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ORIGINAL ARTICLE

Electromyography assessment in zygomaticomaxillary complex fractures

Mohammad Waheed El-Anwar[1] · **Ezzeddin Elsheikh**[1] · **Ahmed Hassan Sweed**[1] · **Nillie Ezzeldin**[2]

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Abstract
Objective The aim of this study was to assess the activity of the masseter and temporalis muscles using surface electromyography (EMG) in patients with zygomaticomaxillary complex (ZMC) fractures.
Patients and methods This prospective study was carried out on 25 patients who had ZMC fractures. Fifteen patients were managed by open reduction and rigid fixation (ORIF) using titanium miniplates. This study, using surface electromyography, analyzed the activity of the masseter and temporalis muscles of 25 patients with ZMC fractures; 15 of them were surgically treated under general anesthesia (GA). Evaluations were made before surgery and 6 weeks after surgery by recording the mean of muscle contraction of 20 motor unit action potential (MUAP) against resistance, and statistical analyses were performed.
Results A significant EMG difference between the normal and ZMC fracture sides was found ($P<0.0001$) for both masseter and temporalis muscles and was significantly improved after ORIF. However, postoperative EMV values of the repaired side was significantly less than measured postoperatively in the normal side ($P<0.0001$) for both muscles.
Conclusion ZMC fractures significantly diminish muscular activity of the masseter and temporalis and even though significant recovery of muscle activity was revealed after 6 weeks, it is still less than normal activity, highlighting the importance of postoperative rehabilitation.

Keywords Fracture zygoma · Electromyography · Internal fixation

Introduction

Zygomatic bone fracture is a common morbidity in plastic surgery [1]. The zygomatic region is involved in 42 % of facial fractures and accounts for 64 % of all middle third fractures [2].

Open reduction and rigid fixation (ORIF) has been used as one of the most standardized methods for treating zygomaticomaxillary complex (ZMC) fractures [1, 3].

ZMC fractures could be treated by observation, closed reduction without fixation, or ORIF at 1 or more buttresses. Most ZMC Fractures (77 to 94 %) are surgically repaired [4].

Both the trauma and its repair procedure can change the masticatory muscle activity share in clinically observed diminished jaw muscle activity in facial fractures [5]. Recovery of normal mouth opening after the fixation of mandibular fractures was reported [6].

Electromyography (EMG) evaluates muscle function by analyzing the electrical signals emanated during muscular contraction, thus providing understanding, interpretation, and recognition of the reduction in muscle function especially in the period required for complete healing [7]. EMG is non-invasive, quick, and painless and allows a safe and correct analysis of the masticatory muscles, especially the masseter and temporalis, through monitoring and data recording [8].

EMG has been widely used in the evaluation of patients with temporomandibular joint disorders [9, 10]. After surgical procedures, EMG is able to monitor the time when the activity

✉ Mohammad Waheed El-Anwar
mwenteg@yahoo.com

[1] Otorhinolaryngology-Head and Neck Surgery Department, Faculty of Medicine, Zagazig University, Zagazig, Egypt

[2] Rheumatology and Rehabilitation department, Faculty of Medicine, Zagazig University, Zagazig, Egypt

of the muscles of mastication is recovered, thus the professional can guide the patient regarding daily activities, type of food, and mastication [8].

This study aimed to assess the activity of the masseter and temporalis muscles, using surface EMG, in patients with ZMC fractures.

Patients and methods

Study design

This prospective study was conducted at the otorhinolaryngology department, Zagazig University Hospitals, Egypt over a period from March 2012 to January 2015. The study was approved by the Institutional Review Board (IRB) at Zagazig University Hospitals and informed consent was signed by all enrolled subjects after explanation of the research purpose.

Study subjects

Twenty-five patients with traumatic unilateral ZMC fractures were included in this study: Exclusion criteria were pathological fractures, nerve injury especially the mandibular and maxillary branches of the trigeminal nerve, neuromuscular diseases, previous temporomandibular joint disorders, patients who required intermaxillary fixation postoperatively, and bilateral ZMC fracture as the non-fracture side was used as a reference for measurement.

Patients were subjected to detailed history especially trauma, ocular, mouth opening, and cosmetic manifestations; radiological assessment (CT maxillofacial; axial, coronal, and 3D); and surface EMG (to the masseter and temporalis muscles).

The participants were grouped according to the type of fractures as follows:

Fifteen patients needed repair and treated by ORIF using mini-titanium plates and screws under general anesthesia (GA), while the other 10 patients were managed conservatively.

Surgical work

Adrenaline, 1/200,000 concentration, was injected at the incision and dissection area. Through subciliary or transconjunctival incision, exposure, dissection, disimpaction, and reduction of the fracture were performed either by zygomatic hook in 12 cases (80 %) which is applied on the posterior wall of the zygoma to elevate the bone to its position or by Kocher's forceps in 3 cases (20 %) which is used to pull the zygoma to its position. Frontozygomatic and zygomaticomaxillary buttresses were held in anatomical position using titanium miniplates with two miniscrews at each side of each fracture line. Care was taken during incision, dissection, and internal fixation to avoid injury of the orbital structures and nearby nerves. Coronal incision was used in one case in which associated frontal outer table fracture was present not for exposure of the zygoma.

EMG measurement

In the Rheumatology and Rehabilitation Department, all patients were subjected to surface EMG (using Nihon Kohden Neuropack apparatus. S1 MEB-9400K EMG EP System) to both the masseter and temporalis muscles preoperatively and sixth week postoperatively to evaluate the degree of improvement of the muscle power by using surface round plate electrodes acting as active and reference electrodes and a third one as ground electrode.

After explanation to the subjects, muscle activity was registered using round plate surface recording electrodes (active and reference) applied on both the temporalis and masseter muscles using a conductive paste and adhesive tape, while a ground electrode was applied around the neck. Then, the patients were asked to clench on a cotton piece covered with tape. The mean of 20 motor unit action potential (MUAP) of the muscles was calculated (in about 10 s of contraction, on both sides) (Figs. 1 and 2).

Results were assessed according to Angle's classification of dental occlusion, the average intrinsic vertical mouth opening (between the upper and lower central incisors) [6], orbital movement, EMG results, and complications.

Statistical analysis

Statistical analyses were performed using SPSS 14.0 statistical software for Windows (SPSS Inc, Chicago, IL). The significance level was set at $P<0.05$.

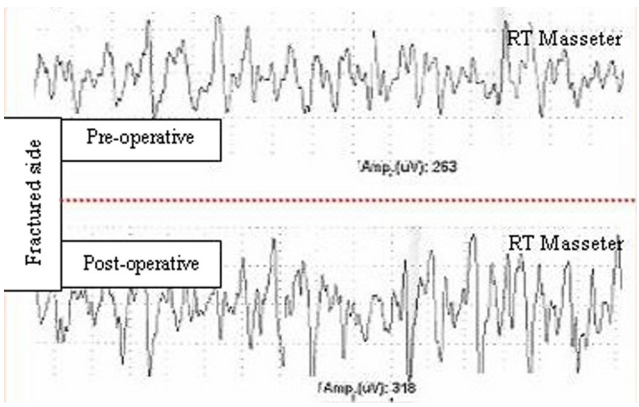

Fig. 1 EMG traces of the masseter muscle in a case had right ZMC fracture, preoperative and postoperative

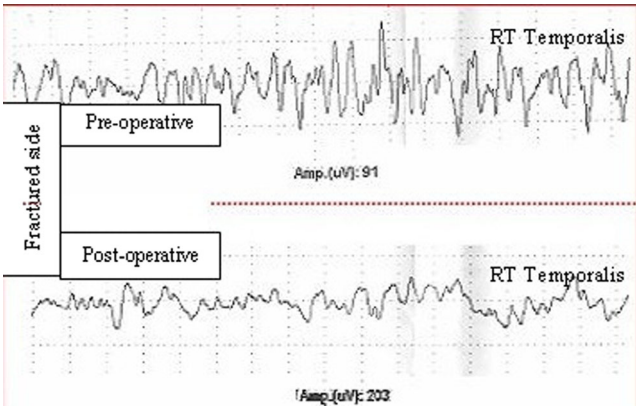

Fig. 2 EMG traces of the temporalis muscle in a case had right ZMC fracture, preoperative and postoperative

Results

The patients included in the study group were 25 patients (22 male and 3 female); their mean age±standard deviation (SD) was 26.7±9.3 years (14 to 58 years). Four patients complained of limited mouth opening (about 2 cm) preoperatively which was improved postoperatively. Only one patient showed medial (inward) rotated zygomatic arch, and the rest of the patients showed either exhibited lateral (outward) rotated arch (14 cases; surgically treated) or non-rotated arch (10 cases; treated conservatively).

In all surgically repaired fractures, frontozygomatic suture and zygomaticomaxillary sutures were held in anatomical position using a titanium miniplate with two titanium miniscrews at each side of each fracture line. All surgically repaired patients got easy recovery from GA with no need for intensive care unit admission. In the present study, no displacement of the zygoma occurred after fixation with proper postoperative functional results (eye movement, mouth opening, and dental occlusion).

Preoperatively, the mean (SD) EMG values for the masseter muscle were 0.266±0.187 mv for the fractured side in all cases, 0.297±0.245 mv in the 10 conservatively treated cases, and 0.246±0.14 mv in the 15 repaired patients. For normal sides, the mean (SD) EMG values for the masseter muscle were 0.968±0.31 mv in all patients, 0.9±0.38 mv in the conservatively treated cases, and 1±0.3 mv in the surgically repaired subjects. The difference between the normal side and fracture side was found to be extremely statistically significant (t=9.17, P<0.0001) (Table 1).

Postoperative, the mean (SD) EMG values for the masseter muscle was 0.47±0.15 mv for the fractured side. The difference between pre- and postoperative in the fracture side was found to be extremely statistically significant (t=4.15, P= 0.0003).

Preoperatively, the mean (SD) EMG values for the temporalis muscle were 25 total 0.22±0.14 mv for the fractured side, 0.3±0.156 mv for the 10 conservatively treated cases, and 0.15±0.09 mv for the 15 surgically repaired subjects. For the normal side, total 0.97± 0.3 mv, conservative 0.9±0.38 mv in surgical cases 1± 0.3. The difference between the normal side and fracture side was found to be extremely statistically significant (t= 10.287, P<0.0001) (Table 1).

Postoperatively, the mean±SD EMG value for the temporalis muscle was 0.3±0.1 mv for the fractured side. The difference between pre- and postoperative in the fracture side was found to be extremely statistically significant (P= 0.0003, t=4.1) (Table 1).

Normal (non-fractured) side exhibits postoperative mean± SD EMG values equal 1.98±0.16 mv for the masseter and 1.74±0.167 mv for the temporalis muscle. Postoperative EMV values of the repaired side was significantly less (P<0.0001) for both the masseter (t=26.7577) and temporalis (t=28.05) muscles (Table 1).

Postoperatively, normal (Class I) dental occlusion was achieved in all cases. At 6 weeks postoperatively, all patients in both groups achieved normal mouth opening and normal orbital movement.

Table 1 Preoperative and postoperative EMG results of ZMC fracture cases

EMG value (mv)	Preoperative		Postoperative		*T* test	*P* value
	SD	Mean	SD	Mean		
Masseter muscle	0.246	0.14	0.47	0.15	4.15	0.0003 S
Temporalis muscle	0.15	0.089	0.3	0.1	4.12	0.0003 S
Preoperative EMG value (mv)	Normal side		Fracture side			
Masseter muscle	0.968	0.31	0.266	0.187	9.1696	<0.0001 HS
Temporalis muscle	0.97	0.3	0.22	0.14	10.287	<0.0001 HS
Postoperative EMG value (mv)	Normal side		Fracture side			
Masseter muscle	1.98	0.16	0.47	0.15	26.7577	<0.0001 HS
Temporalis muscle	1.74	0.167	0.3	0.1	28.05	<0.0001 HS

S significant, *HS* highly significant

Infection, hematoma, malocclusion, delayed union, and nonunion were not encountered. Intramuscular analgesic was sufficient to control pain in all patients and was prescribed for 1 week.

Discussion

ZMC fractures are one of the most frequent injuries of the facial skeleton due to its position and facial contour [2]. The basic principle of fracture treatment is reduction, fixation, immobilization, prevention of infection, and rehabilitation with the least disability and smallest risk for the patient [11]. The simplest method should be chosen whenever it is as effective as the more invasive one [8] considering the four basic principles for repair of a facial fracture: adequate exposure, proper reduction, stable fixation, and minimal complications [4].

Today, ORIF is the standard management of displaced fractures. ORIF of fracture provides stable reconstruction, promotes bone healing, and shortens treatment time [12], allowing immediate jaw mobilization [10].

It is impossible clinically to know 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, giving no detailed analysis of the pattern of contraction. So, clinical assessment could not reveal what proportion of motor units in a muscle is involved and the distribution of active units within the muscle [13].

During the past three decades, in both research and clinical settings, surface EMG has been used to aid in the detection, diagnosis, and treatment of muscle hyperactivity and hypoactivity, muscle imbalance, of the masticatory muscles. EMG has been utilized in TMJ disorders [14]. Surface EMG can make an objective quantitative recording of the masticatory muscle function [15] in a non-invasive method [16].

In the current study, all patients suffered from a decrease in activity of both the masseter and temporalis muscles in the fractured side; this is confirmed by preoperative surface EMG evaluation which found a statistically significant difference between the normal side and fracture side of both muscles. This is consistent with the results of the study of Campolongo et al [5] but they studied masseter activity only and detected a marked drop at 7 days postoperatively.

We did not perform EMG at 7 days postoperative due to its cost and tolerability by the patients besides the difficulty of obtaining a maximum force during EMG in this early postoperative period during the early recovery and healing period. The effect of pain was excluded by use of analgesic sufficient to end the pain before the test.

The results showed that the muscle activity of the anterior temporalis muscle and superficial masseter muscle in ZMC fractures increases significantly from preoperatively to 6 weeks postoperatively. This agreed with the study done by Dal Santo et al [17].

This also agreed with Hagg et al [18] who stated that there are several problems in the clinical application of surface EMG which still limit its use to help clinicians in their daily practice. One of the principal problems is normalization/standardization of surface EMG recording.

To compare EMG recordings among different subjects, it is necessary to relate all measurements to the electrical muscle activity detected during some standardization recording, like a maximum voluntary contraction (MVC) [19]. In this study, we used a cotton piece covered with tape to achieve maximal voluntary contraction of the masseter and temporalis muscles during recording of muscle activity. This is in agreement with Gianluca et al [20] who stated that among the various protocols, an MVC on cotton rolls has been reported to have the lowest inter-individual variability, and a method based on this standardization has been in use in the last 10 years.

All patients showed recovery of muscular activity in 6 weeks, near the value of the study of Campolongo et al (60 days) [5] but still significantly lower than the values of normal sides.

The significant reduction of the myoelectrical activity following fracture treatment might be explained by traumatic or operative trauma to the masseter or to the protective neuromuscular mechanisms of the masticatory system. After bone fracture, muscle splinting components are activated or deactivated to take forces of the damaged bone [21]. 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 [15].

In the study of Campolongo et al [5], the mean values of the masseter activity, in descending order, were from the zygomatic complex, mandibular, maxillary, and associated fractures and they concluded that facial fractures and surgical procedures had negative effects in the muscle activity as observed using EMG [5]. However, trauma needed to cause fracture in a different facial bone is different, so muscle affection in trauma is also different, that is why we preferred to deal with one type of fracture.

Because of miniplate osteosynthesis, all older methods of fixation are not used regularly. Miniplate fixation resulted in ten times higher strength than wire osteosynthesis [22]. This is in concurrence with the results obtained in our study of significantly improved masticatory muscle power after 6 weeks of ORIF of ZMC fractures.

Electrodiagnostic testing is a potentially valuable tool for the management of patients who have suffered craniomaxillofacial trauma. EMG could be employed in clinical practice, to include 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 [13].

Based on the result obtained from this study, we can conclude that by using the quantitative surface EMG, assessment of the improvement of muscle activity of both the masseter and temporalis muscles could be done in both surgically treated and conservatively treated patients; both groups showed improvement in muscle activity at the sixth week postoperatively.

In the current study, in spite of a significant increase in the muscle activities of both studied muscles in ZMC fracture patients and normal dental occlusion, mouth opening, and orbital movement achieved in all cases reflecting proper functional healing, it is still showing lesser muscular function as shown by the normal sides. Thus, in spite of proper healing as regards replacement and function, the postoperative masticatory system rehabilitation is still needed. This highlights the lack of respect shown to the soft tissues and muscles during management of trauma patients.

Therefore, EMG may be used as a valuable adjunct to traditional forms of diagnosis and prognosis of ZMC fractures. Although there is inadequate support for the use of EMG as a diagnostic tool, its use has substantially increased our knowledge on the masticatory system function in an objective manner. Further studies are needed to assess the effect of physiotherapy on muscular recovery.

Conclusion

ZMC fractures significantly diminish muscular activity of the masseter and temporalis. Even though significant recovery of muscle activity was revealed after 6 weeks, it is still less than normal activity, highlighting the possible role of postoperative rehabilitation. Further studies are needed to assess the effect of physiotherapy on muscular recovery.

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Conflict of interest The authors declare no conflict of interest.

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