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Original Article

Artigo Original

Oral-motor and electromyographic characterization of patients submitted to open and closed reductions of mandibular condyle fracture

Caracterização miofuncional orofacial e eletromiográfica de pacientes submetidos à correção da fratura condilar por redução aberta e fechada

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ABSTRACT

Purpose: To characterize the oral-motor system of adults with mandibular condyle facture comparing the performance of individuals submitted to open reduction with internal fixation (ORIF) and closed reduction with mandibulomaxillary fixation (CRMMF). **Methods**: Study participants were 26 adults divided into three groups: G1 – eight individuals submitted to ORIF for correction of condyle fracture; G2 – nine individuals submitted to CRMMF for correction of condyle fracture; CG – nine healthy volunteers with no alterations of the orofacial myofunctional system. All participants underwent the same clinical protocol: assessment of the orofacial myofunctional system; evaluation of the mandibular range of motion; and surface electromyography (sEMG) of the masticatory muscles. **Results**: Results indicated that patients with condyle fractures from both groups presented significant differences compared with those from the control group in terms of mobility of the oral-motor organs, mastication, and deglutition. Regarding the measures obtained for mandibular movements, participants with facial fractures from both groups showed significant differences compared with those from the control group, indicating greater restrictions in mandibular motion. As for the analysis of sEMG results, G1 patients presented more symmetrical masseter activation during the task of maximal voluntary teeth clenching. **Conclusion**: Patients with mandibular condyle fractures present significant deficits in posture, mobility, and function of the oral-motor system. The type of medical treatment does not influence the results of muscle function during the first six months after fracture reduction. Individuals submitted to ORIF of the condyle fracture present more symmetrical activation of the masseter muscle.

Keywords

Speech-language and Hearing Sciences
Electromyography
Stomatognathic System
Mandibular Condyle
Bone Fractures

RESUMO

Objetivo: Realizar a caracterização da performance motora orofacial de indivíduos adultos com fratura em côndilo, comparando indivíduos submetidos à redução aberta e fechada. **Método**: 26 adultos divididos em três grupos: G1 – composto por 8 indivíduos submetidos à redução aberta para correção da fratura em côndilo; G2 – composto por 9 indivíduos submetidos à redução fechada para correção da fratura em côndilo; GC – 9 indivíduos voluntários saudáveis, sem alterações do sistema miofuncional orofacial. Todos os participantes foram submetidos à avaliação que consistiu na aplicação de um protocolo clínico para a avaliação da motricidade orofacial, a amplitude dos movimentos mandibulares e a avaliação da musculatura mastigatória por meio da eletromiografia de superfície (EMGs). **Resultados:** Os resultados indicaram que ambos os grupos com fratura de côndilo se diferenciaram significantemente do grupo controle, apresentando prejuízo na mobilidade dos órgãos fonoarticulatórios e nas funções de mastigação e deglutição. Para as medidas de amplitude mandibular, os grupos se diferenciaram do grupo controle apresentando maior restrição de movimentos. Na avaliação dos músculos mastigatórios por meio da EMGs, G2 se diferenciou de G1 e de GC, apresentando maior assimetria no funcionamento do músculo masseter. **Conclusão**: Os resultados sugerem que, independentemente do tratamento adotado para correção da fratura no período de até 6 meses após a correção, o desempenho motor oral e a amplitude dos movimentos mandibulares se mantêm iguais para os pacientes submetidos à redução aberta ou fechada das fraturas condilares. A redução aberta parece favorecer a simetria no funcionamento do músculo masseter.

Descritores

Fonoaudiologia
Eletromiografia
Sistema Estomatognático
Côndilo Mandibular
Fraturas Ósseas

Study carried out at "Divisão de Fonoaudiologia, Instituto Central do Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo – USP" - São Paulo (SP), Brazil.

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INTRODUCTION

The occurrence of facial trauma cases has grown over the past four decades mostly because of the increased number of traffic accidents and urban violence, which are the main causative factors of these types of trauma. Studies show that interpersonal violence, traffic accidents, and daily household and sporting accidents have a direct relation with facial trauma, with men being the most affected by these fractures[1,2].

Mandibular fractures, especially those in the condylar and subcondylar regions, are the most common among facial fractures[2]. This type of injury can alter the functioning of the temporomandibular joint (TMJ)[1]. The mandibular condyle is essential for the masticatory movements. Changes in its morphology can lead to reduced bite force and discomfort during chewing[3]. Condylar fractures can cause temporomandibular disorders, orofacial pain, joint disc displacement, malocclusion, facial asymmetry, condylar resorption, changes in mandibular growth, ankylosis[4], and alterations in joint lubrication[5].

The literature shows a direct correlation between severity of condylar fracture and damage to the articular disc, with higher fractures leading to retrodiscal tissue inflammation[6]. Changes in soft tissues, such as joint disc displacement, seem to interfere with the functional outcome of treatment[7]. These alterations are primarily observed on the side of the fracture, but they can also occur opposite to it[8]. Patients who present medial condylar displacement after fracture are more likely to develop ankylosis, mainly due to the reduction of mandibular mobility associated with this type of injury[3,9].

Two concepts in the mandibular condyle fracture management are found in the current specific literature: surgical open reduction with internal fixation (ORIF) and closed reduction with mandibulomaxillary fixation (CRMMF). There are several possibilities to conduct CRMMF; however, nearly all approaches involve no direct reduction of the fracture, the use of soft diet for as long as two months, and placement of Erich arch bar to guide occlusion or promote intermaxillary fixation[10]. In contrast, to conduct ORIF, it is possible to perform anatomical reduction and fixation of the factored site, allowing early functional reestablishment and decreased incidence of problems arising from bone vicious healing[10].

Although the existing studies seek to verify and analyze which would be the most effective and least painful treatment, results are divergent[3,11,12]. A study conducted by Nogami et al.[12] clinically compared the outcomes of arthrocentesis and conventional conservative treatment with maxillomandibular fixation for unilateral high condylar fractures. The authors concluded that the first presented better results, with greater mandibular mobility in mouth opening for patients undergoing this type of treatment, and also found that patients had less pain and joint discomfort.

Success in the management of mandibular fractures, especially those of the condyle region, is directly related to the choice of treatment for the case based on diagnosis, stability of bone fixation, and rehabilitation prognosis. Factors such as patient's age, type of fracture, health status, associated fractures, dentition, and the possibility of restoring occlusion are also considered[13]. Muscle rehabilitation is often mentioned when discussing mandibular condyle fractures. Regardless of the type of treatment, it is known that muscular rehabilitation is necessary to improve and enhance the post-fracture functionality of jaw muscles[13].

Boyde[14] analyzed the response of long bones to exercise and noted that exercise led to increased osseous density and less resorption, contributing to bone remodeling. There are few studies addressing this theme with respect to speech-language pathology therapy. Studies in the area indicate that the changes observed during myofunctional evaluation showed significant improvement after speech-language pathology therapy, especially when the mandibular range of motion was considered[1].

The main alterations related to the oral-motor system observed in patients after facial trauma are limitation in the mandibular range of motion; pain in the facial and/or neck musculature due to muscle tension caused by poor positioning of the mandible; muscle alterations regarding traction and direction of muscle strength; changes in sensitivity; alteration in the jaw movements compromising mastication owing to limitation and asymmetry of mandibular movements, and TMJ noise[1].

Efficient evaluation of dental occlusion and masticatory function can bring relevant information to decide on the type of treatment to be performed/indicated[15,16]. Based on what has been previously exposed, there is the need to search, specifically, for muscle functioning standards of the oral-motor system of patients with mandibular condyle fracture, aiming to guide the therapeutic approach and establish parameters to determine the speech-language pathology prognosis.

The objective of the present study was to characterize the oral-motor system of adults with mandibular condyle facture comparing the performance of individuals submitted to surgical open reduction with internal fixation and closed reduction with mandibulomaxillary fixation.

METHODS

This prospective, observational, cross-sectional study was approved by the Research Ethics Committee of the aforementioned institution under protocol no. CAPPesq 495.639. All study participants signed an Informed Consent Form (ICF) before data collection procedures began.

Participants

Data collection occurred between December 2012 and December 2014. The sample was composed of individuals of both genders, aged 18 years or older, diagnosed with facial trauma with mandibular condyle fracture. Participants were referred to the Speech-language Pathology Department of the "Instituto Central do Hospital das Clínicas" - ICHC, "Faculdade de Medicina da Universidade de São Paulo" - FM-USP for evaluation.

The participants were divided into two research groups: G1 - composed of patients undergoing surgical open reduction and internal fixation (ORIF) for correction of condylar fracture;

G2 - composed of patients undergoing closed reduction with mandibulomaxillary fixation (CRMMF) for correction of condylar fracture.

Is worth mentioning that the standard protocol adopted in the institution by the Department of Plastic Surgery and Burns for the correction of mandibular condyle fractures is as follows: a) ORIF – surgical correction of condylar fracture with rigid fixation using plate and screws; b) CRMMF – indirect reduction of condylar fracture using Erich arch bar with maxillomandibular fixation by rubber bands and use of soft diet for up to two months. Patients from both groups only underwent speech-language pathology assessment after removal of arch bar and wires and medical release.

For comparison purposes, we recruited a group of healthy volunteers (CG - control group) with no alterations in the orofacial myofunctional system or in the scapular region, according to the literature; with complete permanent dentition (the absence/extraction of third molars could be accepted); with absence of severe malocclusion and without use of orthodontic appliance during the evaluation period; or with prior speech-language pathology therapy[15].

All groups were paired according to age and gender. Exclusion criteria comprised previous history of head and neck surgery, speech-language pathology comorbidities (hearing and/or communicative deficits or complaints), neurological disorders, and compromised cognition or awareness that would impair understanding of the verbal information needed for the evaluation.

Clinical assessment of orofacial motricity

Participants of the three groups were submitted to clinical evaluation of orofacial motricity. To this end, the expanded protocol of Orofacial Myofunctional Evaluation with Scores (OMES-E) was used[16]. This protocol aims to assess the components of the stomatognathic system (lips, tongue, jaw, and cheeks) with respect to appearance/posture, mobility, and performance during deglutition and mastication. The observed data were converted to a numerical scale, with maximum individual score of 230 points. Data were collected by means of visual inspection during evaluation and, subsequently, by analyzing the photos and footage recorded with the use of a digital camera (Sony DSC – W120).

In order to ensure the reliability of clinical assessment results, all participants were evaluated by two speech-language pathologists, who were independent examiners with expertise in the area. The Kappa coefficient was utilized to verify the concordance between the examiners for the overall score of the OMES-E, whose result showed high inter-rater agreement (0.89).

Mandibular range

A methodology based on the existing literature was used to assess the mandibular range of motion[1,17]. The following measures taken with the use of a digital pachymeter (Digimess Pró-Fono, Pró-Fono Produtos Especializados para Fonoaudiologia Ltda., Brasil) were obtained:

1) maximal mouth opening - distance between the incisal edges of upper and lower incisor teeth plus the measure of vertical overbite;
2) mandibular lateralization - horizontal distance of the line between the mandibular central incisors to the line between the maxillary central incisors after lateral slip of the jaw to the right and left. Appropriate adjustment was performed in case of presence of midline deviation;
3) mandibular protrusion – sum of the measure of the horizontal overlap (overjet) with the measure of the maximum horizontal sliding of the jaw.

Evaluation of masticatory muscles - Surface electromyography (sEMG)

All surface electromyography (sEMG) exams were conducted by the same speech-language pathologist under the same environmental conditions. Assessment of the electric activity of masticatory muscles of the participants was based on specific methodology[18]. To this end, the sEMG was performed using a 4-channel Miotool 400 electromyography device with all channels calibrated as follows: at 500 microvolts (μV) with a bandpass filter (20-500 Hz), a notch filter (60 Hz), and 100x gain, with low noise level (<5 μV RMS). Miograph 2.0 software (Miotec® Biomedical Equipment) was used to capture and process the sEMG exam. This software program performs online acquisition, storage, and processing of signals and runs on the Windows XP (Microsoft®) operating system. The electrical activity signals of the muscle movements were captured with disposable, bipolar surface Ag/AgCl electrodes, model SDS500, double, fixed with Transpore tape (3M®).

Prior to data collection, the facial skin of participants was cleaned using gauze soaked in 70% alcohol and local trichotomy was performed to ensure good impedance during the exam. Electrodes were placed at the midpoint of the central muscle, in the longitudinal direction of the muscle bundle, at the mesodistal position, so that simultaneous electrical activities of the temporalis and masseter muscles were evaluated in both hemifaces. The resulting signals were analyzed by root mean square (RMS) and expressed in microvolts (V). The ground cable was connected to the electrode and set on the right wrist. The electric activity of the muscles was verified according to the situations described ahead:

- at rest – recording time of 30 seconds; three collections were performed to obtain the mean electrical activity;
- at maximal voluntary dental clenching with maximal intercuspal position (MIC) – participants were requested to apply maximum bite force possible for five seconds. Three consecutive recordings were performed with a 5-second interval between trials;
- at maximal voluntary dental clenching with cotton rolls between the teeth (Al) - a cotton roll was placed bilaterally between the first and second molars, and participants were

requested to apply maximum bite force possible for five seconds. Three consecutive recordings were performed with a 5-second interval between trials.

Analysis of the electromyograms

Temporal domain analysis was conducted for the outcomes of the sEMG exams. At rest, the values obtained represent the mean (RMS) of the electromyographic activity observed over 30 seconds. The amplitude of muscle activity during the voluntary dental clenching tasks (Al and MIC) was obtained by selection of the representative period of muscle activation (i.e., on and off situations). The “on” situation was determined by the onset of muscle contraction above baseline values, whereas the “off” situation was determined by the return of the muscle to its baseline value. The mean values of the EMG amplitude for the Al and MIC tasks were normalized in relation to the activity at rest.

Reliability of the sEMG data was also analyzed. To this end, 15 electromyographic samples representative of the MIC and Al dental clenching tasks were randomly selected from a total of 156. These samples underwent blind and independent analysis by two researchers with experience in the field. The correlation coefficient was found to be high for all comparisons (95% confidence interval; [CI] = 0.8873-0.9533), indicating high inter-rater consistency.

Data analysis

Data were statistically analyzed using the SPSS, 22 version, software program. Descriptive analysis was performed including mean, standard deviation, minimum and maximum values, median, and 1st and 3rd quartiles. Because data distribution did not comply with normality, comparison between the performances of all groups was conducted using the Kruskal-Wallis nonparametric test, whereas the *post hoc* analyses of pairs were conducted by the Dunn test. The level of significance adopted for all statistical analyses was 5% (p<0.05).

The muscle asymmetry index for the maximal dental intercuspation measures with and without cotton rolls was calculated by dividing the side with lower muscle activation by the side with greater activation. This index was calculated for each participant separately.

RESULTS

After the implementation of all phases of the research previously described in the methodology, the study groups were characterized as follows: G1 was composed of eight individuals (one woman and seven men) with mean age of 35.5 years (±12.20). Regarding the location of factures, G1 included two patients with bilateral condyle fracture, three patients with left condylar fracture, and three patients with right condylar fracture. All patients presented associated fractures: seven with fractures of the mandibular body, four with mandibular ramus fractures, four with maxillary fractures, three with zygomatic fractures, four with orbital fractures, and two with fractures of the nasal bone.

G2 was composed of nine individuals (two woman and seven men) with mean age of 30.7 years (±11.61). Concerning the location of factures, G2 included two patients with bilateral condyle fracture, three patients with left condylar fracture, and four patients with right condylar fracture. As in the previous group, all patients presented associated fractures: five with fractures of the mandibular body, one with parasymphyseal fracture, one with symphyseal fracture, one with mandibular ramus fracture, six with maxillary fractures, one with zygomatic fracture, three with orbital fractures, and two with fractures of the nasal bone.

The control group (CG) was composed of nine individuals (one woman and eight men) with mean age of 33.1 years (±12.45). The total study sample comprised 26 participants. Statistical analysis indicated significant difference between the ages of the groups (p=0.713). With regard to the time elapsed (in days) between fracture reduction surgery and speech-language pathology clinical assessment in the case of G1, and between maxillomandibular fixation and clinical assessment in the case of G2, statistical analysis also indicated significant difference between the groups (G1 – 48.5±25 and G2 – 38.8±27; p=0.678).

Comparative analyses between the groups for the categories of orofacial motricity clinical assessment, according to the expanded protocol of Orofacial Myofunctional Evaluation with Scores (OMES-E), are described in Table 1. As expected, the study groups (G1 and G2) differed significantly from the control group (CG) for all items and total of the OMES-E protocol, but not between themselves. Although the initial analysis indicated significant differences between the groups for the item functions, *post hoc* analysis showed no difference between the groups. The median indicated that the group that underwent open reduction with internal fixation (ORIF) presented higher scores than the group that underwent closed reduction with mandibulomaxillary fixation (CRMMF) with respect to the items mandibular mobility, functions, and total score of the protocol. Overall, the results indicated that, regardless of the type of treatment used for fracture reduction, the two groups showed similar behavior in the oral-motor evaluation.

Comparison between the groups for the measures of mandibular range of motion is shown in Table 2. Significant difference between the study groups and the CG was observed for all measures taken, except for mandibular protrusion. No significant difference was observed between the ORIF group and the CRMMF group. Considering the medians obtained, it was possible to observe that G2 presented higher values than G1, mainly with regard to the measure of maximal mouth opening.

For comparison purposes of muscle sEMG between groups, the asymmetry index was calculated as described in the analysis of data. Table 3 shows the descriptive statistical analysis of the asymmetry indices found for each of the muscle groups in the different muscle recruitment tasks. G2 showed greater asymmetry in muscle function for both the masseter and temporalis muscles compared with those of G2 and CG. G1 also presented asymmetry in muscle function, but it was closer to that of CG.

Comparative analysis of the data (Table 4) indicated that the groups differed only with respect to the task of maximal voluntary dental clenching with cotton rolls between the teeth (Al). Significant statistical difference was found between G1 and G2, and between G2 and CG regarding maximal voluntary dental clenching with maximal intercuspal position (MIC) for the masseter muscle. G2 exhibited more asymmetrical muscle sEMG compared with those of the other two groups.

Table 1. Comparison between groups according to the results of the categories of the OMES-E protocol

	Group	Median	Interquartile range	Statistics	Comparison between pairs
Posture and position	G1	53.0	49.3-54.8		G1 = G2 p=0.072
	G2	56.5	54.8-58.5	X^2=6.795 gl=2 p=0.033*	G1 = GC p=1.000
	GC	53.0	49.8-55.3		G2 = GC p=0.081
Mobility	G1	82.5	72.8-87.5		G1 = G2 p=1.000
	G2	76.0	66.8-98.8	X^2=6.229 gl=2 p=0.044*	G1 = GC p=0.111
	GC	98.0	84.5-100.8		G2 = GC p=0.086
Functions	G1	31.5	28.5-39.8		G1 = G2 p=1.000
	G2	29.0	24.3-35.8	X^2=15.068 gl=2 p<0.001*	G1 ≠ GC p=0.011*
	GC	45.5	43.8-47.3		G2 ≠ GC p<0.001*
Total OMES-E	G1	166.5	161.0-172.0		G1 = G2 p=1.000
	G2	164.5	147.5-187.0	X^2=10.072 gl=2 p=0.006*	G1 ≠ GC p<0.018*
	GC	198.0	177.5-203.3		G2 ≠ GC p<0.021*

*Statistically significant result (p<0.05); Kruskal-Wallis and Dunn post hoc tests
Caption: OMES-E = Orofacial myofunctional evaluation with expanded scores; G1 = undergoing surgical open reduction with internal fixation (ORIF); G2 = undergoing closed reduction with mandibulomaxillary fixation (CRMMF); CG = control group

Table 2. Comparison between groups for the medians of mandibular range of motion

	Group	Median (mm)	Interquartile range	Statistics	Comparison between pairs
Maximal mouth opening	G1	20.6	13.6-29.1		G1 = G2 p=0.614
	G2	33.3	26.0-42.5	X^2=16.692 gl=2 p<0.001*	G1 ≠ GC p<0.001*
	GC	55.3	44.1-59.4		G2 ≠ GC p<0.014*
Lateralization to the right	G1	2.7	1.3-5.2		G1 = G2 p=1.000
	G2	4.6	2.6-6.2	X^2=12.205 gl=2 p=0.002*	G1 ≠ GC p<0.001*
	GC	8.2	6.4-9.1		G2 ≠ GC p=0.004*
Lateralization to the left	G1	4.2	1.6-6.2		G1 = G2 p=1.000
	G2	4.2	2.2-5.2	X^2=10.990 gl=2 p=0.004*	G1 ≠ GC p=0.024*
	GC	7.9	7.2-8.7		G2 ≠ GC p=0.008*
Mandibular protrusion	G1	3.7	1.6-7.8		
	G2	4.4	2.6-6.9	X^2=5.521 gl=2 p=0.063	-
	GC	7.0	6.0-7.4		

*Statistically significant result (p<0.05); Kruskal-Wallis and Dunn post hoc tests
Caption: mm = millimeters; G1 = undergoing surgical open reduction with internal fixation (ORIF); G2 = undergoing closed reduction with mandibulomaxillary fixation (CRMMF); CG = control group

Table 3. Descriptive analysis of the asymmetry indices of temporal and masseter muscles

		Asymmetry Index				
		Minimum	Maximum	Median	1st quartile	3rd quartile
G1	temporalis - MIC	0.17	0.86	0.53	0.33	0.69
	masseter - MIC	0.22	0.92	0.75	0.61	0.87
	temporalis - AL	0.19	0.88	0.61	0.40	0.81
	masseter - AL	0.24	0.90	0.48	0.31	0.79
G2	temporalis - MIC	0.07	0.95	0.59	0.31	0.73
	masseter - MIC	0.07	0.64	0.48	0.23	0.55
	temporalis - AL	0.03	0.87	0.50	0.33	0.81
	masseter - AL	0.05	0.97	0.54	0.42	0.75
GC	temporalis - MIC	0.31	0.95	0.71	0.62	0.86
	masseter – MIC	0.44	0.99	0.85	0.66	0.97
	temporalis - AL	0.29	0.92	0.67	0.50	0.80
	masseter - AL	0.42	0.99	0.75	0.51	0.90

Caption: G1 = undergoing surgical open reduction with internal fixation (ORIF); G2 = undergoing closed reduction with mandibulomaxillary fixation (CRMMF); CG = control group; MIC = maximal voluntary dental clenching with maximal intercuspal position; Al = maximal voluntary dental clenching with cotton rolls between the teeth

Table 4. Comparison of the asymmetry index of temporal and masseter muscles between groups

Asymmetry Index	Group	Median (μV)	Interquartile range	Statistics	Comparison between pairs
MIC - temporalis muscle	G1	0.5	0.3-0.7	X^2=4.012 gl=2 p=0.135	-
	G2	0.6	0.3-0.7		
	GC	0.7	0.6-0.9		
MIC - masseter muscle	G1	0.8	0.6-0.9	X^2=113.152 gl=2 p<0.001*	G1 ≠ G2 p=0.033*
	G2	0.5	0.2-0.6		G1 = GC p=1.000
	GC	0.9	0.7-1.0		G2 ≠ GC p=0.001*
AL - temporalis muscle	G1	0.6	0.4-0.8	X^2=0.938 gl=2 p=0.626	-
	G2	0.5	0.3-0.8		
	GC	0.7	0.5-0.8		
AL - masseter muscle	G1	0.5	0.3-0.8	X^2=3.185 gl=2 p=0.203	-
	G2	0.5	0.4-0.8		
	GC	0.8	0.5-0.9		

*Statistically significant result (p<0.05); Kruskal-Wallis and Dunn post hoc tests
Caption: μV = microvolts; MIC = maximal voluntary dental clenching with maximal intercuspal position; Al = maximal voluntary dental clenching with cotton rolls between the teeth; G1 = undergoing surgical open reduction with internal fixation (ORIF); G2 = undergoing closed reduction with mandibulomaxillary fixation (CRMMF); CG = control group

DISCUSSION

Overall, the results indicated that for clinical evaluation of the orofacial myofunctional system, both study groups (G1 and G2) differed from the control group (GC), presenting impairment of mastication, deglutition, and mobility of the phonoarticulatory organs. Both study groups did not differ with respect to this assessment item regardless of the type of treatment adopted for fracture reduction, suggesting that the oral-motor performance remains the same. As for the measures of mandibular range of motion, the study groups also differed from the CG, showing greater restriction to mandibular mobility. Qualitatively, the group submitted to closed reduction with mandibulomaxillary fixation (CRMMF) showed greater mandibular range of motion compared with that of the group undergoing surgical open reduction with internal fixation (ORIF). Regarding the surface electromyography (sEMG) of the masticatory muscles, the CRMMF group differed from the ORIF and control groups, presenting greater asymmetry in the sEMG of the masseter muscle at the maximal intercuspal position (MIC).

As previously presented, the medical procedures used for treating facial fractures can be surgical or not. The dentist may choose to manage the fracture using CRMMF or ORIF. According to the literature, the choice of technique is directly related to the fracture location and characteristics, displacement of fragments, and condition of the teeth[3,10]. In the ORIF technique, there is an array of surgical approaches to be used, as well as different types of materials to perform the fixation of fractured bone fragments[3]. The CRMMF technique is usually adopted when the fracture presents significantly disfavored displacements, that is, displacement of fractured bone fragments is likely to become worse through muscular action[3,11], being therefore chosen in more severe fractures.

Data on orofacial myofunctional evaluation in patients with facial trauma are scarce in the specific literature[1,2]. The studies that more closely resemble the cases herein described address the postoperative performance of patients undergoing orthognathic surgery. In these cases, because there is surgical preparation and planning, it is possible to conduct an assessment preliminary to the surgery for determination of the facial pattern and comparison with postoperative outcomes[19-22]. In the case of condylar trauma, because it is not possible to assess the patient before the fracture, it is also not possible to know whether changes of occlusion or dental deformities already existed, leading to alterations in the orofacial motricity.

Post-surgery intramuscular factors indicative of atrophy are observed in studies on dental deformities and orthognathic surgery. For patients who underwent mandibular distraction, this characteristic remains for up to 6 months after surgery, probably due to muscle strain caused by the surgical procedure, which leads to a decrease in the regeneration of muscle fibers[19]. It is known that the musculature produces its own growth factors, which regulate fiber hypertrophy and muscle volume. These growth factors are still not known for the masticatory muscles in humans[20]. Most likely, some types of fracture may lead to muscular strain, initiating a process of muscle atrophy and altering the formation of the masseter muscle fibers. A study that investigated the type of muscle fiber in individuals with dentofacial deformities showed that when occlusion is smaller, muscle activity is reduced and fewer muscle fibers are recruited, leading to reduced muscle volume[21]. Qualitatively, when the OMES-E scores of the groups were considered, analysis of the results raised the hypothesis that the surgical treatment of fractures allows for better and early muscle activation, which justifies why participants of the ORIF group (G1) presented better orofacial myofunctional performance in the short term. As for participants of the CRMMF group (G2), the muscle strains may occur after the fracture, without prompt correction, justifying the worse performance of orofacial functions and mobility.

Regarding mandibular mobility, there are more studies with different outcomes for patients with facial trauma, comparing various treatments, such as open and closed reduction. Two studies reported that the group of patients submitted to ORIF presented lower occurrence of clicking and pain, better condylar regeneration, and better mandibular range of motion compared with those of the group of patients submitted to CRMMF[22,23]. When the functional results of the CRMMF technique are compared with those of intra-articular irrigation for the treatment of mandible condyle fractures, the latter showed better outcomes, with these patients presenting mean mouth opening of 40 mm after three months of follow up, whereas patients of the first group only reached this measure after six months[11]. However, these studies did not perform analysis of the masticatory function, only verified the mandibular mobility.

For the treatment with ORIF, studies show varied mouth opening, from 32 to 64 mm, presence of mandibular deviation, and pain on maximal mouth opening[3,10,12,22,23]. Difficulties with sample size and heterogeneity of individuals are factors reported by most studies. Studies that investigated patients undergoing CRMMF showed that, six months after the procedure, the displaced disc is deformed by reduced thickening of the posterior band and a decrease in the mass of the anterior band of the central area, leading to a biconvex disc. The higher the condylar fracture, the worse the damage to the retrodiscal tissue[6,8].

CRMMF treatment of the fracture followed by functional rehabilitation of the muscles is considered safe; however, the main advantage of the ORIF treatment is the reduction of the displaced fragment to its most anatomical form possible[10]. As a drawback, the ORIF treatment is considered an invasive treatment that can cause damage to nerves and blood vessels during the surgical procedure, as well as post-operative complications such as infections[13]. In the present study, no statistically significant differences were found between the groups with open and closed reductions of fractures with respect to mouth opening, laterality, and jaw protrusion. Again, qualitative analysis shows that measures were smaller for the ORIF group (G1) compared with those of the other groups. This information can be justified both by the small study sample size and the reduced time between the medical procedure and the speech-language pathology clinical assessment - less than three months for all individuals.

When compared with the control group, significant differences were observed for all movements, except for mandibular protrusion. Mandibular motion results in changes in the intraoral space, affecting the functions of chewing, swallowing and speaking, because it enables motion of the intraoral structures[24]. Maximal mouth opening is traditionally mentioned as the major task for the assessment of temporomandibular joint (TMJ) function[25]. According to Schneider[23], mouth opening should be considered a less sensitive component compared with the other movements, because a rotational component can compensate for a deficiency in the translation of the mandibular condyle in the glenoid fossa. Protrusion has been suggested as a more sensitive marker for evaluating the translation movement of the condyle[23].

Regarding the surface electromyographic data (sEMG), studies on the muscle rehabilitation of patients undergoing orthognathic surgery are also found. In general, they describe patients presenting wide variation in bite force measures and sEMG values, with alteration in the occlusal plane angle related to major changes in muscle function data (decreased) owing to verticalization of the direction of the muscle activation vector by increasing the occlusal plane[26]. For trauma patients, it is not possible to determine the occlusal plane prior to fracture. However, it can be considered the existence of this change in direction of the muscle activation vector after surgery for fracture reduction or, yet, that this change occurs during bone regeneration. Further studies should be conducted to investigate this aspect.

In relation to condyle fractures, as observed in the results of the present study, possible muscular strain and postoperative occlusal changes may have led to a worse symmetry with respect to the activation of the masseter muscle for the CRMMF group (G2). For patients of the ORIF group (G1), reapproximation of the bone bases probably enabled better muscle performance, even considering surgical manipulation, which can, in turn, lead to the occurrence of edema, interference with the healing process, and consequent deterioration of muscle performance[27]. A study with patients undergoing orthognathic surgery that also used the asymmetry index[28] describes improvement in muscle balance after surgery and after correction of dentofacial deformities.

With respect to the monitoring of patients postoperatively to orthognathic surgery, studies have shown alteration in the sEMG values in the early postoperative period, with improvement after 6 months[26,29]. These studies showed that, with muscle rehabilitation, recovery of muscle function was faster, but after 6 months, the performance of individuals with and without treatment was similar. Another study suggests that, for patients undergoing orthognathic surgery, recovery of the masticatory function precedes physiological muscle changes[26]. Evaluation after speech-language pathology therapy is needed for patients with condyle trauma so that possible muscle disorders can be observed in the long term.

In general, it is known that compensation may occur during muscle rehabilitation (hyperfunction of the masseter, temporalis and sternocleidomastoid muscles)[4] resulting from changes in bone and muscle structure and in joint function. These offsets are, at first, necessary for functional viability, considering that structural impairment prevents normal physiology and requires the use of adjacent muscles[4,26,28]. Nevertheless, this compensation should be carefully assessed during rehabilitation sessions of the muscular and orofacial functions[1] aiming to minimize muscular atrophy, changes in muscle fibers, condylar alterations, etc[27]. Further studies with larger samples and longitudinal follow-up of participants should be conducted to improve understanding of the process of muscle regeneration after mandibular condyle fracture.

CONCLUSION

Overall, the results of the present study suggest that, regardless of the treatment used to reduce the fracture in a period of up to 6 months after correction, the oral-motor system and mandibular range of motion remain the same for patients undergoing both open or closed reduction of mandibular condyle fractures. The group of patients undergoing surgical open reduction with internal fixation of the fracture showed better symmetry in the activation of the masseter muscle when compared with that of the group treated with closed reduction with mandibulomaxillary fixation.

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Author contributions

APS contributed to the literature search, data collection, and writing of the manuscript; FCS participated in the organization, analysis, and interpretation of data and writing of the manuscript; CRFA was responsible for the design, coordination, and schedule of the study and final version of the manuscript.