Activities of masticatory muscles in patients after orthognathic surgery

Elena DI PALMA\textsuperscript{1}, Giulio GASPARINI\textsuperscript{2}, Sandro PELO\textsuperscript{2}, Gianluca M. TARTAGLIA\textsuperscript{3}, Claudio CHIMENTI\textsuperscript{1}

\textsuperscript{1}Department of Surgical Sciences (Head: Prof. G. Amicucci), Università degli Studi di L’Aquila, Italy; \textsuperscript{2}U.O. Maxillofacial Surgery, Università degli Studi di Roma, Italy; \textsuperscript{3}Department of Human Morphology (Head: Prof. C. Sforza), Functional Anatomy Research Center (FARC), Faculty of Medicine and Surgery, Università degli Studi di Milano, Milan, Italy

SUMMARY. Aim: To evaluate left and right masseter and anterior temporalis muscle activity in patients before and after orthognathic surgery. Patients: Nineteen patients were enrolled, 9 males and 10 females, aged 17–34 years. Four patients were suffering from a prognathic syndrome (skeletal class II with mandibular retrusion) and were candidates for surgical correction involving a mandibular Bilateral Sagittal Split Osteotomy (BSSO), whereas the other 15 patients showed a progenic syndrome (skeletal class III with mandibular protrusion) and were selected for bimaxillary surgery with maxillary advancement and mandibular retraction. Methods: Electromyographic examinations were carried out on all subjects presurgically and 6–8 months postoperatively. To verify the neuromuscular equilibrium, the electromyographic activities of both the right and left masseter and anterior temporalis muscles were registered and analysed calculating: percentage overlapping coefficient (POC, index of the symmetric distribution of the muscular activity determined by the occlusion) and torque coefficient (TC, index of presence of mandibular torque). Results: After surgery, a trend in the improvement of POC and TC indices was found, with a reduced intragroup variability. Conclusion: The electromyographic evaluation allowed the impact of occlusion on neuromuscular equilibrium to be quantified, and showed that improvements gained by surgical intervention are primarily due to better occlusal stability and not to biomechanical advantages. © 2009 European Association for Cranio-Maxillofacial Surgery

Keywords: orthognathic surgery, electromyography, occlusion

INTRODUCTION

The purpose of orthognathic surgery is to improve facial aesthetics, occlusal relations and the functionality of the stomatognathic apparatus in patients with morphological alteration of the facial skeleton.

The patients’ high demand for aesthetics has prompted the development of more sophisticated techniques to forecast with good accuracy the final result of orthognathic surgery treatment. Reliable hardware and software tools for computer assisted planning and guidance of surgical procedures offer new perspectives in modern surgery (Schneider et al., 2005; Mischkowski et al., 2006; Schauf et al., 2006; Ettorre et al., 2006).

In addition, the patient perceives occlusal and muscular incoordination and instability. The patient’s satisfaction is a parameter of major importance to evaluate the success of surgical treatment. Actually, patients not only judge aesthetic advantages but also improvements in the function of their stomatognathic apparatus. However, subjective judgements cannot easily be quantified. To obtain objective parameters about improvements obtained by maxillofacial surgery, we should consider photographs and radiographs (to evaluate facial morphology), photographs and plaster models (to evaluate occlusal relations), electromyography (EMG), bite force and mandibular movements (to evaluate the stomatognathic functionality: the muscles represent the functional component of the stomatognathic apparatus) (Throckmorton et al., 1996, 2000; Youssef et al., 1997; Iwase et al., 1998; Harada et al., 2000; Ettorre et al., 2006; Schauf et al., 2006; Sforza et al., 2008).

In particular, surface EMG is a quick, non-invasive examination, which is not disturbing for the patient: it can also be used in patients with painful symptoms that certainly reduce the compliance of even slightly bothering examinations (Sforza et al., 2008).

The literature reports both studies attesting to muscular activity improvements in patients who underwent different types of orthognathic surgery (Zarrinkelk et al., 1995, 1996; Throckmorton et al., 1996; Song et al., 1997), and studies not proving statistically significant improvements (Youssef et al., 1997; Iwase et al., 1998; Van Den Braber et al., 2004; Sforza et al., 2008). In other investigations, patients reached the level of the normal population only 2–3 years after the surgical intervention (Shiratsuchi et al., 1991; Throckmorton et al., 1995; Ellis et al., 1996; Harada et al., 2000).

Previous studies found that the improvements in muscular activity were due to better occlusal stability (Moss, 1975), and not to biomechanical advantages (Kikuchi et al., 1997; Kim and Oh, 1997) subsequent to surgical treatment. In the current study, the importance of occlusion for the neuromuscular equilibrium was investigated.
in patients undergoing orthognathic surgery for the correction of various facial dysmorphologies. As demonstrated in previous studies (Proffit et al., 1989; Youssef et al., 1997), improvements in the electrical activity of masticatory muscles are independent from the type of surgical treatment. Therefore, patients scheduled to undergo different types of orthognathic surgery were randomly included in our sample.

Measurements were performed before surgery, and 6—8 months after the intervention when patients had subjectively regained good masticatory function.

PATIENTS AND METHODS

Analysed subjects

Nineteen patients, including 9 males and 10 females aged 17—34 years, attending the maxillofacial surgery department of Rome’s Catholic University of the Sacred Heart were enrolled in the study. Four of these patients had features of a prognathic syndrome, and were scheduled for a surgical correction involving a Bilateral Sagittal Split Osteotomy (BSSO); the other 15 patients showed a prognathic syndrome, and were planned to receive bimaxillary surgery, with maxillary advancement and mandibular retraction.

A surface EMG examination was performed on all patients pre- and post-surgically to verify modifications to the standardized electrical activity of their masticatory muscles subsequent to orthognathic surgery. The second recording was carried out 6—8 months after surgery, a time span considered sufficient for the patients to adapt well to their new occlusal situation.

After a detailed explanation of all EMG procedures and possible risks, all patients gave their written consent. The protocol was approved by the local ethics committee.

Bipolar surface electrodes were positioned on both the right and left masseter and anterior temporalis muscles (parallel to the fibres), as described by Ferrario and Sforza (1996):

- anterior temporalis: vertically along the anterior margin of the muscle (approximately along the coronal suture);
- masseter: parallel to the muscle fibres, with the superior pole of the electrode on the intersection of the cheek—tragus and exocanthion—gonion lines.

The skin was cleaned thoroughly before positioning the electrode to reduce impedance and the recordings were carried out after having applied the conducting paste for 5—6 min.

Bipolar electrodes with a diameter of 10 mm were applied, the interelectrode distance was 21 ± 1 mm. The reference electrode was positioned on the forehead. The EMG activity was registered with (4 of the 8 channels of) the instrument (Freely, De Götzen srl; Legnano, Italy).

The EMG signal was amplified, digitised and digitally filtered. The instrument is directly interfaced with a PC that presents the data graphically, and records them on magnetic media for subsequent qualitative and quantitative analysis.

The signals were averaged over 25 ms, with muscle activity assessed as the root mean square (rms) of the amplitude (unit: µV).

Measurement protocol and EMG data analysis

The Functional Anatomy Research Centre (FARC) protocol (Ferrario et al., 2000) includes a first recording for the standardization of EMG potentials: two 10-mm thick cotton rolls were positioned on the mandibular second premolar and molars of each patient, and a 3 s maximum voluntary clenched was recorded. For each muscle, the mean EMG potential was set at 100%, and all further EMG potentials were expressed as a percentage of this value (unit: µV/µV × 100). The relative percentage EMG values found in the experiment should thus be affected only by the occlusal surfaces, because this kind of standardization should annul the variability caused by skin and electrode impedance, electrode positioning, and relative muscular atrophy or hypertrophy (Ferrario et al., 2006).

The height of the cotton roll might slightly modify the vertical dimension (and consequently the length of muscular fibres and the interelectrode distance), but, when clenched, it becomes so thin as to make the effect negligible. The resulting standardized EMG potentials should therefore be determined only by the muscular contraction as it correlates with the occlusal surfaces.

In each subject, EMG activity was then recorded during a 3-s maximum voluntary clench. The test was performed without changing the electrodes or moving the cables. During testing, the patients sat with their heads unsupported and were asked to maintain a natural erect position. For each patient and muscle, the standardized EMG potentials were used to plot the relevant EMG waves. The following calculations were then performed.

1. The EMG record of paired muscles were compared by computing a percentage overlapping coefficient (POC, unit: %). POC is an index of the symmetric distribution of the muscular activity determined by the occlusion: if two muscles contract with perfect symmetry, a POC up to 100% is to be expected. Calculations were performed for each pair of muscles, thus obtaining a temporalis and a masseter POC.

2. The EMG recordings of the left and right masseter and anterior temporalis muscles of each subject were further analysed to assess the presence of a possible lateral-deviation effect on the mandible during the test given by unbalanced right temporalis and left masseter, and left temporalis and right masseter couples. Considering the direction of the resultant forces of the masseter and temporalis muscles, a couple with a lateral-deviating effect on the mandible may be produced. Indeed, while the result of the temporalis muscle of one side is directed upward and backward, the result of the contralateral masseter is directed upward and forward. A force couple that may deviate the mandible towards the temporalis side could thus be produced, and its presence was assessed by calculating a torque coefficient (TC, unit, %).

However, an effective torsion of the mandible does not occur, due presumably the action of the other jaw and
head and neck muscles. Nevertheless, the unbalanced muscle activity may provoke muscular and joint alterations (Ferrario et al., 2000).

Mean values and standard deviations (SDs) were calculated pre- and post treatment. Data obtained pre- and post-surgically were compared by the Student’s t test for paired samples with a significance level set at 5% (P < 0.05).

The repeatability of EMG registrations of masseter and anterior temporalis muscles has previously been tested in FARC laboratory and in Orthognathic Department of University of L’Aquila, and found to be good (Ferrario et al., 2006).

RESULTS

The statistical analysis (Table 1) showed an improvement in the POC indexes recorded after orthognathic surgery (values nearer to a theoretical maximum of 100%), which indicates that after surgical treatment a better balance between right and left masseter and anterior temporalis muscles was obtained.

The improvement of the examined parameters was not statistically significant (P > 0.05, Student’s t test for paired samples). However, a reduction of the within-sample variability was seen, with smaller coefficients of variation (percentage ratio between SD and relevant mean) for both POCs (masseter POC from 8.64% pre-surgically to 5.85% post-surgically; temporalis POC from 8.22% to 3.35%).

When compared with the pre-surgical value, also the TC index showed an improvement after surgery; the difference, even if not significant (P > 0.05) pointed out to a reduction of torque movements in the mandible.

DISCUSSION

Several investigations have shown correlations between facial skeletal morphology and muscular functionality (Throckmorton et al., 1996, 2000; Zarrinkelk et al., 1996; Kikuchi et al., 1997; Kim and Oh, 1997). On the other hand, other studies did not prove correlations between craniofacial morphology and muscular activity (Youssef et al., 1997; Iwase et al., 1998).

Indeed, investigations stating an absence of correlation between EMG improvement and biomechanical advantages depending on surgical intervention are becoming more and more numerous (Ahlgren et al., 1985; Proffit et al., 1989; Youssef et al., 1997), and the hypothesis that occlusal stability is the only reason for all EMG improvements is considered more and more likely (Bakke et al., 1992; Bakke, 1993; Harada et al., 2000; Throckmorton et al., 2000, Ferrario et al., 2002).

The EMG protocol used in the present study provided a measurement of muscular symmetry and of the neuromuscular equilibrium determined by occlusion. Therefore, it provided objective measurements showing how occlusion influences the variations of electrical activity recorded pre- and post-surgically. The choice of the measurement protocol was fundamental because the repeatability of the indices, and the use of standardized potentials (Castroflorio et al., 2005; Ferrario et al., 2006) allowed the comparison of pre-surgical recordings with longitudinal evaluations performed after the intervention, when patients had regained good masticatory function (Sforza et al., 2008).

The current findings are in good agreement with previous studies, showing some improvements (that did not reach the statistical significance) in the neuromuscular activity (greater muscular symmetry as assessed by POC and TC indexes) after orthognathic surgery (Sforza et al., 2008).

The effect was similar irrespective of the kind of surgical correction (BSSO or bimaxillary advancement or mandibular retrusion). It can be concluded that surgical treatment induced improvements in the characteristics of occlusal contact, causing better neuromuscular equilibrium. Hence occlusion appears to be the determining factor for muscular function (Bakke et al., 1992; Bakke, 1993; Harada et al., 2000; Throckmorton et al., 2000, Ferrario et al., 2002), beyond all potential problems caused by craniofacial morphology or theoretical supposed biomechanical advantages.

More significant improvements in muscular function may possibly be achieved after a longer follow up. This subsequent assessment could also verify any alteration in occlusal stability, and it could be associated with evaluations of bite force, masticatory efficiency and dynamic coordination of muscular activity (Ferrario and Sforza, 1996).

CONCLUSION

The surface EMG evaluation performed on the current group of surgical patients allowed the impact of occlusion on the neuromuscular equilibrium to be assessed during static “function” of the stomatognathic apparatus. The improvements gained by surgical intervention were primarily due to better occlusal stability and not to biomechanical advantages. The use of such non-invasive tests should be considered during patient’s follow-up, to obtain a more refined analysis of the rehabilitation process.
References


Dr. Elena DI PALMA
University of L’Aquila
Via Vetoio
 Coppito, Edificio D 6
 c.a.p. 67100, L’Aquila
 Italy
 Tel.: +39 0862433834
 Fax: +39 0862433833
 E-mail: dipalmaleena@tiscali.it

Paper received 19 May 2009
Accepted 26 May 2009