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ORIGINAL ARTICLE

Does the Method of Open Reduction and Internal Fixation of Mandibular Angle Fracture Differentially Affect Postoperative Strength of Jaw Muscles as Assessed by Surface Electromyography? An Analytical Study

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Abstract

Objective To analyze differential postoperative strength of masticatory muscles by surface electromyography (sEMG) in mandibular angle fractures (MAFs) using two open reduction and internal fixation (ORIF) approaches.

Materials and Methods Present study evaluated the two ORIF approaches in unilateral non-comminuted central MAFs operated by intraoral ORIF (group A, $n = 17$) and extraoral ORIF (group B, $n = 8$). Root mean square (RMS) values of sEMG (μV.s) of bilateral masseter and temporalis muscles for 10 s each, i.e., rest, maximum clenching, maximum mouth opening (MMO), ipsilateral and contralateral excursion, were compared from preoperative and postoperative visits at 1, 3 and 6 months. Further, MMO, ipsilateral and contralateral excursions were measured using caliper.

Results No significant difference ($p > 0.05$) in sEMG of all four muscles during all five conditions between the groups was observed from pre-op to post-op 6 months. Post-op group A showed significantly higher MMO and statistically significant difference in sEMG of ipsilateral masseter ($p = 0.017$) and temporalis muscles ($p = 0.019$) compared to contralateral muscles at 1 month. When comparing percentage sEMG change from pre-op to 6 months, muscles of both groups revealed positive changes.

Conclusion The intraoral ORIF technique for MAFs shows early improvements in MMO and subsequent changes in sEMG of the masticatory muscles due to minimal muscle stripping, thus favoring its use in clinical practice.

Keywords Mandibular fractures · Jaw fixation · Surface electromyography · Masticatory muscles · Open reduction

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Introduction

In modern maxillofacial practice, open reduction and internal fixation (ORIF) of mandibular fractures has become the norm, albeit there are still concerns about how to approach and fix mandibular angle fractures (MAFs). Intraoral method using single miniplates at external oblique ridge is gaining popularity among surgeons as compared to extraoral ORIF [1].

Surface electromyography (sEMG) provides a noninvasive method in the measurement of the superficial masticator muscle activity for statistical analyses [2]. Only the temporalis and masseter muscles are located superficially, making them amenable to sEMG recordings. Trauma to the maxillofacial region, particularly the ramus–condyle–angle unit, can alter the minute balance of the masticatory muscles, resulting in altered physiology and patient discomfort [3]. The skeletal muscle analysis after ORIF is of great value to uncover the changes in the masticatory system that can be assessed by sEMG activity and mandibular mobility. These indicators of masticatory activity would help to individualize treatment approach.

MAFs being common in clinical practice have multitude options of ORIF at various subsites, causing disturbances of stomatognathic physiology [4]. There is a lack of evidence-based consensus about the most effective approach for MAF based on sound musculoskeletal physiology.

Only few studies have evaluated individual ORIF approaches for MAF using sEMG, i.e., using extraoral [5] or intraoral [6] method and compared these to sEMG of the matched controls. However, no study has ever attempted to analyze sEMG of masticatory muscles comparing outcomes of two different ORIF techniques in mandibular angle fractures.

The aim of our study is to evaluate the differences in sEMG of masseter and anterior temporalis muscles in patients with MAF with respect to the ORIF techniques and change in sEMG over a period of 6 months postoperatively. sEMG of masticatory muscles was recorded during five different activities of mandible (described later in data recording), but maximum voluntary clenching at bilateral molars was thought to yield maximum muscle forces that plays a primary role in mastication [5–8].

Table 1 Patient characteristics

Characteristics	Group A	Group B
Sample Size	20	10
Patients included (*n*), Male	17	8
Age (years), Mean ± SD	26.65 ± 8.61	27.75 ± 9.91
Mandibular angle fracture		
Isolated	7	3
Associated with contralateral mandibular fractures	10	5
Angle fracture classification		
Horizontally favorable (HF)	0	0
Horizontally unfavorable (HU)	17	8
Vertically favorable (VF)	12	3
Vertically unfavorable (VU)	5	5
Need for third molar removal	2	1
Postoperative complications	2	0

Materials and Methods

The study was conducted at Department of Oral and Maxillofacial Surgery and Department of Physiology of our institute after obtaining approval of the Institutional Ethical Committee. It included male patients with central MAF after obtaining participant's written informed consent. Pretreatment CT scans were used to classify the mandibular fractures and assess fracture displacement (Table 1).

Only patients with unilateral non-comminuted central MAFs with bilateral functional molar occlusal relationship, classified into American Society of Anesthesiologists (ASA) class I or II, and motivated to maintain good oral hygiene were included. Those with a previous history of any craniofacial trauma, dentofacial deformity, craniocervical disorders, temporomandibular joint (TMJ) disorders or mandibular pathologies were excluded. Similarly, patients who were medically compromised, had a history of chemotherapy or radiotherapy, or were unwilling to participate in regular follow-up were excluded.

Of the 30 patients with MAF selected following randomization by random-numbers table, 20 underwent ORIF via vestibular mucosal incision, i.e., intraoral approach using a single 2-mm titanium miniplate (4 hole with gap) at the external oblique ridge (group A). The remaining 10 patients were treated with an extraoral ORIF through a submandibular incision and two 2-mm titanium miniplates (4 hole with gap), one at the inferior border and one at the superior border (group B). Lesser number of patients in group B was due to refusal by some patients for extraoral approach. Following surgery, five subjects did not come for regular follow-up and sEMG recording, resulting in 17 in group A and 8 subjects in group B.

All patients underwent ORIF in sterile aseptic conditions under general anesthesia by single experienced surgeon. Patients having associated contralateral fractures of body of mandible were operated by ORIF through intraoral approach using two 2.5-mm titanium miniplates for rigid fixation. Those third molars in fracture line precluding reduction, with periapical infection, structural damage and/or subluxation, dental caries and advanced periodontal disease were removed [9]. Intermaxillary fixation (IMF) was done only intraoperatively to achieve occlusal reduction. Patients were recommended liquid diet during the initial 2 weeks followed by soft semisolid diet for the next 2 weeks.

Data Recording

A 4-channel digital data acquisition system (*PowerLab 15* T® by AD instrument, Australia) with two input channels with bioamplifiers (*BioAmp*) for biopotential's recoding with recording and ground electrodes, computer software (*LabChart 8*) for real-time and offline data analysis and storage were used for the study. The patients sat with the back fully supported and the Frankfurt plane parallel to the ground, eyes open, feet flat on the floor and arms resting on the lower limbs. As described by Sharma et al. [10], disposable surface electrodes of 2 cm^2 were placed on the skin's surface above the masseter and temporalis anterior muscle bellies, parallel to the muscle fibers.

Patients were instructed about performing five unrestrained activities of mandible for 10 s each, i.e., rest, maximum bite/clenching, maximum mouth opening (MMO), ipsilateral and contralateral excursions with a rest of 30 s between each activity. Muscles and excursion movements toward the side of MAF were termed as 'ipsilateral' and toward opposite side were termed as 'contralateral.' sEMG was recorded for bilateral masseter and anterior temporalis thrice for all five activities and their mean value was used for comparison. During offline analysis, a 10-Hz high pass filter was applied in obtained records to removed motion artifacts such as blinking and notch filter applied to remove line artifacts. Root mean square (RMS) value of the resultant sEMG data in μV.s was used for computation. This sEMG data for each muscle and caliper measurements of MMO, ipsilateral and contralateral excursion in mm were recorded preoperatively and postoperatively at follow-up visits 1, 3 and 6 month. The data obtained was stored in Microsoft Excel Sheet and statistically analyzed using SPSS version 20.0 software (SPSS Inc., Chicago, IL, USA).

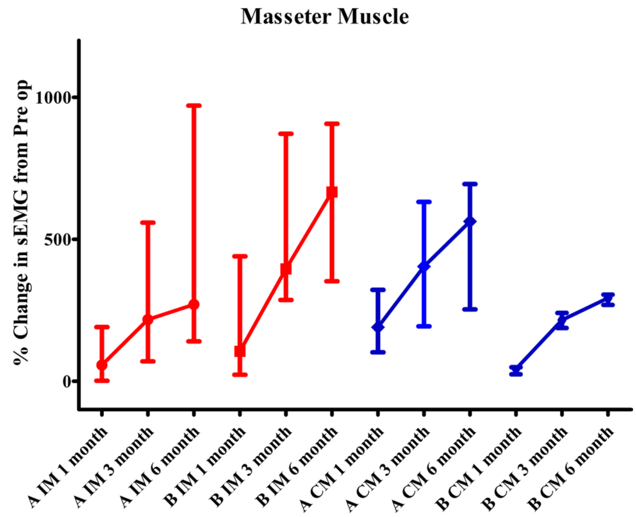

Fig. 1 Depiction of percentage change in sEMG of ipsilateral (IM) and contralateral masseter (CM) muscle in both groups A and B in the form of median with interquartile range

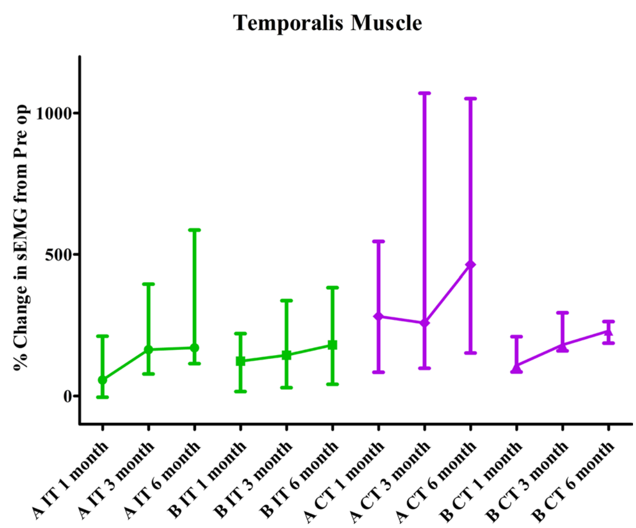

Fig. 2 Depiction of percentage change in sEMG of ipsilateral (IT) and contralateral Temporalis (CT) muscle in both groups A and B in the form of median with interquartile range

Statistical Analysis

Descriptive statistics like mean, median, standard deviation and percentages of various parameters were calculated. Nonparametric tests were applied to variables that do not have a Gaussian distribution. To compare the variables between the two groups during sEMG records, Mann–Whitney U test was used. Related samples Wilcoxon signed-rank test was done to check sEMG differences among ipsilateral and contralateral sides within same groups. Differences were regarded as statistically significant if $p < 0.05$. Percentage change in sEMG activity postoperatively from pre-op records was calculated and with help of median and interquartile range represented in Figs. 1 and 2.

Results

Patient characteristics of both groups such as MAF patterns, classification, need for mandibular third molar removal and complications are depicted in Table 1.

There was no significant difference ($p > 0.05$) in sEMG values of all four muscles during all five different activities of mandible between the groups from pre-op to post-op 1, 3 and 6 months (Table 2).

Post-op MMO was significantly higher in group A ($p < 0.05$), being very much higher at initial 1 month suggestive of quick recovery ($p = 0.005$) (Table 3).

When sEMG records of bilateral muscles were compared, only ipsilateral masseter ($p = 0.017$) and ipsilateral temporalis ($p = 0.019$) of group A patients showed statistically significant differences at first post-op (Table 4). Comparing percentage change in sEMG of bilateral masseter and temporalis muscles in both groups from pre-op to 6 months post-op showed positive changes (Figs. 1 and 2).

Table 2 Mann–Whitney U test for comparison of Intraoral (Group A) and Extraoral (Group B) ORIF sEMG records (mean ± s.d.) in µV.s for 10 s of bilateral masseter and anterior temporalis muscles during rest, clenching, maximum mouth opening, ipsilateral and contralateral excursion

Muscle and Time period		Rest			Clenching		
		Group A	Group B	*p*- value	Group A	Group B	*p*- value
I M	Pre-op	2.55 ± 1.09	2.46 ± 0.47	0.618	34.68 ± 26.74	22.15 ± 11.45	0.221
	PO 1 month	3.08 ± 1.15	2.61 ± 0.76	0.306	56.16 ± 46.55	58.81 ± 46.18	0.896
	PO 3 month	3.19 ± 1.32	3.62 ± 1.65	0.497	105.17 ± 67.12	122.70 ± 52.63	0.523
	PO 6 month	2.73 ± 0.50	2.59 ± 0.35	0.473	133.96 ± 76.83	145.67 ± 52.28	0.701
C M	Pre-op	2.38 ± 0.72	2.46 ± 0.91	0.804	30.58 ± 21.71	45.51 ± 16.46	0.099
	PO 1 month	3.45 ± 1.55	3.00 ± 1.35	0.492	95.08 ± 71.16	63.87 ± 21.23	0.241
	PO 3 month	3.46 ± 1.24	4.35 ± 1.65	0.146	129.71 ± 68.18	143.48 ± 41.37	0.605
	PO 6 month	4.03 ± 1.66	4.17 ± 1.79	0.849	159.27 ± 77.76	179.52 ± 59.16	0.522
I T	Pre-op	4.04 ± 1.99	3.89 ± 2.31	0.868	28.30 ± 17.14	28.66 ± 12.23	0.958
	PO 1 month	5.43 ± 3.11	5.07 ± 1.60	0.766	43.44 ± 27.22	58.94 ± 27.22	0.201
	PO 3 month	5.78 ± 2.85	4.09 ± 2.22	0.155	70.22 ± 38.16	70.48 ± 46.47	0.988
	PO 6 month	5.15 ± 2.53	7.58 ± 4.10	0.080	86.06 ± 36.81	77.88 ± 45.61	0.635
C T	Pre-op	3.52 ± 1.94	3.68 ± 1.98	0.844	22.59 ± 18.99	27.79 ± 9.44	0.474
	PO 1 month	6.33 ± 3.59	6.35 ± 2.30	0.984	66.99 ± 47.56	63.24 ± 22.42	0.835
	PO 3 month	4.69 ± 2.34	4.55 ± 2.54	0.887	85.92 ± 54.53	85.27 ± 17.74	0.974
	PO 6 month	4.67 ± 2.33	4.41 ± 1.10	0.765	97.12 ± 49.00	84.37 ± 18.27	0.487

Muscle and Time period		Maximum mouth opening			Ipsilateral excursion			Contralateral excursion		
		Group A	Group B	*p*- value	Group A	Group B	*p*- value	Group A	Group B	*p*- value
I M	Pre-op	3.94 ± 3.18	4.58 ± 2.17	0.612	5.94 ± 4.86	4.66 ± 2.46	0.493	5.39 ± 4.28	0.785	0.785
	PO 1 month	9.99 ± 5.85	8.58 ± 4.08	0.543	13.59 ± 11.14	12.10 ± 9.88	0.749	18.76 ± 14.10	0.776	0.776
	PO 3 month	20.15 ± 16.07	16.81 ± 9.28	0.593	13.61 ± 9.74	13.43 ± 5.09	0.961	16.13 ± 13.82	0.083	0.083
	PO 6 month	22.35 ± 17.90	33.30 ± 14.85	0.147	14.55 ± 8.27	24.75 ± 18.21	0.067	18.04 ± 14.95	0.588	0.588
C M	Pre-op	5.22 ± 3.49	5.79 ± 1.87	0.669	4.73 ± 3.14	4.02 ± 1.96	0.562	5.13 ± 2.07	0.885	0.885
	PO 1 month	14.12 ± 11.05	17.04 ± 15.73	0.596	13.43 ± 11.58	16.35 ± 6.42	0.516	11.34 ± 4.66	0.071	0.071
	PO 3 month	23.54 ± 21.01	21.57 ± 15.59	0.816	15.99 ± 13.78	14.36 ± 4.85	0.749	18.38 ± 13.46	0.842	0.842
	PO 6 month	32.79 ± 25.99	32.36 ± 16.47	0.966	17.76 ± 16.16	13.94 ± 3.06	0.519	22.61 ± 13.01	0.690	0.690
I T	Pre-op	5.61 ± 4.02	7.88 ± 3.68	0.190	7.86 ± 6.52	6.21 ± 3.91	0.516	4.88 ± 2.93	0.114	0.114
	PO 1 month	16.06 ± 11.73	10.22 ± 5.14	0.194	13.88 ± 9.85	9.47 ± 6.05	0.258	19.31 ± 14.24	0.190	0.190
	PO 3 month	17.22 ± 13.25	13.31 ± 5.06	0.432	10.16 ± 9.31	14.64 ± 7.10	0.242	18.79 ± 8.99	0.919	0.919
	PO 6 month	20.85 ± 12.07	30.69 ± 13.47	0.080	10.12 ± 8.27	7.06 ± 4.11	0.336	20.41 ± 8.53	0.231	0.231
C T	Pre-op	4.11 ± 2.21	4.15 ± 2.20	0.966	5.75 ± 3.11	5.04 ± 2.96	0.594	5.98 ± 4.93	0.189	0.189
	PO 1 month	14.88 ± 11.19	12.28 ± 5.69	0.543	19.86 ± 13.73	24.64 ± 23.96	0.531	13.01 ± 12.59	0.157	0.157
	PO 3 month	17.53 ± 14.24	19.52 ± 5.32	0.707	18.77 ± 13.59	30.12 ± 20.80	0.115	13.02 ± 12.84	0.945	0.945
	PO 6 month	20.83 ± 14.54	27.21 ± 3.66	0.238	21.09 ± 15.26	33.08 ± 21.87	0.125	15.06 ± 8.65	0.428	0.428

IM—Ipsilateral masseter, CM—contralateral masseter, IT—ipsilateral temporalis, CT—contralateral temporalis, PO—postoperative, statistically significant if $p < 0.05$

Discussion

sEMG 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 [3, 7, 10]. Assessment of masseter and anterior temporalis using sEMG during maximum clenching yields maximum compound muscle action potentials and are considered to play a primary role in mastication that are noninvasively recordable [5, 7, 8]. Only male subjects were selected in the study due to substantial evidence of higher sEMG during clenching in males [10] and epidemiological preponderance of males to be affected with MAFs compared to females [11, 12].

In MAFs, the suprahyoid group of muscles exerts an inferior pull on the anterior mandible, while pterygomasseteric

Table 3 Mann–Whitney U test for comparison of measurements of MMO, ipsilateral and contralateral excursion (in mm)

Parameter	Time period	Group A (mean ± S.D.)	Group B (mean ± S.D.)	p- value
MMO	Pre-op	20.82 ± 5.95	17.50 ± 4.87	0.183
	Post-op 1 month	30.24 ± 5.64	23.00 ± 4.96	**0.005**
	Post-op 3 month	43.71 ± 6.68	37.75 ± 4.01	**0.030**
	Post-op 6 month	48.06 ± 5.63	43.25 ± 2.55	**0.032**
Ipsilateral excursion	Pre-op	2.82 ± 1.24	2.00 ± 0.53	0.087
	Post-op 1 month	5.76 ± 2.02	4.25 ± 0.88	0.056
	Post-op 3 month	8.24 ± 1.64	8.25 ± 0.88	0.981
	Post-op 6 month	9.53 ± 1.58	10.25 ± 1.16	0.265
Contralateral excursion	Pre-op	2.47 ± 1.07	2.13 ± 0.64	0.409
	Post-op 1 month	5.76 ± 2.16	4.25 ± 1.75	0.098
	Post-op 3 month	7.82 ± 2.18	7.00 ± 1.31	0.338
	Post-op 6 month	9.00 ± 1.77	9.00 ± 0.75	1.000

*statistically significant ($p < 0.05$)

Table 4 Related samples Wilcoxon signed-rank test for comparison of ipsilateral vs contralateral muscles' sEMG records during maximum clenching

Time period	Muscles	Group A (p- value)	Group B (p- value)
Pre-op	Masseter	0.653	0.065
	Temporalis	0.266	0.483
Post-op 1 month	Masseter	**0.017**	0.326
	Temporalis	**0.019**	0.779
Post-op 3 month	Masseter	0.084	0.092
	Temporalis	0.056	0.263
Post-op 6 month	Masseter	0.055	0.068
	Temporalis	0.102	0.484

*statistically significant ($p < 0.05$)

sling and temporalis muscle exert superior pull, causing displacement of the fractured segments at the angle region [13]. This indicates the necessity for ORIF of MAFs either intraorally or extraorally [14]. However, decisions regarding approaches for ORIF at angle region are often dictated by type, location, displacement as well as ease of accessibility, visibility, surgeon's experience and training [15].

Extraoral approach provides a sterile environment, excellent direct exposure, accessibility and better fracture reduction [15]. The advantage of the extraoral approach is the placement of two miniplates to control tension forces in the upper border and compression forces in the lower border. However, some authors consider a single superior border plating is sufficient when using the intraoral approach [16]. Concerns about a cutaneous scar, marginal mandibular nerve injury and the possibility of postoperative edema due to extensive detachment of the pterygomasseteric sling make this approach less popular among maxillofacial surgeons.

Bither et al. [5] analyzed sEMG of superficial masseter and anterior temporalis in six male cases of MAF operated by extraoral ORIF technique and evaluated the changes in electrical activity over a period of 6 months. Although 6 months post-op, sEMG activity significantly increased but was less than sEMG of muscles of controls. There was nearly 190% change in anterior temporalis and 226% change in masseter muscle activity, respectively, from pre-op to 6 months post-op. In addition, they found younger age group < 25 years shown promising improvement in the masticatory system compared to other age groups.

Our study showed that at 6 months post-op, in group B patients ipsilateral masseter showed 661.06% change (B IM 6 month in Fig. 1) while ipsilateral temporalis showed 180.50% change in sEMG (B IT 6 month in Fig. 2). Higher sEMG percentage change in masseter in our study could be attributed to records of only ipsilateral side, whereas previous study [5] analyzed the mean sEMG values of right- and left-side measurements of the extraoral ORIF subjects. Another study [10] on normal young Indian subjects showed that sEMG values on both sides are not always symmetric; therefore, both fracture and non-fracture side parameters should be computed separately.

Intraoral approach has become popular, as it is esthetic, relatively simpler, of short duration with lesser postoperative complications, minimal morbidity, early masticatory function with short hospital stay [14, 15, 17]. The use of a single miniplate on the superior border of the mandible for non-comminuted MAFs and an extraoral approach with rigid fixation for comminuted fractures are the contemporary norms of treatment [18]. Undisplaced and favorable fracture can be precisely treated intraorally along with IMF as it leads to comparatively less stripping of masseter muscle [17].

Pepato et al. [6] examined MAF in seven patients (six male, one female) operated by intraoral ORIF with 2-mm titanium miniplates and recorded mandibular mobility and sEMG in different clinical conditions 2 months postoperatively. They used normalized sEMG data of clenching in the maximum voluntary contraction and found a regular decrease in the EMG activity at second post-op month. Present study found a significant change in sEMG of group A at post-op 3 months with 217.01% increase in sEMG of ipsilateral masseter (A IM 3 month in Fig. 1) and 164.12% increase in sEMG of ipsilateral temporalis (A IT 3 month in Fig. 2). This could be attributed to larger ($n = 17$) and more homogeneous sample size of our study. MMO at 2 months post-op (45.25 ± 3.08 mm) in previous study [6] was comparable to 3 months post-op MMO of group A (43.71 ± 6.68 mm) of our study (Table 3).

Previous sEMG studies involving masseter and anterior temporalis have been conducted in mandibular condylar fractures [19, 20], MAFs [5, 6], mandibular third molar extractions [21] all requiring different surgical techniques, but none have compared the ORIF approaches for a single fracture type in male subjects. The present study compared techniques of ORIF of MAFs using sEMG recordings of masseter and anterior temporalis muscles. Comparing sEMG of ipsilateral and contralateral muscles of both groups showed no significant difference ($p > 0.05$) (Table 2). However, in both approaches, final sEMG at post-op 6 months was less than the clenching sEMG values of normal male subjects obtained from similar background conditions [10]. Therefore, either of ORIF method can be used for MAFs with aim of achieving good functional recovery and mandibular mobility; however, final sEMG activity at 6 months postoperatively would always be less than normal subjects [10] who never had any maxillofacial trauma.

Within group A, during maximum clenching, a significant difference in sEMG between ipsilateral and contralateral muscles was observed only at first month (Table 4), possibly due to dietary changes, chewing difficulties and apprehension leading to frequent use of contralateral muscles for chewing. However, no such difference observed between both sided muscles in group B. The probable reason of significant higher postoperative MMO in group A (Table 3) could be due to comparatively minimal muscle stripping intraorally to that of generous stripping of pterygomasseteric sling and resultant fibrosis in group B.

In all patients irrespective of ORIF method, both masseter and anterior temporalis shown significant positive change in sEMG from pre-op to post-op 6 months (Figs. 1 and 2) attributed to healing sequel and return of near normal masticatory activity.

The patient's willingness to bite maximally is an influencing factor of sEMG as it is related to both mental attitude and the dentition, since some patients especially within the first postoperative month are afraid to use their jaws vigorously. Maximum voluntary bite force is usually modulated by neurosensory input from the dentition and surrounding periodontium [8, 22]. Furthermore, sEMG patterns of the masticatory muscles during maximal clenching depend upon occlusal and facial morphological factors [23]. As all patients were evaluated in standard acquisition environment in a standardized manner, above factors were nullified. Hence, sEMG record during non-painful maximum clenching could be regarded as an indirect measure of functional masticatory activity.

Conclusion

There is no difference in sEMG of masticatory muscles of MAF patients irrespective of ORIF approach. However, in intraoral ORIF group, higher MMO is achieved and significant difference observed in sEMG masseter and anterior temporalis muscles on fracture side. MAFs thus can be managed using either ORIF method; however, the intraoral technique shows early improvements in MMO and subsequent changes in the masticatory muscles sEMG favoring its use in clinical practice.

Declarations

Ethical approval The study was approved by Institutional Ethical Committee with letter no. Dean/2019/EC/1726.

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