

Electromyographic analysis of anterior temporalis and superficial masseter muscles in mandibular angle fractures—a pilot study

Saurab Bither · Uma Mahindra · Rajshekhar Halli ·
Makarand Bakshi · Yogesh Kini · Mahendra Shende ·
Rupika Bither

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Abstract

Introduction Fracture of the mandible occurs more frequently and the surgical anatomy of the mandible and adjacent structures is extremely important in understanding the pattern of fracture, the displacement of fractured fragments, and factors necessary for uncomplicated healing. In the field of dentistry, surface electromyography, electrokinesiology, and more recently, TMJ sound analysis have been particularly important developments. Previous electromyographic studies involving anterior temporalis and superficial masseter have been conducted in mandibular condylar fractures and in orthognathic and cosmetic procedures of the jaws.

Materials and methods This experimental study was undertaken to measure the electrical activity of the anterior temporalis and superficial masseter muscles in mandibular angle fracture cases ($n=6$) and the changes in the electrical activity over a period of 6 months.

Results The study shows that muscle activity increases significantly over a period of time but never matches the muscle activity of the normal subjects of same sex and age in a follow-up of 6 months post-trauma.

Discussion Electrodiagnostic testing is a potentially valuable tool for the management of patients who have suffered cranio-maxillofacial trauma. Electromyography is being employed in clinical practice, and allows the inclusion of quantitative data on the qualitative aspects of a diagnosis. These data are often of significant importance in the correct management of therapy and patient follow-up, particularly if the subject is at risk of developing a different and/or more serious disease.

S. Bither (✉)
Christian Dental College,
Brown Road,
Ludhiana, India
e-mail: saurabbither@yahoo.com

U. Mahindra · M. Bakshi · Y. Kini
Rural Dental College,
Pravara Medical Trust, Loni Bk.,
Maharashtra, India

R. Halli
Bharti Vidyapeeth Dental College,
Pune,
Maharashtra, India

M. Shende
College of Physiotherapy,
Pravara Medical Trust, Loni Bk.,
Maharashtra, India

R. Bither
National Dental College,
Dera Bassi,
Punjab, India

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Introduction

It is impossible clinically to decide whether or not a muscle is in fact participating in any particular movement merely by considering its origin and insertion. In living subjects, visual inspection or palpation may reveal contraction or relaxation of a muscle, which will not provide any detailed analysis of the pattern of contraction. In particular, it fails to reveal what proportion of motor units in a muscle is involved and the distribution of active units within the muscle.

Ever since the introduction of electromyography in odontology, the apparatuses, electrodes, and techniques have

been improved and standardized, with the result that it is now possible to work with quantitative methods in the evaluation of the electromyographic (EMG) activity. This in turn, offers greater possibilities of statistical analysis of the data obtained [1].

Moyers pioneered the electromyographic study of the masticatory muscles and was the first to investigate muscle activity in patients with an angle class II, division I malocclusion. The clinical use of electromyography for orthodontic diagnosis and for monitoring treatment was soon introduced. Ahlgren utilized the technique to investigate the mechanism of mastication and Möller reported on its correlation with facial morphology [2].

Serious attempts to describe the action of the muscles of mastication began in 1950s. Many investigators used surface electromyography primarily to describe the superficial muscle action of the anterior and posterior temporal and superficial masseter muscle [3]. Surface EMG of masticatory muscles is currently a part of patient assessment in dentistry, providing quantitative data on the function of superficial muscles with minimal discomfort to the patient and without invasive or dangerous procedures [4, 5]. The results obtained with surface electromyography compare favorably with those obtained with concentric needle electrodes [6].

During the past three decades, in both research and clinical settings, surface electromyography has been utilized to aid in the detection, diagnosis, and treatment of muscle hyperactivity and hypoactivity, muscle imbalance, rest position, spasm, and fatigue of the muscles of mastication. Electromyography has been used in temporomandibular joint (TMJ) disorders [5], condylar fractures [7, 8], orthognathic surgeries [9, 10], and craniomandibular disorders [11]; and facial EMG application on masticatory function evaluation, speech analysis and recognition, and emotional expression observation [12]. However, no previous study has attempted to relate electromyography and mandibular angle fractures.

The aim of the study was to implement the use of surface electromyography in the mandibular angle fractures to evaluate activity, change in electrical activity for a period of 6 months postoperatively, the difference in electrical activities of anterior temporalis muscle and superficial masseter muscle in patients with mandibular angle fractures from that of normal subjects. Electromyogram measurements were recorded during bites at right and left first molar tooth position as this position is believed to yield maximum muscle forces [13] and they are considered to play a primarily role in mastication and accessible to recording noninvasively [3, 14].

Material and methods

The study was carried out in the department of Oral and Maxillofacial Surgery. All study-related procedures and tests were approved by the institutional ethical committee.

Table 1 Details of patients in group A

Sr. no.	Name of patient	Age (years)	Sex	Fracture site
1	Case 1	24	M	Left, HF
2	Case 2	50	M	Right, HUF
3	Case 3	35	M	Right, HUF
4	Case 4	50	M	Left, HUF
5	Case 5	27	M	Right, HF
6	Case 6	50	M	Left, HUF

HF horizontally favorable fracture, *HUF* horizontally unfavorable fracture

Six patients of isolated unilateral mandibular angle fracture were enrolled in the study (group A). PA view of the mandible and pretreatment panoramic radiograph were used to classify the mandibular fractures and find out the displacement of the fractures.

All the patients in group A (Table 1) were treated with extra-oral open reduction and internal fixation method. Two titanium miniplates (four holes with gap) were used for fixation one at inferior border and one at superior border. Mandibular third molars showing signs of periapical infection, structural damage, subluxation from the socket, advanced periodontal disease and caries, and those involved in infected fracture line were removed. Surface electromyography of individuals in group A was carried out using RMS EMG.EP MARKII software equipment according to the following time frame:

1. preoperatively,
2. first postoperative day,
3. second week postoperatively,
4. third week postoperatively,
5. fourth week postoperatively,
6. fifth week postoperatively,
7. sixth week postoperatively, and
8. sixth month postoperatively.

Group B (27 subjects) comprised of normal individuals who underwent only a single surface EMG recording and were matched in terms of age and sex with that of group A subjects. Inclusion criteria for group A patients were patients with mandibular angle fractures, patients who could bite on molars, no history of previous craniofacial trauma, and no neurosensory deficit. Informed consent was taken from all the patients and data was recorded. Group B comprised of individuals with normal functional occlusion, no dentofacial deformity, no evidence of TMJ dysfunction, no evidence of musculo-skeletal disturbances, no previous history of craniofacial trauma, no craniocervical disorders, and no neurosensory deficit. A four channel EMG machine (RMS EPK MARK II) with surface electrodes, ground electrode, computer with software, data storage device, inkjet printer, sound amplifier, electrode jelly, and micropore tape was used for the study.

Electrode positioning

The anterior temporalis muscle and superficial masseter muscle on both sides (left and right) were examined. Beckman-type bipolar silver chloride surface electrodes with a diameter of 6 mm were used (active and reference). Ground electrode of a larger diameter was fixed on bony chin prominence (Fig. 1).

All the electrodes were immersed in conductive gel and adhered to the skin with the help of micropore tape. Care was taken that the orientation of these electrodes was approximately symmetrical on the two sides.

Measurement protocol

Patients and control subjects received explanations about the examination, an informed written consent was obtained, and subjects were carefully instructed regarding the kind of intermaxillary relationship to maintain and muscular activity to perform.



Electrode positioning anterior temporalis muscle



Electrodes positioning superficial masseter muscle

Fig. 1 Electrodes positioning

Subjects were made to lie down in supine position on a bed in a quiet room with the head in neutral position and were told to relax completely. The subjects were instructed to remain in this position throughout the procedure and to refrain from extraneous movements. Two experimental sessions with full setup of EMG recording were made for each subject; the first one was for an adaptation and the second one for the data collection. The data obtained in the second session were employed for analyses.

After the placement of electrodes in position the participants were instructed to clench their teeth in centric occlusion/habitual occlusion as hard as they can and were asked to maintain that position for 10 s followed by 10 s rest performed over a span of 1 min (30-s clench and 30-s rest).

Electromyogram measurements were recorded during bites at right and left first molar tooth position. For evaluation, the mean value of five consecutive biting cycles from each patient was recorded. For both the temporal and masseter muscles, the mean value of right- and left-side measurements was used. The myoelectrical activity shown on the screen was calculated based on the average means of the highest fives compound muscle action potential.

Changes within subjects were compared with each other by means of an unpaired *t* test. For all the parameters only mean scores per patient was the statistical unit. All statistical calculations were made with the Excel program of the Microsoft Office 2007 package.

Results

The results show that the muscle activity of anterior temporalis muscle and superficial masseter muscle in fracture group patients increases significantly from preoperatively to sixth month postoperatively and that there was nearly 190% and 226% change in the anterior temporalis and superficial masseter muscles, respectively (Table 2 and Table 3), with superficial masseter muscles seeing an increase from 701.25 to 2,289 μ V in 6 months postoperatively. The muscle activity is significantly less in fracture group patients when

Table 2 Comparison of mean values of percentage change in preoperative to sixth week and sixth months in group A—angle fracture (*n*=6)

Parameters	Preoperative to 6th week Mean percentage change (%)	Preoperative to 6th month Mean percentage change (%)
Anterior temporalis muscle	174.56	190.07
Superficial masseter muscle	167.41	226.44

Table 3 Change in muscle activity (microvolts) in Group A—angle fracture ($n=6$)

Parameter	Pre-op	6th week	6th month
Anterior temporalis muscle	419.17	1,149.75	1,248.33
Superficial masseter muscle	701.25	1,892.17	2,289

compared with normal subject group even at sixth month postoperatively (Table 4). The younger age group (<25 year) shows a promising improvement in the masticatory system as compared with other age groups (Table 5).

Discussion

The study of muscle action in humans is limited to an estimation of the force of contraction derived from recordings of electromyographic activity [3]. Fortunately, the achievement of masticatory action relies on the coordination of muscles of mastication. We can evaluate the masticatory function from the muscle efficiency, the performance of mastication activity and the biting force [12]. Electrical changes accompany normal muscular activity and these may be picked up by the electrodes placed on the skin or embedded in the muscle, amplified, and recorded photographically or mechanically [15].

Activity patterns of the masticatory muscles during maximal clenching in intercuspal position depend upon occlusal factors such as the number of teeth, premature tooth contacts, and cuspal interference causing lateral deviation of mandible during its movement from retruded contact to intercuspal position and on facial morphological factors [16]. In a study by Santo et al. (1992), comparison of masseter muscle force in ten male controls with that in ten male patients who had sustained unilateral zygomaticomaxillary complex (ZMC) fractures was done. It was found that the masseter muscle in patients with ZMC fractures developed significantly less force than masseter muscle in controls [13]. The functioning of the masseter and anterior temporalis muscles was assessed by electromyography in 18 patients

Table 4 Comparison of mean values of anterior temporalis muscle and superficial masseter muscle in groups A and B

	Group A ($n=6$) Mean \pm SD	Group B ($n=27$) Mean \pm SD
Anterior temporalis muscle	1,248.33 \pm 130.6*	2,006.8 \pm 139.64*
Superficial masseter muscle	2,289.0 \pm 276.12*	3,496.27 \pm 417.29*

* $p<0.01$ highly significant when compared with group B (after applying student unpaired t test)

before orthognathic surgery and 6 weeks, 3 months, 1 year, and 2 years afterwards by Raustia and Oikarinen in 1994. EMG recordings were made during maximal bite in intercuspal position and chewing. The mean electrical activity in the masseter and anterior temporalis muscles decreased markedly 6 weeks after surgery but increased clearly for 1 year in both functions. Only a slight further increase was observed at a 2-year follow-up during chewing, but during maximal bite in intercuspidation [10].

Gregory Tate et al. in 1994 recorded voluntary bite forces at varying periods in 35 males treated with rigid internal fixation for fractures of the mandibular angle. Bite forces were also obtained in 29 male controls for comparison. It was found that molar bite forces in patients were significantly less than in controls for several weeks after surgery. Further molar bite forces on the side of fracture were significantly less than on the nonfractured side [17].

The significant reduction of the myoelectrical activity following fracture treatment of the mandible might be explained by traumatic or operative trauma to the masseter or to the protective neuromuscular mechanisms of the masticatory system when after bone fracture, muscle splinting components are activated or deactivated to take forces of the damaged bone. Furthermore, the patient's willingness to bite hard is also a major factor. This is related both to mental attitude and to the comfort of the teeth, so some patients especially within the first postoperative weeks are afraid to use their jaws vigorously [18]. Maximum voluntary bite force is generally thought to be modulated by sensory input from the dentition and surrounding periodontium. It is then thought that these sensory receptors are protective in nature. For instance, when bite forces increases to a level where potential damage to the teeth, periodontium and bone might be produced; the central nervous system, sensing this potential damage, reduces motor output to muscles involved in generating bite force. Altered muscle activity patterns and reduced bite forces after unilateral fractures could be a mechanism to reduce loads on the injured side.

Maximal biting forces were evaluated in 22 patients with mandibular angle fractures treated with miniplate osteosynthesis according to Champy by Gerlach et al. (2002). An electric test procedure for evaluating the load resistance between the incisors, canines, and molars was carried out 1 to 6 weeks following the treatment and additionally in 15 controls, too. This revealed that after surgical fracture treatment 1 week postoperatively only 31% of the maximal vertical loading found in controls was registered. These values increased to 58% at the sixth week postoperatively [18]. The better bone positioning obtained after surgery establishes a harmonic relation between the osseous bases and rapidly produces satisfactory dental occlusion. With improvement in dental occlusion and oromyofunctional

Table 5 Comparison of mean values of muscles according to age in years in groups A and B

Age in years	Group A (n=6)		Group B (n=27)	
	Mean±SD		Mean±SD	
	Superficial masseter muscle	Anterior temporalis muscle	Superficial masseter muscle	Anterior temporalis muscle
15–25	2,457.0±190.0 (n=1)*	1,156.5±46.5 (n=1)*	3,719.99±337.46 (n=5)*	1,967.8±226.09 (n=5)*
26–35	2,214.5±266.5 (n=1)*	1,110.0±20.0 (n=1)*	3,800.28±303.41 (n=9)*	2,046.5±137.01 (n=9)*
35–45	2,279.5±218.5 (n=1)*	1,193.0±111.0 (n=1)*	3,258.37±249.13 (n=8)*	2,007.56±104.55 (n=8)*
>45	2,261.0±305.76 (n=3)*	1,346.83±103.76 (n=3)*	3,104.1±282.41 (n=5)*	1,972.9±91.09 (n=5)*

treatment, it is possible to eliminate poor habits and to obtain a better use of masticatory function [19].

Electromyography may be used as a valuable adjunct to traditional forms of diagnosis and prognosis. The accuracy of electrodiagnostic data reported in literature ranges from 50% to 67% in some studies and 77% to 90% in others [20]. Despite its widespread use as a quantitative measurement tool, the EMG recording’s reliability and indications for use have not been unequivocally established due to conflicting available evidence. Meanwhile, advancements in hardware technology currently allow for at least a 1,000-fold increase in multichannel EMG data to be gathered and processed in real time, with the direct effect being an increase in statistical precision. Efforts are being made to introduce electromyography as a routine diagnostic and prognostic measure in clinical dentistry, but no satisfactory method has been established. Although there is inadequate support for the use of electromyography as a diagnostic tool, its use has substantially increased our knowledge of the function and dysfunction of the masticatory system.

The approaches (extra-oral and intra-oral) to fracture reduction have their own advantages and limitations. Despite the fact that there is less stripping and manipulation of the masseter muscle in the intra-oral approach as compared to the extra-oral approach, we were able to standardize the miniplate placement and incisions owing to better visibility in the extra-oral approach.

The study concludes that in spite of significant increase in the muscle activities of both anterior temporalis muscle and superficial masseter muscle in fracture group patients; it is still showing lesser muscular function as shown by the normal subjects. Thus in spite of the various advances in oral and maxillofacial surgery and use of better techniques and instrumentation, the postoperative masticatory system rehabilitation is still not achieving the levels of normal subjects as shown in this study.

This makes us rethink the treatment modalities, which are being used in managing the trauma patients. We reduce, fix the fracture fragments, and achieve a perfect occlusion; still, there is a decreased muscular function even 6 months postoperatively. This shows the lack of respect shown to the soft

tissues and muscles during management of trauma patients. A holistic approach to the treatment of the mandibular fractures can be suggested, wherein we not only address the fracture and the occlusion but also pay heed to the concerned soft tissues and muscles.

Intra-oral approaches using Champy’s lines of osteosynthesis for fracture reduction and fixation so that there is less stripping of the muscles and the use of transbuccal trocar instrumentation, use of better implants in the form of high- or good-quality titanium mini plates and screws so as to provide better rigidity to the fractured segment and early muscle mobilization and rigorous physiotherapy are some of the measures which can be followed to improve the muscular rehabilitation postoperatively.

Studies of the electrical activity of human skeletal muscle provide much valuable information with respect to time, duration, and phasic relationships of muscle contraction, as well as for the diagnosis and prognosis of neuromuscular disorders. The relatively small sample size is the limitation of the study; however, further studies to document the adaptation of masticatory apparatus over a longer duration of time and with higher number of sample size is desired.

Competing interests None declared.

Ethical approval Ethical approval was given by institutional ethical board.

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