

Electromyographic evaluation of masticatory, neck, and trunk muscle activity in patients with posterior crossbites

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SUMMARY This study investigated the pattern of masticatory, neck, and trunk muscle activity in patients with posterior crossbites and associated mandibular displacement. The test group consisted of 75 patients [45 males mean age 19.5 years, SD 5.6 years, and 30 females mean age 20.4 (SD 3.2) years]. Of this group, 25 patients presented a left posterior crossbite, 25 a right posterior crossbite, and the remaining 25 patients a bilateral posterior crossbite. A control group of 25 subjects (19 males and 6 females aged 22.5 ± 5.8 years) without any crossbite were included. Surface electromyographic (sEMG) activity was recorded bilaterally, in the mandibular rest position and during maximum voluntary clenching (MVC), at the following sites: anterior and posterior temporal, masseter, sternocleidomastoid (SCM), upper and lower trapezius, and cervical muscles.

In the mandibular rest position, patients with unilateral crossbites showed a significant difference ($P < 0.05$) in sEMG activity of the anterior temporal muscle, with the greatest activity being detected on the side to which the mandible displaced. Control subjects demonstrated significantly lower ($P < 0.05$) sEMG activity but only in the SCM muscle when compared with patients with bilateral posterior crossbites; no such differences were detected in relation to unilateral crossbites. During MVC, control subjects showed significantly lower ($P < 0.01$) sEMG activity in both the SCM and the posterior cervical muscles compared with patients demonstrating both unilateral and bilateral crossbites.

The findings of the present study indicate that the presence of a crossbite can affect electromyography activity of masticatory, neck, and trunk muscles.

Introduction

Experimental data indicate that the presence of an altered occlusion may result in a reduction or inhibition of the surface electromyographic (sEMG) activity of the elevator muscles (Ingervall and Carlsson, 1982). These authors reported that in patients with an experimentally induced interference on the balancing side, significantly lower sEMG activity in both masseter and anterior temporal muscles in the rest position was observed when compared with controls. Christensen and Rassouli (1995) observed masseter muscle activity, in the presence of an experimentally induced pre-contact, and found an increase in contraction power of the ipsilateral and a decrease on the contralateral side. No association was observed between the height of the pre-contact and the sEMG activity of the muscle. Jiménez (1987) examined sEMG activity of the masticatory muscles during maximum voluntary clenching (MVC) with and without a stabilization splint. The results indicated that the presence of an unstable occlusal contact not only inhibited sEMG activity of the masseter muscle but also reduced activity in both the anterior and the posterior temporal muscles. That author further observed that clenching masticatory sEMG muscle activity returned to normal after insertion of a stabilization splint. This behaviour was observed in both the retruded contact and the intercuspal

positions. These results indicate that the determinants of maximum masseter isometric muscle contraction are due more to the amount of occlusal stability than to the jaw position itself, and that masticatory muscles can be rapidly inhibited in the presence of an unstable occlusal contact. Saifuddin and Miamoto (2003) evaluated sEMG activity of the elevator muscles in patients with a lateral deviation of the mandible and in healthy subjects, both during daily activity and sleep. They noted a statistically significant increase in asymmetry of anterior temporal and masseter muscle activity in patients compared with controls, during daily activity. No such difference was observed during sleep.

From a functional point of view, masticatory, neck, and trunk muscle activity is considered to be strongly associated due to a reciprocal innervation between the trigeminal and cervical system that produces a mutual inhibition and activation. It is well known that there is a dynamic relationship between dental occlusion and head posture (Daly *et al.*, 1982). The sternocleidomastoid (SCM) and trapezius muscles are the main muscles of the neck and trunk. It has been shown that both muscles have the tendency to develop stress disorders and exhibit referred pain patterns that overlap the pattern of masticatory muscles (Weeks and Travell, 1955). Ferrario *et al.* (2003) investigated the

contraction of the SCM muscle during MVC in subjects with and without asymmetric occlusal interferences, which resulted in lateral displacement of the mandible. They found that in all patients, a previously symmetric pattern of the SCM muscle contraction became asymmetric, suggesting an altered neuromuscular coordination (Ferrario *et al.*, 1999) following the relatively rapid adaptation to the altered occlusal condition (Karlsson *et al.*, 1992).

The present study aimed to evaluate the pattern of sEMG activity of masticatory, neck, and trunk muscles in the mandibular rest position and during MVC in patients with unilateral and bilateral crossbites, and to compare these patterns with those of control subjects.

Subjects and methods

Informed consent was obtained from all participants.

Subjects

The controls and patients for the present study were selected from students of the School of Dentistry and patients in the Orthodontic Clinic, University 'G. d'Annunzio', Chieti, Italy, respectively.

Nineteen males and six females [mean age 22.5 years standard deviation (SD) 5.8 years] served as the controls. They were selected on the basis of an Angle Class I molar relationship, no crossbite, severe malocclusion, temporomandibular disorders (TMD), or history of bruxism. The test group consisted of 75 subjects (45 males, mean age 19.5 years, SD 5.6 years, and 30 females, mean age 20.4 years, SD 3.2 years), of which 25 (mean age 18.5 years, SD 2.2 years) had a left posterior crossbite, 25 (mean age 19.8 years, SD 4.4 years) a right posterior crossbite, and the remaining 25 (mean age 20.4 years, SD 4.3 years) a bilateral posterior crossbite. All posterior crossbites were diagnosed by a single investigator (S.T.). The test group patients reported no TMD or history of bruxism.

Methods

sEMG recordings. The study was performed using a Key-Win 2.0 surface electromyograph (Biotronic s.r.l., San Benedetto Del Tronto, Ascoli Piceno, Italy) with disposable electrodes (DUO F3010 bipolar—10 mm, Ag-AgCl, lithium chloride gel, unit distance 22 mm; LTT FIAB Vicchio, Firenze, Italy). The Key-Win 2.0 is a 60 channel electromyograph recording device, with a 15–430 Hz band-pass filter containing a special 60 Hz notch filter to eliminate any electrical noise from the recording environment that exceeds the capabilities of the common mode rejection scheme. All monitoring was performed with the patients in a standing position. The subjects were asked to make themselves comfortable, with their arms by their sides, to look straight ahead, and make no head or body movements during the recordings. The electrodes,

which determine to a large extent the quality of the recordings, were placed according to the atlas of Cram and Kasman (1997). Before the electrodes were applied, the skin was thoroughly cleaned with alcohol. sEMG activity of the following seven muscles was studied, bilaterally, with the mandible in the rest position and during MVC: masseter, anterior and posterior temporal, SCM area, posterior cervicals, and upper and lower trapezius. For MVC recordings, the subjects were instructed to close their jaws in centric occlusion as forcefully as possible. Movement patterns were repeated three times to ascertain stability according to the protocol developed by Donaldson and Donaldson (1990). The first movement patterns were eliminated as a 'learning' sequence as they were frequently observed to be dissimilar to the other two repetitions. Thus, sEMG activity for each muscle was the mean of the last two surface sEMG recordings. sEMG recording time for each analysis was at least 15 seconds, and the values were expressed in microvolts per second (Van der Bilt *et al.*, 2001).

Intra-observer method error

To evaluate intra-observer method error, duplicate sEMG evaluations were performed for 10 subjects, for each muscle, after an interval of 1 day, by the same operator. The results of the duplicate evaluations were compared and the error variance calculated using the formula of Dahlberg (1940):

$$\delta = \sqrt{\left(\frac{\sum d^2}{2n} \right)}$$

Where d is the difference between the first and the second evaluations and n is the number of duplicate evaluations.

Data analysis

All statistical analyses were performed using the Statistical Package for Social Sciences (SPSS Inc., Chicago, Illinois, USA). sEMG activity was expressed as the mean and SD. For each condition (mandibular rest position and MVC) and each muscle, one-way ANOVA test and *post hoc* evaluations were employed to test determine significance level of the differences observed in sEMG activity between the test and control groups. In addition, the bilateral sEMG activity of each muscle was compared using a paired *t*-test. Statistical significance was set at the 0.05 level.

Results

Error study

When sEMG was evaluated, the difference in the means between the first and second evaluations revealed that intra-observer method error was less than 5 per cent of the biological variance of the whole sample for each tested muscle.

sEMG activity in the mandibular rest position

Descriptive statistics of sEMG activity of all muscle groups investigated are shown in Figure 1. For the mandibular rest position, the sEMG activity of the anterior temporal and SCM muscles showed significant differences ($P < 0.05$) among the three groups.

For the anterior temporal muscles, significant differences ($P < 0.05$) were observed between the right and left sides in patients with a unilateral crossbite, with the greatest activity being detected on the side to which the mandible displaced. In addition, in the anterior temporal area, significantly lower ($P < 0.05$) sEMG activity was seen in the control group. However, no significant difference was observed in sEMG activity of the anterior temporal muscles among the three study groups. Patients with a bilateral posterior crossbite showed significantly higher ($P < 0.05$) bilateral sEMG activity in the SCM muscle compared with the control group.

sEMG activity during MCV

Descriptive statistics for sEMG activity of the all muscles are shown in Figure 1b. During MCV, significantly lower ($P < 0.01$) bilateral sEMG activity was observed in the SCM and cervical muscles in the control group compared with the test group.

Discussion

For all subjects, the sEMG recording was the arithmetic mean of two consecutive recordings. This was done in an attempt to reduce, albeit not fully erase, the effects of the non-stationary nature of sEMG signals (Christensen, 1989; Christensen and Hutching, 1992).

In the current study, the sEMG recordings of the males and females were pooled and analysed together. Ueda *et al.* (1998) reported no significant differences in sEMG activity of masseter, temporal, or digastric muscles between males

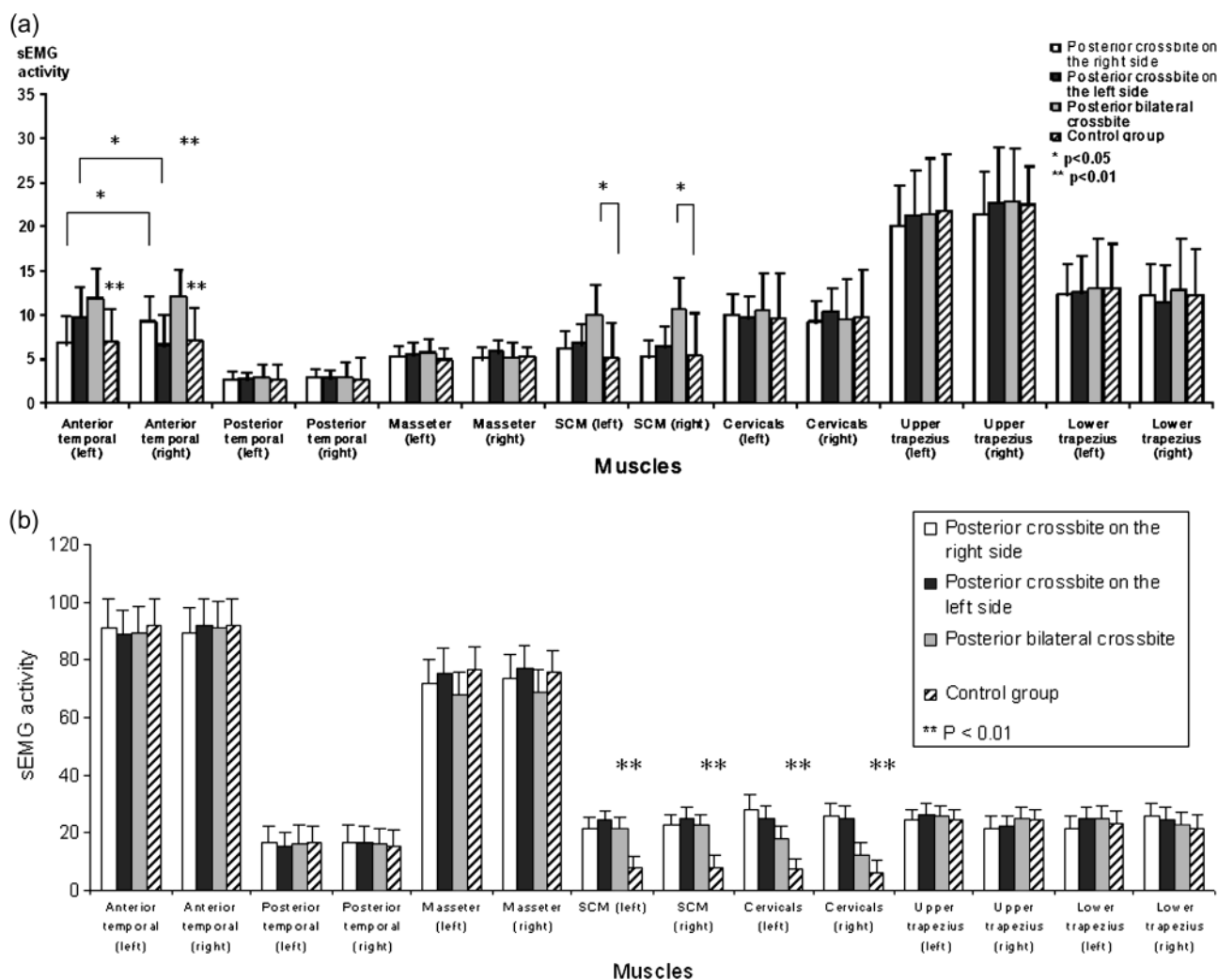


Figure 1 Surface electromyographic (sEMG) activity of the muscles in (a) mandibular rest position and (b) during maximal voluntary clenching.

and females, during a 3 hour daytime recording. Similarly, Miyamoto *et al.* (1996) found no significant gender differences during 24 hour masseter muscle activity recording.

Masticatory muscles

One of the most important finding in the present investigation was that subjects with a unilateral crossbite and mandibular displacement showed significantly different bilateral sEMG activity in the anterior temporal area in the mandibular rest position. This finding is consistent with that of Troelstrup and Møller (1970), who found sEMG activity of the anterior temporal muscle in the rest position to be bilaterally significantly different in adolescents with a unilateral crossbite.

The significant differences may be the result of sensory nerve input from the periodontal ligaments produced by tooth contacts during chewing and swallowing. The difference could be explained by the fact that a slight change in the position of the mandible generates altered innervation of the anterior temporal muscle, whereas the masseter muscle remains unaffected (Møller, 1966). In addition, it has been suggested that bilateral occlusal stability is a prerequisite for optimal neuromuscular generation of well-adjusted bilateral clenching forces and that optimal occlusal stability appears to facilitate bilateral central motor commands of equal strength (Christensen, 1989). The presence of a crossbite and displacement could distort the central motor commands to the paired jaw elevator muscles, probably because of the chaotic information from the periphery (Bakke and Møller, 1980). Christensen and Rassouli (1995) observed that a unilateral intercuspal interference caused a distortion of the amplitude but not the duration of bilateral masseteric clenching sEMG activity, with a facilitation on the side of the interference (increase of the masseteric clenching activity) and an inhibition (decrease of the masseteric clenching activity) on the opposite side.

In the present study, while there was a difference in sEMG activity of the anterior temporal muscle with the mandible in the rest position, no such difference was observed during MVC. This observation seems not to be in accord with the data of Christensen and Rassouli (1995). The difference could relate to the fact that in the current investigation, the mandibular lateral deviation was not experimentally induced but naturally observed. This would seem to suggest that when the occlusal situation is experimentally induced, the altered neuromuscular coordination observed during MVC, reported by Christensen and Rassouli (1995), could be due to a relatively rapid adaptation of the muscles during function rather than to a real asymmetric functional pattern, which could be better observed in the mandibular rest position, as noted in the present investigation. Regarding experimentally induced occlusal interferences, Christensen and Rassouli (1995)

also suggested that in experiments involving humans, sEMG should only be employed under rigid experimental and interpretational conditions as previous studies have shown both inconsistent and consistent sEMG changes, with some failing to demonstrate any clinically significant sEMG effect of experimental occlusal interferences.

In the present study, no significant bilateral differences were observed in sEMG activity of the masseter muscles between the test and control subjects, suggesting that the occlusal alterations investigated have no predictable effect on the activity pattern of this muscle. This observation is in agreement with previous studies in which it was reported that the masseter muscle is not sensitive to either bilateral tooth contact patterns or mandibular shifts, although it may be reasonably assumed that occlusal instability seems to be responsible for the significantly different sEMG activities observed in the anterior temporal muscles (Belser and Hannam, 1985; McCarroll *et al.*, 1989; Baba *et al.*, 1996, 2000).

Neck and trunk muscles

Patients with a bilateral posterior crossbite in the present study showed significantly higher bilateral sEMG activity in the SCM muscle compared with the control group in both the mandibular rest position ($P < 0.05$) and during MVC ($P < 0.01$). In addition, during MVC, subjects in the control group showed significantly lower sEMG activity in the SCM and cervical muscle areas than all other test groups. Previously, it has been shown that voluntary clenching provokes a co-activation of the SCM muscle (Ehrlich *et al.*, 1999), with both the SCM and the trapezius muscles developing stress disorders and exhibiting referred pain that overlap the pattern of the masticatory muscles (Weeks and Travell, 1955). This may be due to reciprocal innervation between the trigeminal and cervical system that produces a mutual inhibition and activation (Weeks and Travell, 1955). The anatomical basis of these correlations has been studied in mammals and neuronal connections between the trigeminal afferents and the cervical spinal cord have been demonstrated (Zuniga *et al.*, 1995). Trigeminal sensory afferents have been found to project in several 'non-trigeminal' areas of the central nervous system, including the lower cervical neurones; neurones of the three divisions of the V cranial nerve and VII, IX, and X cranial nerves seem to share the same neurone pool as those of the upper cervical spinal segments (Green *et al.*, 1957). Thus, trigeminal inputs from periodontal, temporomandibular joint, and muscular receptors may play some role in modulation of the motor neurone pool of the cervical muscles. In addition, in non-human primates, the nucleus of the medullary reticular formation was found to possess a specific role for concomitant jaw, facial, head, and upper limb movements, suggesting that feeding and eating behaviour are probably related to all these anatomical connections (Eriksson *et al.*, 1998). It is of note that

innervation for the SCM and trapezius muscles is provided not only by the spinal accessory cranial nerve XI but also by the II and sometimes III cervical nerves (SCM) as well as the II to IV cervical spine nerves (trapezius), which supply the mainly sensory fibres to the muscles (Travell and Simons, 1983). According to these observations, it is possible that afferents from cervical nerves triggered by variations in occlusal contacts might also modulate the motor neurone pools innervating SCM and cervical muscles. The findings observed in the present investigation seem to confirm these previous general observations.

Ferrario *et al.* (2003) investigated sEMG activity of the SCM before and after experimentally induced mandibular lateral deviation and found a functional asymmetry in the SCM muscle following the induction of lateral deviation. However, in the present study, no significant difference in bilateral sEMG activity of the neck and trunk muscles during MVC was detected. These differences could be due to the fact that in the current study, a unilateral deviation was not induced and the sEMG patterns of patients with unilateral and bilateral crossbites were observed.

The current findings seem to support the concept of a functional association between the stomatognathic apparatus and the neck and trunk locomotor apparatus: alterations in one structure seem to immediately affect the other. No definite conclusions can be made concerning the mechanisms involved in the associations observed because of the cross-sectional methodology and the lack of investigations regarding long-term changes after orthodontic correction of malocclusions. Nevertheless, consideration should be given to the presence of these types of malocclusion in patients reporting neck and trunk muscular problems.

Conclusions

The findings of the current study suggest that patients with a unilateral or bilateral posterior crossbite show significantly different bilateral sEMG activity in the anterior temporal muscles during the mandibular rest position, with higher sEMG activity observed on the side to which the mandible is being displaced. Furthermore, patients with a bilateral posterior crossbite seem to show significantly higher sEMG activity in the SCM in the rest position than control subjects. Patients with posterior unilateral or bilateral crossbites show higher sEMG activity in the SCM and cervical muscles during MVC compared with control subjects.

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