Review Article

ELECTROMYOGRAPHIC CHANGES IN THE MASTICATORY MUSCLES AFTER ORTHOGNATHIC SURGERY: A SYSTEMATIC REVIEW

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https://doi.org/10.51847/wUhLZjo1XC

ABSTRACT

Maxillofacial skeletal deformities affect the functional activity of the masticatory muscles. The combination of orthodontic treatment and orthognathic surgery is recommended as an effective way to correct dentofacial deformities beyond the capabilities of orthodontic treatment. This systematic review aims to assess the effect of orthognathic surgery on the changes in the electromyography of the masticatory muscles. A comprehensive electronic search was carried out in compliance with Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) guidelines. An electronic search was conducted using the following terms: (masticatory muscle activity) AND (electromyographic activity) AND (orthognathic surgery). After an initial search, 2070 scientific records were found, 5 studies that met the eligibility criteria were included in the final analysis. The Joanna Briggs Institute (JBI) tool was utilized to assess the methodological quality of the studies. An average improvement in masticatory muscle activity was observed six months post-orthognathic surgery, according to the analyzed studies. Longer post-surgical follow-up and additional interventions are needed to ensure that the masticatory muscles adapt better to the occlusion and skeletal morphology.

Key words: Electromyography, Masseter and temporalis muscles, Functional activity, Orthognathic surgery.

Introduction

The interaction of genetic and extrinsic factors determines facial development [1]. The functional activity of the masticatory muscles has a notable impact on the morphology of the developing craniofacial system [2]. The relationship between the functional activity of the masticatory muscles and dental occlusion was first described by Moyers [3, 4]. Patients with a slight mandibular inclination and pronounced mandibular prognathism exhibit increased muscular force [1, 5]. Miralles *et al.* found that individuals with skeletal Class III have greater activity of the masseter and temporal muscles than skeletal Class I and II patients [6].

The combination of orthodontic treatment and orthognathic surgery (OGS) is recommended as an effective way to correct dentofacial deformities beyond the capabilities of orthodontic treatment. The main objectives of OGS are not only improved function but also facial and dental aesthetics, as these factors affect the patient's long-term quality of life after completing orthodontic-surgical treatment [7].

Craniofacial modifications impact alterations in the functional activity of the masseter muscles [1, 3]. Precious *et al*. found that the first changes in the neuromuscular system are observed during pre-surgical orthodontic treatment [1, 8]. According to Dean *et al.* patients receiving pre-surgical orthodontic treatment had a decrease in bite force compared to their initial bite force before starting the orthodontic treatment [9]. Previous studies have shown that surgical correction of Class III malocclusion improved the balance of both sides of the masseter muscles (MM) and the dominance of the masticatory muscles [10, 11].

The range of mandibular movement, dental occlusal contact, masticatory efficiency, bite force, and electromyographic activity of the masticatory muscles can be used to evaluate the function of the masticatory muscles [3]. Surface electromyography (EMG) is an effective method to investigate neuromuscular function in dentistry. The bioelectric potentials of the muscle fibers are recorded by using electrodes placed on the surface of the masticatory muscles [12]. Tatsumi *et al.* state that orthodontic surgical intervention has the potential to enhance the functional activity of masticatory muscles [13]. To assess alterations in the EMG of the masticatory muscles, it is essential to review the studies that have investigated the functional activity of the masseter and temporal muscles before and after OGS.

This systematic analysis of scientific records aims to assess the effect of OGS on the changes in the EMG of the masticatory muscles.

Materials and Methods

Protocol and registration

The systematic literature review followed the Preferred Reporting Item for Systematic and Meta-Analyses (PRISMA) methodological guidelines [14]. The protocol was registered in the International Prospective Register of Systematic Reviews (PROSPERO).

Search strategy

A comprehensive search of scientific records was performed in PubMed (Medline), Science Direct (Elsevier), Wiley Online Library, and The Cochrane Library electronic databases using combinations of the following keywords: (masticatory muscle activity) AND (electromyographic activity) AND (orthognathic surgery).

Selection of studies

The selection of articles was conducted by two authors according to pre-established inclusion and exclusion criteria. The eligibility of scientific records was carried out in two stages. During the first stage, each article was reviewed based on the title and abstract. Following this stage, 25 records were chosen for further review. In the second stage, the full text of pre-selected records was evaluated according to eligibility criteria. 5 scientific records that met all the inclusion criteria were selected for final analysis. All records were managed using RefWorks software.

Eligibility criteria

- Studies published less than 5 years ago;
- Research articles written in English;
- Clinical studies analyzing electromyographic changes in the masticatory muscles after orthognathic surgical intervention;
- Full-text articles with open access.

Exclusion criteria

- Systematic reviews, meta-analyses, case reports, case series, conference abstracts, editorials, and opinion articles;
- Non-human studies;
- Human trials with missing or unclear data.

Assessment of methodological quality

Two authors independently evaluated the risk of bias in included studies. The quality of individual studies was assessed using the Joanna Briggs Institute (JBI) critical appraisal tool [15]. After considering each of the quality items, the selected records were assessed into one of three categories: low risk (+), some concerns risk (?), or high risk (-) of bias.

Results and Discussion

Study selection

After the initial search, 2070 scientific records were found. The search range filter (2018-2023) yielded 675 records. The remaining 660 articles have been selected based on their titles, abstracts, and full text after duplicates have been eliminated. The detailed process of study selection is illustrated in the PRISMA flowchart **(Figure 1)**. This systematic literature review included 5 scientific records that met the eligibility criteria. **Table 1** provides data on the characteristics of the scientific papers and the results of the individual studies.

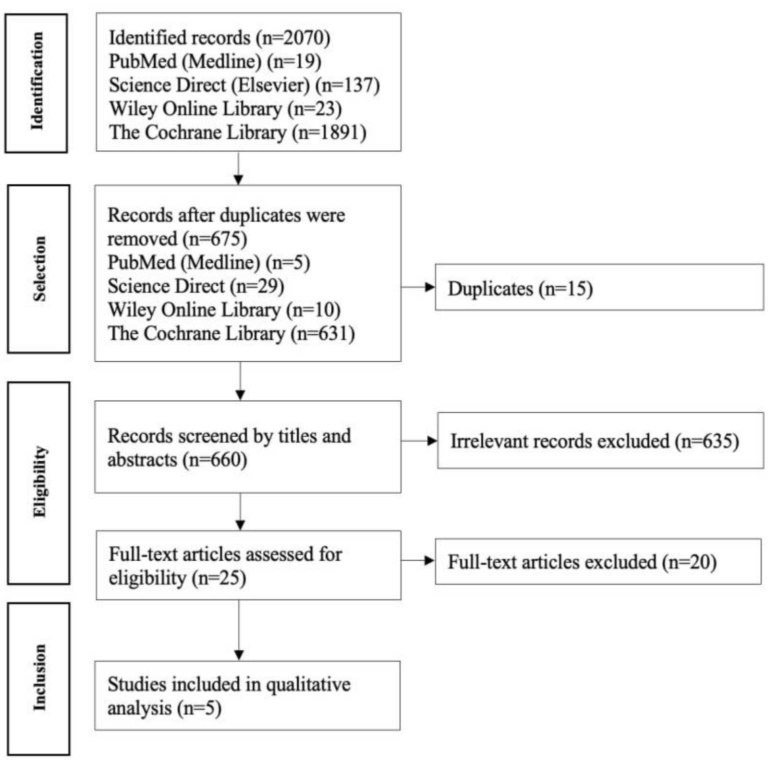

Figure 1. PRISMA flow chart.

Quality assessment

After finishing the evaluation of systematic errors in the scientific records, it was concluded that three studies [16-18] based on the JBI tool were of high quality (low risk of systematic errors), and two studies [19, 20] were of moderate quality (medium risk of systematic errors), as they did not describe extraneous factors that could have influenced the results of the studies and did not identify ways to avoid them. The detailed process for assessing the risk of systemic errors is presented below **(Figure 2)**.

Patient's data

A total of 84 patients diagnosed with Class III skeletal malocclusion were included in the studies. As the reviewed studies indicate, the patients underwent different types of OGS. In three studies, a double jaw osteotomy was performed to adjust the position of the jaws [16, 18, 19]. Other surgical modifications used include Le Fort type I [17], bilateral sagittal split [17], set-back [16], and intraoral oblique sliding (or subsigmoid) [20] osteotomies.

Authors/year	CHECKLIST ITEMS								
	Clear inclusion criteria	Description of study subjects and setting	Exposure measurements	Measurement criteria	Identification of confounding factor	Strategies for confouding factors	Outcomes measurement	Proper statistical analysis	Overall rating
González Olivares *et al.* (2019) [20]	✓	✓	✓	✓	?	⊖	✓	✓	?
Ozge Muftuoglu *et al.* (2023) [16]	✓	✓	✓	✓	✓	?	✓	✓	✓
Ezgi Sunal Akturk *et al.* (2020) [17]	✓	✓	✓	✓	✓	✓	✓	✓	✓
Deniz Celakil *et al.* (2018) [18]	✓	✓	✓	✓	✓	?	✓	✓	✓
Kyung-A Kim *et al.* (2019) [19]	✓	✓	✓	✓	?	⊖	✓	✓	?

✓ low risk; ? some concerns; ⊖ high risk.

Figure 2. Quality assessment using Joanna Briggs Institute (JBI) critical appraisal tool

Electromyography outcomes

In the study conducted by González Olivares *et al.* an intraoral oblique sliding (or subsigmoid) [20] osteotomy was performed on all patients. There was no statistically significant difference between the measurements taken at T1 (7 days before OGS), T2 (3 months after OGS), and T1-T3 (6 months after OGS) evaluating the frequency of electrical impulses generated by motor neurons in the *m. masseter* (Wilcoxon Z = 1.42, P = 0.154; Wilcoxon Z = 2.04, P = 0.132). Based on the authors' findings, the lack of a statistically significant difference in the frequency indicates that the *m. masseter* motor centers were not harmed during the surgery. A statistically significant difference was observed while comparing the average amplitude of the *m. masseter* electrical signals between the T1 and T3 measurement moments (17.0 vs 14.7, Wilcoxon Z = 2.31, P = 0.020). The amplitude values of the right and left side *m. masseter* revealed a statistically significant and equivalent change at 6 months after OGS (Wilcoxon Z = 2.93, P = 0.003; Wilcoxon Z = 2.67, P = 0.007). There was a statistically significant increase in the mean amplitude value of *m. temporalis* between T1 and T3 measurement moments (18.2 vs 25.6, Wilcoxon Z = -2.57, P= 0.009).

González Olivares *et al*. indicate that MM activity recovered within 6 months following OGS, according to the gathered data.

Ozge Muftuoglu *et al.* found that after performing a set-back osteotomy, the control group had higher *m. masseter* activity at maximum clenching (MC) than the study group at all measurement moments during the one-year follow-up after OGS (P<0.05). In the control group, the average EMG activity (μV) during MC was 145.9 μV; T1 (before OGS) during MC EMG activity was 77.85 μV; T2 (3 months after OGS) 68.86 μV; T3 (1 year after OGS) 113,6 μV.

According to the authors, after OGS, a longer patient postoperative follow-up and additional interventions are needed to ensure a better adaptation of the masticatory muscles to the occlusion and skeletal morphology.

According to the results of the study conducted by Ezgi Sunal Akturk *et al.* there was no statistically significant difference between the study group and the control group after performing the measurements of masticatory muscle activity at rest at T1 (before OGS) and at T2 (3 months after OGS). In the study group, the activity of the masticatory muscles during MC increased during the 3 months of the postoperative period.

The activity of masticatory muscles increased after OGS. The authors contend that a three-month postoperative period is not long enough for the masticatory muscles to adapt to the skeletal morphology and occlusion.

According to the investigation that was carried out using double jaw OGS, Deniz Celakil *et al.* found that resting *m. temporalis anterior* activity and activity during maximum biting reduced between the T0 (before the use of the stabilization splint) and the T1 (after the use of the stabilization splint) at performed measurement moments. T0 (relaxation) 8,24 μV; T0 (maximum bite) 76,74 μV; T1 (relaxation) 7,37 μV; T1 (maximum bite) 75,37 μV (P=0.001; P<0.01). After the surgical intervention, a decrease in the activity of the *m. temporalis anterior* and *m. masseter* muscles were identified.

Measurements at T3 (6-8 months after OGS) showed higher MM activity compared to measurements performed at T0 (P<0.01). *M. temporalis anterior* EMG activity at T0 (maximum bite) 76,74 μV; T3 102,52 μV. *M. masseter* T0 (maximum bite) 70,07 μV; T3 (maximum bite) 96,22 μV.

Kyung-A Kim *et al.* found no statistically significant differences in assessing postoperative changes in EMG. It was observed that 7 to 8 months after undergoing OGS, the EMG activity of the MM returned to normal.

In a study by Kyung-A Kim *et al.* the possible influence of facial asymmetry on the measurement results was considered when assessing the activity of masticatory muscles.

Table 1. Characteristics of included studies.

Authors, year	**Study type**	**Patients, F/M, mean age (SD)**	**Malocclusion**	**Type of OGS**	**Follow-up**	**Outcomes**	**EMG results**
González Olivares *et al.* (2019) [20]	RS	11	Class III	Intraoral oblique sliding (or sub-sigmoid) osteotomy	T1 – 7 days before surgery; T2 – 3 months post-surgery; T3 – 6 months post-surgery	Changes in the frequency, mean amplitude, and peak-to-peak amplitude of the MM and TM	EMG activity of the MM and TM was recovered 6 months following OGS
Ozge Muftuoglu *et al.* (2023) [16]	RS	29 (19/10) Mean age 20.37 ± 2.19 **Control:** 20 (11/9) Mean age 23.60 ± 1.50	Class III, SNA: 80.30°± 3.10°, SNB: 84.10°±3.70°, ANB: -3.80°±2.60°, GoGN/SN: 33.30°±4.90°. **Control:** Class I	22 patients – double jaw OGS; 7 patients – mandibular set-back osteotomy	T1 – before surgery; T2 – 3 months post-surgery; T3 – 1 year post-surgery	EMG, ultrasonography, and ultrasound elastography changes of the MM after OGS	The EMG activity of the masseter muscle during MC increased one year after OGS but did not reach the levels observed in the control group
Ezgi Sunal Akturk *et al.* (2020) [17]	RS	15 (9/6) Mean age 19.40 ± 1.70 **Control:** 15 (8/7) Mean age 23.21±1.05	Class III, SNA: 79.42° ± 2.51°, SNB: 84.77° ± 3.12°, ANB: -5.35° ± 2.46°, GoGN/SN: 32.87° ± 5.17°	11 patients – Le Fort I osteotomy; 4 patients – bilateral sagittal split osteotomy	T1 – before surgery; T2 – 3 months post-surgery	EMG, thickness, width, and hardness changes of the MM before and after OGS	Muscle activity during MVC increased after OGS but did not reach control group levels at 3 months postoperatively
Deniz Celakil *et al.* (2018) [18]	RS	12 (8/4) **Control:** 13 (9/4)	Class III	Double jaw OGS	T0 – before stabilization splint application; T1 – after stabilization splint application; T2 – 1-month post-surgery; T3 – 6-8 months post surgery	Masticatory performance and EMG activity changes of the MM and anterior TM after OGS	Masticatory muscle activity increased during relaxation compared to the control group. EMG activity attained the value of the control group 6–8 months after double jaw OGS. Masticatory performance and EMG activity during the MBF test improved after 6–8 months of double jaw OGS but remained lower than in the control group

Kyung-A Kim *et al.* (2019) [19]	RS	17 (6/11) Mean age 22.2 ± 4.1 **Control:** 10 (6/4) Mean age 21.5 ± 2.0	Class III, ANB<0°	Double jaw OGS	T0 – before surgery; T1 – 7-8 months post-surgery	Masticatory muscle activity and mandibular movement pattern changes of the MM and anterior TM after OGS	7-8 months following the OGS, the EMG activity returned to pre-surgical levels. The EMG activity changed to the MM-dominant pattern only during the anterior cotton roll biting

RS, retrospective study; OGS, orthognathic surgery; EMG, electromyography; MM, masseter muscle; TM, temporal muscle; MC, maximum clenching; MVC, maximum voluntary contraction; MBF, maximum biting force.

Some authors suggest that the activity of the *m. masseter* is lower on the side from which the midline of the mandible is deviated. The EMG parameters of *m. masseter* is greater on the side where the mandible deviation is observed when the mouth is opened, according to studies conducted by other authors.

The researchers evaluated the activity of the masticatory muscles by instructing the individuals to bite down a cotton roll with their anterior teeth. This type of intercuspation relies on Roth's methodology, which is utilized to record the centric relation (CR). This technique eliminates occlusal contacts between posterior teeth and shifts the patient's condylar position to CR [21]. This approach involves minimum movement of the *m. temporalis* and *m. masseter* muscles. The authors indicate that correcting the position of the jaws in the sagittal plane has a significant impact on the activity of masticatory muscles, particularly the MM, in cases of anterior occlusion. The authors of the analyzed studies state that the average recovery time for MM activity following OGS is 6 months.

Skeletal deformities requiring orthodontic-surgical treatment are often associated with pathologies of the temporomandibular joint (TMJ) [22]. After OGS, the increased activity of masticatory muscles and the pressure on the alveolar processes and the TMJ can lead to the development of parafunction. Postoperative facial soft tissue and muscle edema, leading to an increase in intramuscular pressure and muscle hardness, may be associated with the subsequent development of parafunction. Previous studies show that facial soft tissue edema is reduced by 50% after OGS and by 80% after 3 months. Minimal swelling of the surgical site persists even 6 months after the intervention [23, 24]. Postoperative edema may be one of the factors contributing to inaccurate EMG results in the postoperative evaluation.

Massaging the masticatory muscles during rehabilitation can help reduce the hardness of the masticatory muscles [25, 26]. A meta-analysis on the use of systemic corticosteroids in OGS by Jean *et al*. found that systemic corticosteroids reduced facial soft tissue and muscle edema, but according to the authors, the use of systemic corticosteroids in surgical intervention is not justified enough because of potential side effects such as bleeding [27].

Surface EMG is one of the most non-invasive methods to assess the functional activity of masticatory muscles. According to the data of a previous study, the size of the electrodes, the location of the fixation, and the inter-electrode distance led to different characteristics of the EMG signals and may influence the results of the study [28].

According to two studies included in the systematic analysis, the electrodes were fixed parallel to the muscle fibers, 20 mm apart [17, 18]. 20 × 20 mm electrodes were used to assess the EMG activity of masticatory muscles in two studies [16, 17]. In a study by Deniz Celakil *et al.* 8 mm diameter electrodes were chosen for EMG assessment [18]. We believe that different electrode fixation protocols may be one of the factors contributing to the difference in results between the studies analyzed.

Myotonometry is another non-invasive method for assessing the mechanical characteristics of muscles. Mechanical impulses generated by the myotonometer allow to recording of data on muscle tone, stiffness, and elasticity [29]. This method can be used to assess different muscle groups but there are no studies analyzing the myotonometric characteristics of masticatory muscles. It is important to note that myotonometry does not assess the neuromuscular activity of muscles, which can only be assessed by EMG.

Conclusion

The analyzed studies found that there was a moderate improvement in masticatory muscle activity 6 months after orthognathic surgery. Longer post-operative follow-up and additional interventions are necessary to guarantee optimal adaptation of the masticatory muscles to the occlusion and skeletal morphology.

Acknowledgments: None

Conflict of interest: None

Financial support: None

Ethics statement: This study fulfils the ethical requirements of Lithuanian University of Health Sciences.

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