An Objective Tool for the Assessment of Masticatory Forces Following the Open Reduction and Internal Fixation of Posterior Mandibular Fracture

Original Article

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ABSTRACT

Objective: The purpose of this study was to to present maximum voluntary bite force as a reliable objective assessment tool for the analysis of the management of mandibular fracture.

Materials and methods: The study is a prospective case series for evaluation of the postoperative bite force in patients suffering from mandibular fracture posterior to the mental foramen and managed with open reduction and internal fixation. Statistical significance was set at the 5% level.

Results: Twelve patients were enrolled in this study. Nine of the involved patients suffered from a mandibular angle fracture, while three patients complained from mandibular body fracture. All patients across the follow-up sessions reported a statistically significant decrease in the level of the experienced pain intensity. All of the operated patients reported a statistically significant increase in the level of the measured inter-incisal mouth opening. Across the examination period, the mean reported maximum voluntary bite force showed a statistically significant increase.

Conclusion: Postoperative maximum voluntary bite force analysis is a a reliable objective tool for the assessment of the quality of posterior mandibular fracture management, outlining the favourable outcome of open reduction and internal fixation.

Key Words: mandibular fracture, bite force, Piezoresistive.

Received: 30 November 2022, **Accepted:** 4 December 2022.

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ISSN: 2090-097X, July 2022, Vol. 13, No. 3

INTRODUCTION

A common Surgeons consensus relies on the patient's subjective relief and the outcomes' long-term stability to evaluate the results of any surgery. Regaining normal bite force serves as a significant measuring tool for assessing the effects of intervention on functional abilities of the masticatory apparatus [1].

Closed mandibular fracture management is a simple method with bare minimum effect on the hospital resources and slightest surgical liability with a leeway for occlusal adjustment, despite that its use in angle fractures is not a common practice [2].

Posterior mandible fractures, especially those in the mandibular angle region, are un-dominatable by closed reduction and indirect dental fixation, as the forceful elevator muscles are attached to the lesser segment of the fracture, the distal ramus. Closed reductions in posterior mandible fractures are associated with high rate of malunions and nonunion, owing to the frequent upward and forward rotation of the ramus. That may explain the popularity of open reduction with internal fixation in the management of angle of the mandible fractures [3].

Furthermore; in order to reduce functional strain across the fracture line and hasten secondary osseous healing, the indirect skeletal fixation must be left in place for a while because it s not strong enough to offer three-dimensional stability across the fracture line during function.

Reduced patient compliance, weight loss, lost productivity, trouble with nutrition and oral hygiene, and decreased postoperative mouth opening are side effects of this lengthy period of immobilization period, along with diminished bite power, muscular atrophy, and decreased masticatory efficiency [4, 5] .

Giovanni Alfonso Borrelli became the first person to measure the Maximum Voluntary Bite Force (MVBF) experimentally [6]. Numerous investigations were carried out in an effort to establish a more precise MVBF value in light of the development in the technology at hand [7- 10].

 DOI: 10.21608/OMX.2022.177898.1177

In the assessment of the masticatory ability and the treatment success in various maxillofacial surgeries, especially in orthognathic surgery and maxillofacial fractures, evaluation of the postoperative bite force has become a more rational parameter [11,12]. The majority of the studies that were conducted agreed that the MVBF sharply declines after fracture and progressively returns to normal as healing proceeds [11- 13].

Patel et al. (2022) stated that the utilization of the MVBF is a reliable and objective assessment tool to monitor the regain in masticatory efficiency following surgical management of mandibular fracture [14].

After either a closed or an open reduction of the condylar fracture, Ellis and Throckmorton (2001) employed the biting force to assess the postoperative functional recovery and the efficacy of the treatment approach [11]. While Kumar et al. (2014) compared the treatment outcome after employing two distinct internal osteosynthesis systems using the bite force [13].Hence, this study was conducted to demonstrate wherever the measurement of mean voluntary bite force act as a reliable assessment tool for the rgain of masticatory function in posterior mandibular fracture patients, body and angle, managed with open reduction and internal fixation.

MATERIALS AND METHOD

Study Design

A prospective case series study design was conscripted in this research work to monitor the rate of regain in normal bite force in patients suffered from fracture in the posterior part of the mandible. A one-sample t-test with an 80% study power was used. To perform a sample size calculation for this study zero (Gpower 3.0.10). A total sample of 12 patients was calculated with respect to the drop in follow-up. Adherence to the Helsinki declaration guidelines, and all patients enrolled in the study signed a written consent were performed during the conduction of this study, along with the exemption from the Local Research Ethics Committee (IRB NO: 00010556-IORG: 0008839).

Inclusion criteria were set for patient recruitment from those admitted to the emergency department of the Alexandria University Teaching Hospital as subjects suffering from an isolated mandibular fracture posterior to the mental foramen are and not involving the sub-condylar region. Patients must be eligible for open reduction and internal fixation. Patient with concurrent mandibular fracture or any associated fracture in the maxillofacial region were excluded from this study.

Regarding to the state of the patient dentition, molar and canine occlusion must be available in both sides of the mandible for the patient to be enrolled in this study.

Surgical procedures

Patients were selected and operated up in the internal department of the oral and maxillofacial department, Alexandria University. All patients were operated upon under general anesthesia with nasotracheal intubation. Exposure of the fracture line was achieved with one of the following techniques

• Intraoral vestibular approach.

• A trans-buccal double plate fixation for the angle fracture, using an intraoral vestibular incision with the aid of trocar extraoral stab incision for the placement of the lower border plate.

• Extraoral submandibular approach or trans-laceration approach for body and angle fractures.In patients with body fractures, a subapical single 2.0-mm miniplate with mono-cortical screws was performed, while in mandibular angle fractures, one of the following fixation techniques was utilized:

• Single 2.0-mm miniplate with mono-cortical screws on the external oblique ridge according to Champy's guidelines.

• A trans-buccal double plate fixation, using an intraoral vestibular incision for the external oblique plate placement with the aid of trocar extraoral stab incision for the placement of the lower border plate.

• Extraoral approach or trans-laceration approach for the placement of two lateral 2.0-mm miniplate with mono-cortical screws

After the proper choice of the fixation scheme, the intraoperative temporary intermaxillary fixation was removed. Patients were instructed to a soft diet protocol for 4 weeks postoperative.

Clinical Follow-up analysis

Patients were scheduled for a follow-up protocol 24-hours postoperative and then every 1,4, and 6 weeks. In every setting wound healing, sensory nerve function, occlusion status, and interincisal mouth opening was assessed

Bite Force Analysis

A Piezoresistive force transduce FlexiForce A201 Sensor with a load range of 100 Ib, corresponding to 440 N, and 0.01 V/N sensitivity was used to analyze the bite force of the managed patients (FlexiForce sensor, Tekscan Boston, MA, USA. www.tekscan.com).

The transducer's output measurements are in Volts, so the sensor was initially pre-habituated using an equation suggested by the manufacturer to get the expressed reading in Newtons (N) [15]. The sensor consists of a pressure-sensitive ink, in an active zone of 1-cm, embedded between two polyester film layers. This flexible printed circuit comes with a final thickness of 0.2-mm (Figure 1).

Figure 1. FlexiForce A201 sensor.

At one week, four-, six-, and twelve-weeks following fracture fixation, bite force measurements were taken. In each measurement setting the sensor is placed inside a disposable clear plastic sheet to avoid coming in touch with the patient's saliva, as the sensor is unable to withstand immersion or heat sterilization. In each measurement setting the patients were positioned in a natural, unsupported position with their heads up and facing ahead. The sensor is placed in the inter-molar intercuspation area, and the patients were instructed to bite as hard as they could for 5 seconds.The MVBF was calculated for the ipsilateral and the contra-lateral sides of the fracture at the first molar areas.

Statistical Analysis

IBM SPSS for windows version 23.0. (IBM Corp, NY, USA) was used for data analysis utilizing a 5% margin as a significance level for the obtained results. ANOVA with repeated measures was utilized for normally distributed quantitative variables, while the Friedman test was utilized for abnormally distributed quantitative variables

RESULTS

Based on the sample size calculation, the study consists of twelve patients with isolated fracture posterior to the mental foramen. The included patients age ranged from 21 to 52 years, with a mean reported age of 28.2 ± 6.74 years and a male to female ratio of 1.4:1 (seven males to five female subjects). The predominant fracture etiological factor was inter-personal violence, with seven wounded subjects. This was followed by claimed falls, three patients, and sport-related violence in two subjects. Table 1 demonstrate the demographic data of the subjects involved in this study.

Table 1: Demographic Analysis of the study.

n=12	N	%
Gender		
Male	7	58.3
Female	5	41.7
Side		
Right	8	66.6
Left	4	33.3
Fracture Location		
Angle	9	75
Body	3	25
Etiology		
Interpersonal Violence	7	58.3
Claimed Falls	3	25
Sported-Related Injury	2	16.7

Eight of the involved subjects suffered from fracture in the right side of the face, in contrast to four patients with trauma in the left side of the patient. The included pool in this study was for patients with mandibular fracture posterior to the mental foramen and not involving the sub-condylar region. Nine of the involved patients suffered from a mandibular angle fracture, while three patients complained from mandibular body fracture.

Regarding the nine patients with mandibular angle fracture, five patients were approached through an extraoral submandibular incision, and the fracture was fixed with two lateral 2.0-mm miniplates with mono-cortical screws.

On the other hand, four patients were managed with a combination of an intraoral vestibular incision with a trans-buccal incision for the trocar placement, and fixation was achieved with an external oblique ridge 2.0-mm miniplate with another lower border miniplate, both with mono-cortical screws. None of the included patients was managed with a single plate fixation as per Champy's recommendation. All of the three patients with mandibular body fracture were managed with an intra-oral vestibular incision and a single 2.0-mm subapical miniplate with mono-cortical screws. Regarding the clinical follow-up criteria, the patients were followed for 6 weeks for the assessment of pain,

wound healing, sensory nerve function, state of occlusion, and mouth opening. All patients across the follow-up sessions reported a statistically significant decrease in the level of the experienced pain intensity, based on the VAS ($p<0.001$). At the end of the six weeks follow up period, all patients reported zero to 1 VAS score, delineating lack of preserved pain sensation. Upon occlusion examination, all managed patients reported a normal state of inter-canine and inter-cuspal occlusal relation at the different examination sessions. Selective grinding was not required in none of the managed cases.

In all of the managed cases, none of the patients reported disturbance in the course of the inferior alveolar nerve subjectively or upon objective examination. In a postoperatively obtained panoramic X-ray, none of the utilized screws showed canal impingement in any of the managed cases. In the five cases managed with extraoral incision, an uneventful wound healing was observed in all of the managed cases. In the cases where an intraoral vestibular incision was utilized (n=7), only 1 case reported wound dehiscence revealed in the second examination period. This case was managed with wound margin debridement and irrigation. The case reported normal wound healing in the third examination period. None of the operated patients developed postoperative or nosocomial infection.

All of the operated patients reported a statistically significant increase in the level of the measured inter-incisal mouth opening ($p<0.001$). The immediate postoperative measurements ranged from 6.3 to 24.4 mm, with a mean calculated value of 16.4±3.12 mm. In the six-weeks follow-up session, the maximum interincisal opening ranged from 31.6 to 46.0 mm with a mean calculated value of 36.8± 2.42 mm (Table 2).

Table 2: Descriptive analysis of maximum mouth opening (n=12).

Max Mouth opening/ mm	24-H	1-W	4-W	6-W	P1
Min. – Max	6.3 - 24.4	8.0 – 30.0	16.0 – 41.0	31.6 - 46.0	<0.001*
Mean ± SD	16.4±3.12	19.10 ± 6.57	25.50 ± 7.85	36.8± 2.42	
P2		0.007*	<0.001*	<0.001*	

p1 : p value for ANOVA with repeated measures
p2 : p value for Post Hoc test (Bonferroni) for comparison between 24h with each other periods
*: Statistically significant at $p \leq 0.05$

Bite Force Measurement

Postoperative Maximum Voluntary Bite Force (MVBF) was assessed by calculating the average reported value from both sides. The measurement was expressed in Newton (N).

in the first week measurement session, the MVBF reported a mean value of 119.40 ± 6.01 N. This value reported a statistically significant increase in the measured MVBF in the four-weeks session to report a mean value of 179.70 ± 18.82 N ($P<0.042$).

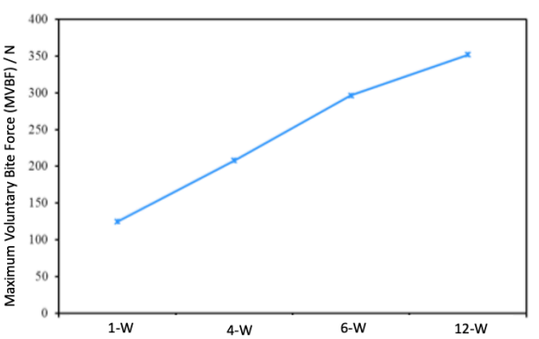
In the six-weeks session, the mean reported MVBF was 260.37 ± 19.57 N, while in the final twelve-weeks examination session, the mean reported MVBF was 328.83 ± 9.34 N. Across the MVBF analysis period, the mean reported bite force showed a statistically significant increase ($p<0.001$) (Table 3, Figure 2).

Table 3: Descriptive analysis of mean calculated Maximum Voluntary Bite Force (n=12).

MVBF/ N	1-W	4-W	6-W	12-W	P1
Mean ± SD	119.40 ± 6.01	179.70 ± 18.82	260.37 ± 19.57	328.83 ± 9.34	<0.001*
P2		0.042*	<0.001*	<0.001*	

p1 : p value for ANOVA with repeated measures
p2 : p value for Post Hoc test (Bonferroni) for comparison between 24h with each other periods *: Statistically significant at $p \leq 0.05$

Figure 2. Descriptive analysis of the studied cases according to mean bite force.



DISCUSSION

Regaining normal bite power is an important benchmark for evaluating how well the masticatory apparatus functions after intervention in mandibular fracture cases. A common Surgeons unanimity relies on the patient's subjective relief to evaluate the results of any surgery [16].

Hence, this study was set to demonstrate wherever the measurement of mean voluntary bite force act as a reliable assessment tool for the regain of masticatory function in posterior mandibular fracture patients

The demographic analysis of the data in this study reported the most prevailing affected group of the population to be men in the third decade of their life, where a 1.4:1 male to female ratio is reported with a mean age of 28.2 ± 6.74 years. In an epidemiological analysis conducted on the Egyptian population, Mabrouk et al. (2014) discovered that people with a mean age of 25.7 years or younger were significantly more likely to sustain facial fracture, which is younger than the results of this study but still within the same decade of life [17].

The literate has an unanimity regarding the most sustainable part of the population that suffer from facial trauma, which is the young adult male group [18]. The greater frequency of daily tasks and more participation in taxing activities may account for this age group's susceptibility to traumatic occurrences.

Although there were more affected men than women in this study, the stated male to female ratio was lower than the range that had been published, which ranged from 2:1 to 4:1. [16,17]. According to the study's reported etiological factors, which included falls and interpersonal violence (IPV), the high percentage of afflicted female patients may be related to these factors. An unappreciated domestic violence etiological component for maxillofacial fractures in the female population was shown in a study by Clark et al. (2014). 20% of IPV was listed as the reported trauma etiology, and 7.6% of those cases listed an intimate partner as the responsible party [19].

The most contemporary aspect of the literature report road traffic accidents, especially in developing countries, as the leading etiological factor for maxillofacial trauma [17,20,21]. This was not the case in this study, where none of the twelve enrolled patients suffered from road-related accidents. The most prevailing factor was interpersonal violence.

This may be correlated by the chosen inclusion criteria in this study, where patients with isolated mandibular fracture were only selected. The high-impact nature of road traffic and motorcycle accidents is rarely presented as an isolated fracture, but as a devastating high-energy traumatic event with multiple or even comminuted fracture lines.

To better understand biological features of cranio-mandibular anatomy, neuromuscular feedback, and muscle strength, as well as to evaluate the therapeutic benefit of various dental operations, dentists often measure each patient's bite force levels (1). In this experiment, a piezoresistive force transducer sensor was used to measure the bite [15].

The literature reports several methods for bite force analysis. Castroflorio et al. (2008) used intraoral load cells put in a custom acrylic splint, where patients bite on to record the force generated from the stomatognathic apparatus [7].

Hoyuela et al. (2015) used a fork with a strain gauge, while Turker et al. (2004) employed a variety of complicated extra oral devices to measure bite force and oral reflexes [8,9]. Harada et al. (2000) used a pressure-indicating mylerbased film with a layer of tiny microcapsules to show the size and distribution of forces between any two impacting surfaces as a novel, rapid, and useful method to record the MVBF [10].

Flanagan et al. (2012) utilized piezoresistive force transducer sensor for bite force assessment [15]. As a flexible sensor with a paper-thin thickness that enables the masticatory muscles to work at their ideal length and adequately represent the force. This gives the sensor an advantage over existing bite force measuring methods [15,22]. It is also a cheap method that doesn't require any additional sophisticated equipment. Therefore, it is a special,

affordable, and practical tool for determining the force between any two striking surfaces [22].

In this study, the average voluntary biting force expatiated with a statistically significance over the course of the follow-up period ($P< 0.001$). This growth is in line with the anticipated healing process, which was made possible by the utilization of functionally stabilized fixation schemes, which promotes quick functional recovery. The results of numerous investigations were consistent. The results of this study agree with those of Kumar et al. (2014) and Ellis and Throckmorton (2001) [11,13].

The literature consists of a plethora of studies on biting force with contradictory findings due to a variety of influencing factors, such as sex differences, growth patterns, and overall muscle force [1]. Fontijn-Tekamp et al. (2000) outlined that the Maximum Voluntary Bite Force (MVBF) in a healthy patients may range from 127 to 721 N, with several influencing factors such as age, sex, and method of measurement [23]. Whereas Kshirsagar et al. (2011) determined that the MVBF of a healthy American male is 220 N (50 pounds) [24]. These reported values fall in line with the values reported at the end of the postoperative examination period.

As numerous separate components come to play when the bite force is assessed, the study opted for the analysis of a single isolated fracture, with no other concurrent mandibular or associated maxillofacial fracture. This specification was thought about as a trial to limit the confounding factors for proper interpolation of the obtained results. Furthermore; the status of the patients occlusion was also monitored

with great scrutiny during the enrollment process for this study. Patients with missing molar or canine inter-cuspation were omitted not to have an adverse effect on the results of the study The MVBF in the first examination period reported low mean values in this study. This may be correlated with the increased levels of reported pain in the early clinical follow-up sessions. Early postoperative pain participates in achieving a much lower bite force values than those in normal healthy population or later in the follow-up period.

Over the course of the follow-up period, inter-incisal measures revealed a statistically significant rise ($P< 0.001$). The average inter-incisal distance at the conclusion of the three-month follow-up period was 36.8± 2.42 mm, allowing each patient to fit their middle three fingers between their maxillary and mandibular incisors.

Niezen et al. (2015) reported a similar increase in the reported interincisal distance, but with higher millimeter values than our study did [25]. In numerous studies, the rise in mouth opening readings during the follow-up period has been extensively documented [25,26]. One of the main benefits of ORIF over closed reduction treatment is the quicker return to work and normal function, as well as the reduced risk of muscular atrophy [26]. However, there are few studies that compare the maximum mouth opening results of various brands of osteosynthesis in the literature.

The increase in the MVBF at the end of the follow-up period may be correlated with the increase in the maximum interincisal mouth opening reported across the follow-up period. Early muscular edema and painful reflex prohibited the proper use of the stomatognathic apparatus with both of its components; the muscles and the teeth. The ability to achieve a rigid fixation across the fracture line is manifested as a stable interfragmentary connection. The lack of movement across the fracture line will not only result in a primary and prompt bone healing, but it also aids in rapid dissipation of pain. The early dissipation of the perception of pain is the main motivation for the patients to use their muscles. This is documented in this study with the regain in bit force and increase in mouth opening.

All of the individuals displayed a normal inter-cuspal centric occlusal connection regarding the postoperative occlusion, necessitating neither elastic tension nor any type of selective grinding or extraction. The similar conclusion was reached by other authors [27,28]. But according to Kotrashetti and Singh's (2017), there were 26.7% (n=2) of postoperative malocclusion cases that needed elastic traction for 15 days in order to reestablish their premorbid occlusion [29]. Furthermore; the meticulous attention to the status of the occlusion is manifested in the favorable regain of bite force with acceptable force. Any occlusal derangement usually affects the degree of muscle utilization and hence the degree of maximum force of the bite,

Along with the limited sample size, this study may be limited by the inclusion of both genders in the pool for patient selection. The muscular efficiency of those muscles affecting the bite force has a gender discrimination, where male subjects are proclaimed to having a higher maximum bite force than their female counterparts. Furthermore; the emergency nature of the studied subject, mandibular fracture, limits the ability of obtaining a preoperative control value for each patient. Hence, the values reported in the literature by the normal healthy population acted as the correspondent for the value reported in this study.

CONCLUSION

With respect to the limitations of this study, the utilization of maximum voluntary bite force is a reliable objective tool for the assessment of the quality of posterior mandibular fracture management, outlining the favourable outcome of open reduction and internal fixation. Furthermore, the use of a Piezoresistive force transduce Sensor as bite force assessment tools offers an easy to apply, comprehendible, and available analysis tool with outstanding clinical performance.

ACKNOWLEDGEMENTS

We are extremely obliged and grateful to the stuff of the Oral and Maxillofacial Surgery Department of Alexandria University for their great support in achieving this work.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest. The authors declare that they received no funding to perform this study.

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