-operatively occlusion and pain was assessed in addition to bite force assessment. Pain and chewing ability assessment was done using visual analog scale (VAS) giving a scoring of 0 to 10 and classifying it as mild (1-3), moderate (4-7) and severe (8-10). At the end of 2nd, 4th and 6th post-operative week bite force of the patients was recorded in the right and left first molar using Nupai bite scan analyser (Fuji™).

Bite force assessment was done with Nupai pre-scale film (Fuji™). It consisted of two films sandwiched over each other (Figure 1). One named A film also called transfer sheet and the other C film also called developer sheet. This method of measuring bite force was chosen because the combined thickness of both the films is 200 micrometers and hence it will not interfere in the physiologic occlusion of the teeth. The films are designed such that when there is application of external pressure to the sheets, the microcapsules of the A film is broken and stain the developer in C film in magenta. The distribution and density of the magenta color depends on the magnitude of the pressure applied. Through PSC (particle size control) technology the microcapsules are designed to react to various degrees of pressure, releasing their color forming material at a density that corresponds to the specific levels of pressure applied. Thus the pre-scale film can record the distribution of normal force applied to it. The whole assembly was covered with a water proof cellophane sheet, to prevent any chemicals from leaking out accidentally and injuring the patients.

The patients were made to sit comfortably on a chair and were asked to bite on the loaded films, as assembled, with as much force as possible and maintain the same pressure for 5 seconds. The film changed color depending on the amount of pressure applied. The bite force pre-scale paper was removed and impression was scanned (Figure 2). The scanned image interpretation was done by FPD-705 pressure distribution mapping system software and bite force at 1st molar level was recorded post operatively at 2, 4 and 6 weeks post-operatively.



**Figure 1: Nupai pre-scale film (Fuji™) before bite.**



**Figure 2: Nupai pre-scale film (Fuji™) after the bite.**

Statistical analysis was done using student t test and Chi square ( $\chi^2$ ) test. The software used was SPSS 21 software.

## RESULTS

A total of 31 patients were taken for the study 13 (41.9%) were in the age group <30 years, least percentage (22.6%) were in the age group >40 years. Majority of the patients (87.1%) were males. Most of the patients admitted for the study had history of road side accident (83.9%). Assault (9.7%) and history of fall (6.5%) accounted for rest of the cases. Hepatitis C was present in 2 of the patients (6.5%). Rest all the patients did not have any associated co-morbidities. Mostly we came across patients with single fracture (42.5%), two fractures were seen in 12 patients (38.7%) and more than 2 fractures were seen in 5 patients (16.1%). Para symphyseal fracture was the most common site identified (80.6%). Body of mandible fractures comprised 19.4% of all fractures. Angle of mandible fracture was seen in 4 patients. Symphysis of mandible fracture was seen in one patient (3.2%).

Most of the patients got operated on the second day of injury (48.4%). 35.5% of patients underwent surgery on the first day of injury. 9.7% of patients underwent surgery on third day of injury. 2 patients (6.5%) were operated on day 4 of the injury (Figure 3). Angle of mandible fractures were approached through the extraoral approach (16.1%). Rest all the other cases were approached through the intraoral route (83.9%). Postoperative maxilla-mandibular fixation was done in 19 patients (61.3%) while in 12 patients (38.7%) maxillomandibular fixation was not found necessary.

Post-operative VAS score was observed at 2nd post-op week. Most of the patients had a pain score of 4 (moderate) (38.7%). The second most common was pain score of 3 (mild pain) (35.5%). Post-operative chewing ability was assessed using VAS score (0-10), majority of the patients (77.4%) had a VAS score of 5, 19.4% had a VAS score of 4 and 3.2% had a VAS score of 3.

Majority of the patients did not demonstrate any post-operative complications at two weeks of surgery (74.2%). Paresthesia was seen in 4 of the patients (12.9%). Malocclusion and surgical site infection were seen in 2 patients each (6.5%).

The mean increase in bite force in case of parasymphyseal fractures at 4 weeks was 22 N with SD 5.5 on right side and 24.2 N with SD 6.7 on left side. At 6 weeks was 43.5N with SD 4.2 on right side and 45.1N with SD 4.7 on left side. In case of body of mandible fractures mean increase at 4 weeks was 24.9 N with SD 6.3 on right side and 25.2 N with SD 6.4 on left side. At 6 weeks was 45.1N with SD 4.4 on right side and 44.6N with SD 3.4 on left side. In case of angle of mandible fracture mean increase at 4 weeks was 18.5 N with SD 5.5 on right side and 23.0 N with SD 7.3 on left side. At 6

weeks was 41.4 N with SD 5.4 on right side and 46.4 N with SD 5.6 on left side. In case of subcondylar fracture mean increase in bite force at 4 weeks was 22.6 N with SD 5.4 on right side and 23.2 N with SD 5.3 on left side. At 6 weeks was 43.9 N with SD 4.8 on right side and 43.9 N with SD 3.9 on left side. Improvement of bite force was seen in fractures at all sites, to a lesser degree in case of subcondylar fractures. But the improvement was not statistically significant in any of the fracture sites. This difference was not dependent upon the site and number of fracture (Table 1). The increase is demonstrated but statistically not significant. There was a

definite trend in improvement of bite force when the time duration between injury and surgery was less (Table 2).

In our study the mean bite force at 2 weeks post operatively was 134.5±5.4 N for right first molar and 133±5.2 N for left first molar (Figure 4). The mean bite force at 4 weeks post operatively was 164±8.4 N for right first molar and 164.3±9.2 N for left first molar (Figure 5). A mean bite force of 193.1±8 N and 192.6±8 N was observed at 6 weeks post-operatively for right and left first molar (Figure 6).

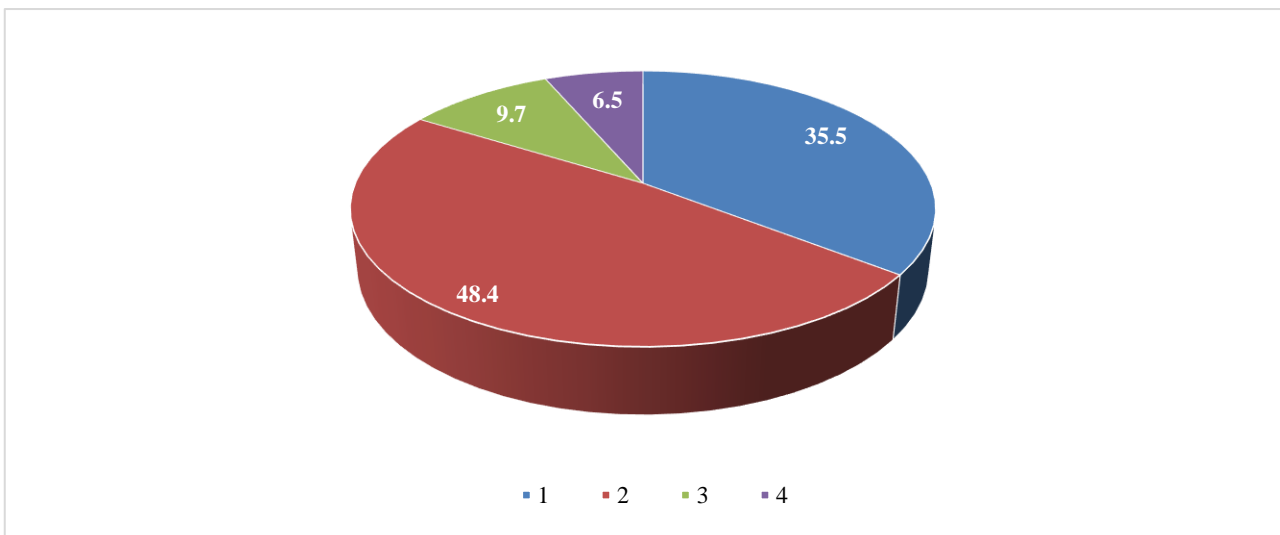


Figure 3: Distribution of patient according to duration from date of injury to surgery (in days).

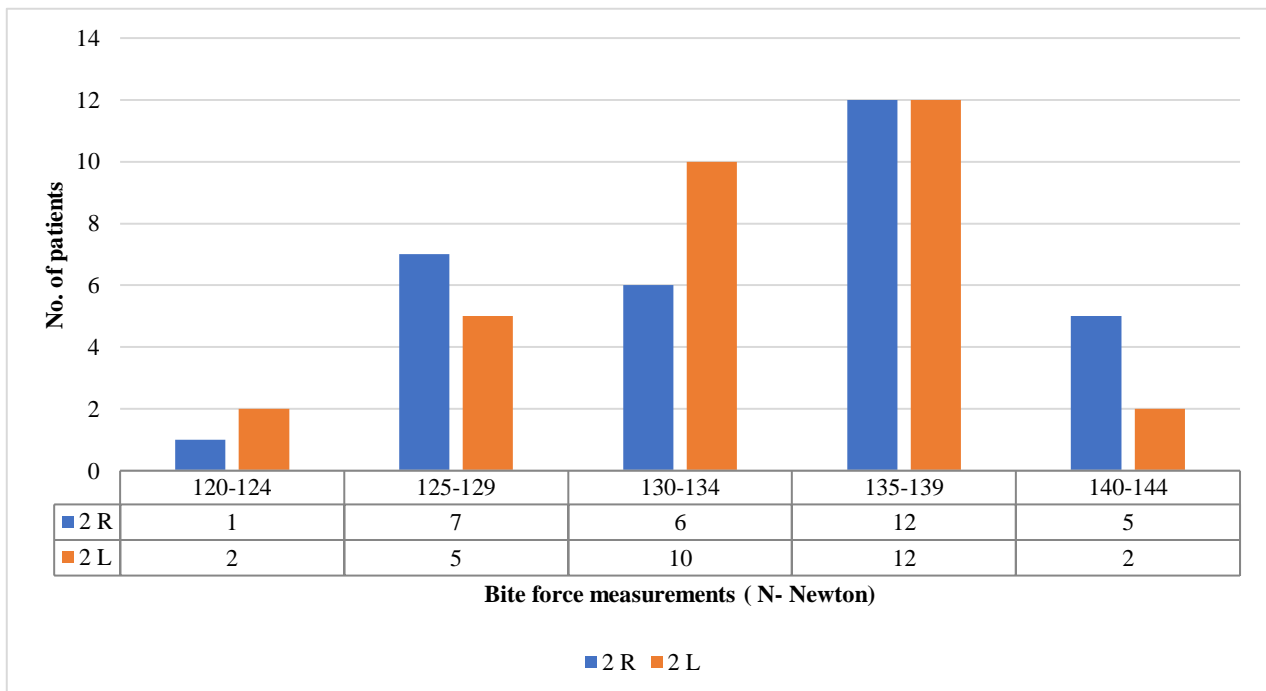
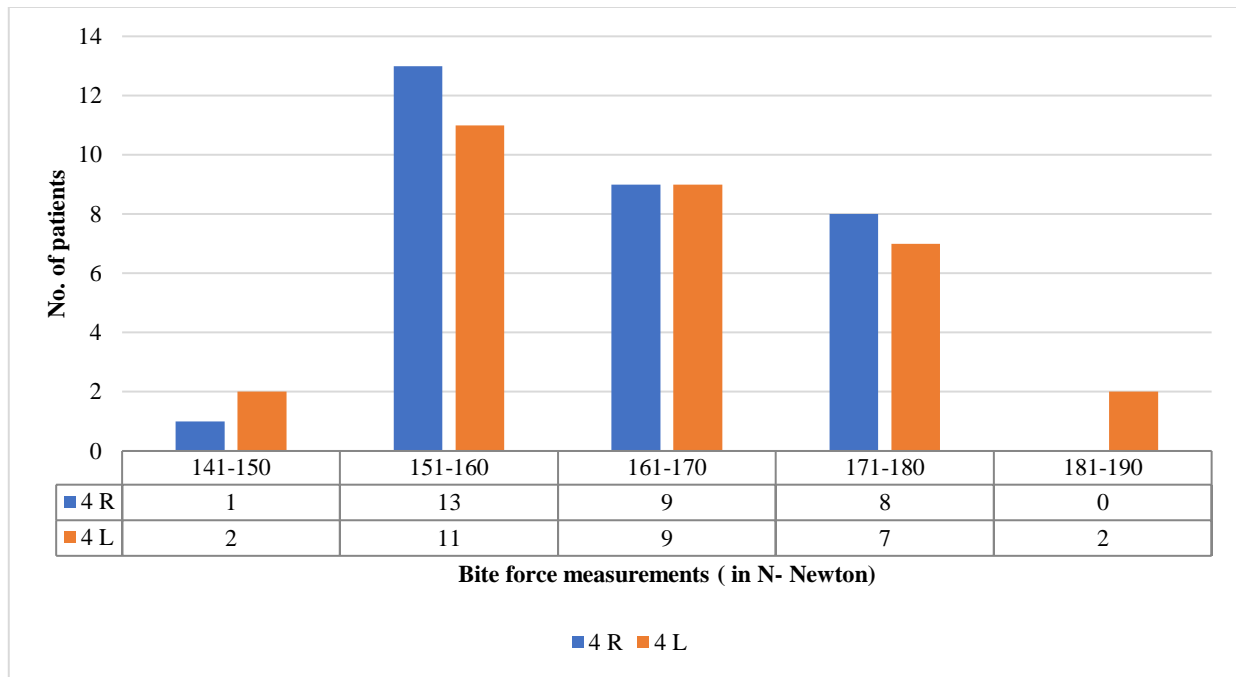
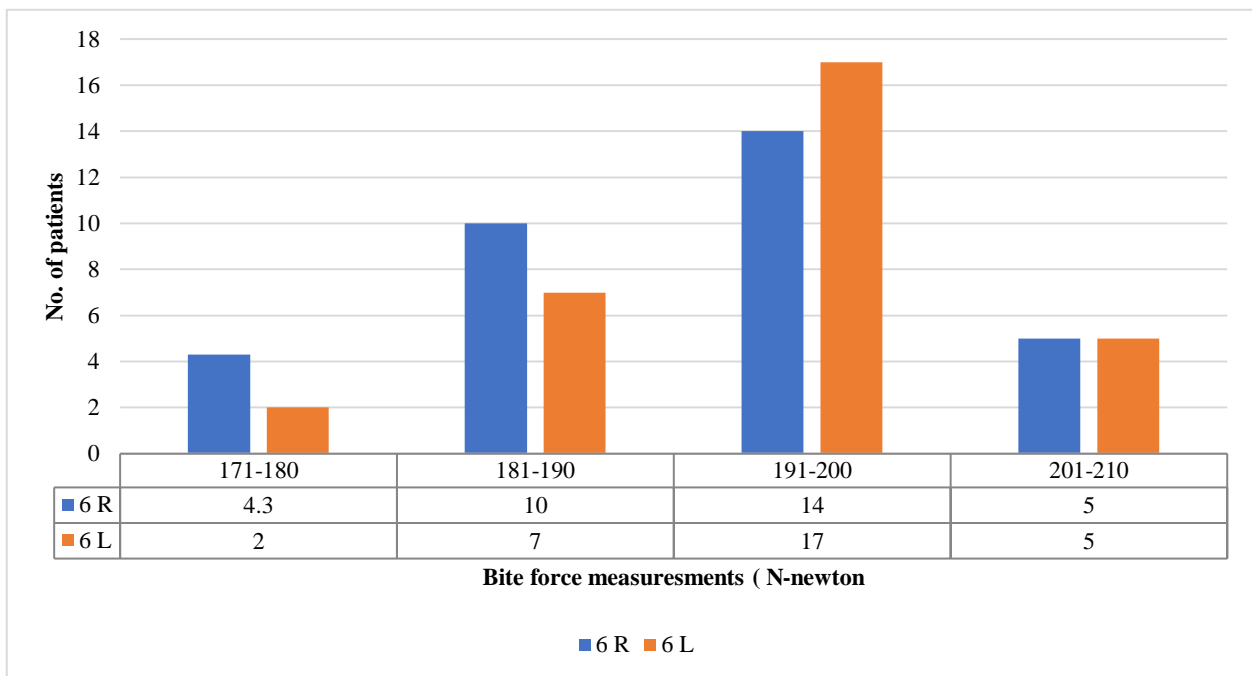


Figure 4: Distribution of patients according to bite force measurements at 2 weeks post operatively.



**Figure 5: Distribution of patients according to bite force measurements at 4 weeks post operatively.**



**Figure 6: Distribution of patients according to bite force measurements at 6 weeks post operatively.**

**Table 1: Correlation between various factors and post-op bite force ((R-right and L-left).**

Correlations	N	Minimum	Maximum	Mean	Standard deviation
Age (in years)	31	20.0	48.0	33.7	8.3
Time interval from injury to surgery	31	1.0	4.0	1.9	0.8
Post-op pain	31	2.0	5.0	3.3	0.9
Post-op chewing	31	3.0	5.0	4.7	0.5
Bite force 2 R	31	121.0	142.0	134.5	5.4

Continued.

Correlations	N	Minimum	Maximum	Mean	Standard deviation
Bite force 2 L	31	120.0	143.0	133.0	5.2
Bite force 4 R	31	148.0	179.0	164.0	8.4
Bite force 4 L	31	145.0	182.0	164.3	9.2
Bite force 6 R	31	171.0	206.0	193.1	8.0
Bite force 6 L	31	176.0	209.0	192.6	8.0
Difference at 4 weeks R	31	11.8	34.1	22.1	6.0
Difference at 4 weeks L	31	11.6	34.4	23.6	6.5
Difference at 6 weeks R	31	34.8	52.3	43.7	4.5
Difference at 6 weeks L	31	37.4	53.1	44.9	4.5

**Table 2 : Correlation between injury to surgery interval and post-op bite force (R-right and L-left).**

Time travel from injury to surgery	N	Mean	Standard deviation	Standard error	95% confidence interval for mean		Minimum	Maximum	F	P value	
					Lower bound	Upper bound					
Difference at 4 weeks R	1	11	23.9	5.0	1.5	20.6	27.3	14.2	30.2	2.519	0.079
	2	15	22.8	6.3	1.6	19.2	26.3	11.8	34.1		
	3	3	16.5	4.2	2.4	6.0	26.9	12.1	20.4		
	4	2	15.0	2.2	1.5	-4.5	34.5	13.5	16.6		
	Total	31	22.1	6.0	1.1	19.9	24.3	11.8	34.1		
Difference at 4 weeks L	1	11	24.5	5.7	1.7	20.7	28.3	15.4	34.4	2.355	0.094
	2	15	25.1	6.4	1.7	21.6	28.7	11.6	33.3		
	3	3	18.8	7.2	4.1	1.0	36.6	13.2	26.9		
	4	2	15.0	0.4	0.3	11.8	18.1	14.7	15.2		
	Total	31	23.6	6.5	1.2	21.2	26.0	11.6	34.4		
Difference at 6 weeks R	1	11	44.9	4.3	1.3	42.0	47.7	39.4	52.2	1.16	0.343
	2	15	43.7	4.7	1.2	41.2	46.3	35.3	52.3		
	3	3	39.4	4.2	2.4	28.9	50.0	34.8	43.1		
	4	2	43.2	4.1	2.9	6.4	80.0	40.3	46.1		
	Total	31	43.7	4.5	0.8	42.0	45.3	34.8	52.3		
Difference at 6 weeks L	1	11	44.1	4.5	1.4	41.0	47.1	37.9	53.1	0.421	0.739
	2	15	45.5	4.8	1.3	42.8	48.2	37.4	53.0		
	3	3	46.5	4.4	2.5	35.5	57.4	43.7	51.5		
	4	2	43.0	4.4	3.1	3.0	83.0	39.9	46.2		
	Total	31	44.9	4.5	0.8	43.3	46.6	37.4	53.1		

**DISCUSSION**

The aim of surgical open reduction and internal fixation for fracture mandible is to attain post-operative occlusion and normal masticatory functions. Bite force is one indicator of the functional state of the masticatory system that results from the action of jaw elevator muscles modified by the craniomandibular biomechanics.<sup>4</sup> The bite force measurements can be made directly by using a suitable transducer that has been placed between a pair of teeth. This direct method of force assessment appears to be a convenient way of assessing the submaximal force. An alternative method is indirect evaluation of the bite force by employing the other physiologic variables known to be functionally related to the force production. This involves assessing the electromyographic activity of the surface elevator muscles of the mandible.<sup>5,6</sup>

Therefore, bite force measurements are excellent assessment criteria for restoration of the skeletal architecture and the repair and healing of masticatory soft tissues.<sup>7</sup> Maximum voluntary bite force measurement 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.<sup>8</sup>

Various studies have been done for evaluating the intra-oral forces. At first, these studies focused on realization of the specific forces needed for various food types (Heald in 1906 and Anderson in 1955), but today they are used for other aims like examining changes in mastication and biting forces due to injuries after trauma or maxillary facial plastic surgery.<sup>9,10</sup> For this reason, the importance of devices which measure interior forces practically has been proven (Sandberg et al 1969).<sup>11</sup>

Advancement in technologies have made the measurement of bite force or pressure more easy and reliable without causing any harm to the patients. The dental pre-scale film developed by Fuji, Japan in 1977, has gained wide acceptance for measuring bite forces in recent years. The miniature size and simplicity of its use are the two main contributing factors for its increasing popularity, in comparison to the t scan system. Though the Nupai bite scan has limited application in occlusal analysis but it is more advantageous where calculating the amount of force is required.<sup>12</sup> Various authors have preferred the use of pre-scale films transducers for the following reasons: avoids patient exposure to any electrical circuits, their small size permits recording bite force in near physiologic position, with their use occlusal contact at different places in the arch can be measured at the same point of time.

In our study the mean bite force at 2 weeks post operatively was  $134.5 \pm 5.4$  N for right first molar and  $133 \pm 5.2$  N for left first molar. The mean bite force at 4 weeks post operatively was  $164 \pm 8.4$  N for right first molar and  $164.3 \pm 9.2$  N for left first molar. A mean bite force of  $193.1 \pm 8$  N and  $192.6 \pm 8$  N was observed at 6 weeks post-operatively for right and left first molar. Suzana et al in their study observed maximum voluntary molar bite force using an portable occlusal force gauge comprising of a hydraulic pressure gauge and biting element, in adult males to be to  $777.7 \pm 78.7$  N and  $481.6 \pm 190.4$  N in females with normal occlusion which was much higher than our observation.<sup>13</sup> On the contrary in a study by Braun et al bilateral bite force was measured in a sample of 457 subjects (231 males and 226 females) from 6 years through 20 years using a pressurized tube with pressure sensing element connected to a digital strain indicator and the mean maximum bite force was found to increase from 78 newtons at 6 to 8 years to 176 newtons at 18 to 20 years.<sup>14</sup> Similarly Sasaki et al in their study had physiological recordings of bite force made in the region of the right first molar by means of a customized transducer aligned perpendicular to the functional occlusal plane and observed the average bite force for randomly selected fully dentate individuals as a whole was  $189 \pm 78$  N.<sup>15</sup> The difference in bite force between the studies could be due to the fact that subjects in the study of Sasaki et al and Braun et al comprised randomly selected fully dentate adults. A normal occlusion was not a required parameter. The difference in values could possibly be due to usage of different techniques for measuring bite force.

In an in vivo experiment by Champy et al, plates which had been used to stabilize angle fractures were connected to strain gauges so that the strains within the plates could be measured within a 4 week postoperative time.<sup>16</sup> They found only traction forces from 135-300 N/mm<sup>2</sup>. During the first 3 weeks postoperatively, these values were reduced step by step down to 10% of the initial values after 4 weeks. Study by Gerlach et al shows regain in the maximal bite force values from 31% at the end of first

post-operative week to 58% at the end of fourth post-operative week.<sup>17</sup> In a comparable study Tate et al also evaluated vertical bite forces after treatment of angle fractures using two miniplates.<sup>8</sup> They found at 6 weeks postoperatively 52% of molar forces was obtained within control group and Sonnenberg and Voelker reported 50% after use of compression osteosynthesis.<sup>18</sup> Garrett et al reported much lower values during mastication.<sup>19</sup> The average biting force for each single power stroke when masticating was 16.5 N for a cracker, 22.2 N for whole-meal bread, 16.7 N for hard sausage and 34 N for bacon. These values are also lower than the vertically applied directed functional loads during the different experimental trial.

The findings of our study show that within standard post-operative bite force assessment protocol mean bite force showed increase in all types of fractures, however the increase was not statistically significant. It may be due to small sample size or individual characteristics of the patients chiefly pain, protective reflex mechanism known as muscle splinting that occurs following fracture of bones. The neuromuscular system is activated or deactivated accordingly to take forces off the damaged skeleton and traumatic and surgical damage caused to the muscle during injury and surgery, respectively. The present study was an attempt to evaluate the post-operative bite forces in mandible fracture patients and we observed that bite force value in our patients measured 6 weeks after mandible fracture reduction and fixation was within the normal range of bite force for a healthy adult. However, a more elaborate study on more number of patients with a longer period of follow up is required. A drawback of this study is that dental occlusion was not taken into consideration while assessing the bite force which can be incorporated in future studies aimed at measuring the bite force.

## CONCLUSION

Bite force is a relatively untouched area of maxillofacial surgery. With regard to trauma, the return to normal functional forces does not correspond to return of the maximum bite forces. The findings of present study show that within standard postoperative bite force assessment protocol mean bite force showed increase in all types of fractures, however the increase was not statistically significant. Decreased time interval from injury to surgery resulted in improved bite force measurements, that too was not statistically significant.

The present study was an attempt to evaluate post-operative bite force in mandible fracture patients which can aid in transitioning from liquid to semi-solid and finally full solid diet post-operatively. A more elaborate study involving more patients with a longer period of follow up is required.

The present study could also lead to other interesting studies such as a study of bite force in patients with facial

deformity undergoing orthognathic surgery as well as patients treated with implant supported prostheses. This study would throw more light on evaluation of bite force in various maxillofacial treatment procedures.

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