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Influence of Pre-Orthodontic Trainer treatment on the perioral and masticatory muscles in patients with Class II division 1 malocclusion

Tancan Uysal*,**, Ahmet Yagci*, Sadik Kara*** and Sukru Okkesim***
*Department of Orthodontics, Faculty of Dentistry, Erciyes University, Kayseri, Turkey, **Department of Orthodontics, College of Dentistry, King Saud University, Riyadh, Saudi Arabia and ***Institute of Biomedical Engineering, Fatih University, Istanbul, Turkey

Correspondence to: Dr Tancan Uysal, Erciyes Universitesi, Dis Hekimligi Fakultesi, Ortodonti AD, Melikgazi, Kayseri 38039, Turkey. E-mail: tancanuysal@yahoo.com

SUMMARY The aim of this follow-up study was to evaluate the effects of Pre-Orthodontic Trainer (POT) appliance on the anterior temporal, mental, orbicularis oris, and masseter muscles through electromyography (EMG) evaluations in subjects with Class II division 1 malocclusion and incompetent lips. Twenty patients (mean age: 9.8 ± 2.2 years) with a Class II division 1 malocclusion were treated with POT (Myofunctional Research Co., Queensland, Australia). A group of 15 subjects (mean age: 9.2 ± 0.9 years) with untreated Class II division 1 malocclusions was used as a control. EMG recordings of treatment group were taken at the beginning and at the end of the POT therapy (mean treatment period: 7.43 ± 1.06 months). Follow-up records of the control group were taken after 8 months of the first records. Recordings were taken during different oral functions: clenching, sucking, and swallowing. Statistical analyses were undertaken with Wilcoxon and Mann–Whitney *U*-tests. During the POT treatment, activity of anterior temporal, mental, and masseter muscles was decreased and orbicularis oris activity was increased during clenching and these differences were found statistically significant when compared to control. Orbicularis oris activity during sucking was increased in the treatment group ($P < 0.05$). In the control group, significant changes were determined for anterior temporal ($P < 0.05$) and masseter ($P < 0.01$) muscle at clenching and orbicularis oris ($P < 0.05$) muscle at swallowing during observation period. Present findings indicated that treatment with POT appliance showed a positive influence on the masticatory and perioral musculature.

Introduction

The influence of myofunctional habits like abnormal lip and tongue function on craniofacial development and orthodontic problems has been regularly reported in publications. Various appliances have been used for the treatment of this problem (Walpole Day *et al.*, 1949; Massler, 1952; Tallgren *et al.*, 1998; Schievano *et al.*, 1999; Quadrelli *et al.*, 2001, 2002; Usumez *et al.*, 2004). The main reason for using myofunctional appliances has been to establish muscular balance, eliminate oral dysfunction, and correct or reduce maxillary incisor protrusion/proclination (Tallgren *et al.*, 1998). The growth and development of craniofacial structures and the influence of the perioral muscles on the position of teeth have been discussed very extensively, but many questions are still unanswered, notably with regard to muscular behaviour during various orthodontic treatment methods (Stavridi and Ahlgren, 1992).

The clinical use of electromyography (EMG) for orthodontic diagnosis and for treatment planning has been suggested (Grossman *et al.*, 1961). The EMG was used to evaluate masticatory movements in children, with special reference to occlusion (Ahlgren, 1966), and the actions of masticator muscles and association with facial morphology were investigated (Möller, 1966). In both research and clinical studies, surface EMG has been utilized to aid in the detection, diagnosis, and treatment of muscle hyperactivity and hypoactivity, muscle imbalance, rest position, and spasm and fatigue of the muscles of mastication (Ahlgren *et al.*, 1985; Dahlström, 1989). Masticatory muscle activity pattern was found to be different or highly associated with respect to the age, malocclusion type, and type and stage of orthodontic treatment (Moss, 1975; Freeland, 1979; Leung and Hägg, 2001).

Myofunctional appliances have been used for many years (Tallgren *et al.*, 1998; Schievano *et al.*, 1999; Quadrelli *et al.*, 2001, 2002; Usumez *et al.*, 2004) and have definite place in orthodontics today. They are simple and economical, but the cases need to be carefully selected, and the operator needs to be well trained in their use (Usumez *et al.*, 2004).

By starting the Class II orthopaedic treatment at early ages and correcting the functional problems of soft tissues and muscles, oral respiration and bruxism are need to be part of the target (Gay *et al.*, 1994). With this objective, our attention was drawn to the Pre-Orthodontic Trainer (POT; Figure 1) appliance, a myofunctional device usable in children from the age of 4–10 years. The POT is claimed to correct a skeletal Class II by an active mandibular force. By separation of the lower lip from the dental alveolar arch, the POT is claimed to prevent a malposition of the tongue and lower lip during swallowing, thus solving the associated dental open bite. Usumez *et al.* (2004) investigated the treatment effects induced by a POT appliance on Class II division 1 cases and compared these changes with an untreated Class II division 1 control group. Those authors reported that the POT induced basically dentoalveolar changes that result in significant reduction of overjet and could be used with appropriate patient selection.

The aim of this follow-up controlled study was to evaluate the effects of POT on the anterior temporal, mental, orbicularis oris, and masseter muscles during several oral activities (swallowing, sucking, and clenching), through EMG evaluations in Class II division 1 malocclusion subjects with incompetent lips.

Subjects and methods

Subjects

This study was organized as a parallel group design with one group receiving the experimental protocol and the other served as control. The power analysis was established by G*Power Version 3.0.10 (Franz Faul Universität, Kiel, Germany) software. Based on 1:1 ratio between groups, total sample size of 35 patients would give 70 per cent power to detect significant differences with 0.30 effect size and at $\alpha = 0.05$ significance level.

Figure 1 Pre-Orthodontic Trainer appliance *in situ*.

This study was approved by the Ethical Committee on Research of the Erciyes University Faculty of Dentistry. The study included 40 subjects with skeletal Class II division 1 malocclusions and incompetent lips. Lip incompetence is defined as a resting lip separation of more than 4 mm. The study included 40 subjects with incompetent lip and lip separation ranged from 4.2 to 6.4 mm (mean: 5.1 ± 1.1 mm).

Ten male and 15 female patients, treated between years 2006 and 2007, were selected as the treatment group. Subjects in the treatment group were instructed to use the POT every day for 1 hour and overnight while they slept. Five non-cooperative patients (5 females) were excluded from the study and the treatment group was consisted of 20 patients (10 males and 10 females). The ANB angles of all patients were greater than 4 degrees, and their overjets were greater than 4.5 mm (mean ANB: 5.62 ± 1.46 degrees and mean overjet: 6.0 ± 1.1 mm). None of the children in the test or control group had a thumb-sucking habit. All were Caucasian and their ages ranged from 7.8 to 11.5 years (mean age: 9.8 ± 2.2 years). All were treated exclusively with the POT appliance (Myofunctional Research Co., Queensland, Australia).

The remaining samples formed the untreated control group to eliminate possible growth and development effects. This group consisted of six males and nine females that have similar characteristics of Class II division 1 malocclusions (mean ANB: 5.23 ± 1.02 degrees and mean overjet: 6.0 ± 1.5 mm). All were Caucasian with ages ranging from 8.6 to 10.2 years (mean age: 9.2 ± 0.9 years). The subjects in the control group were informed about two-stage Class II orthodontic treatment but refused early treatment.

Positioning of electrodes

The skin over the muscles was cleaned with alcohol. The electrodes were filled with an electrode gel and attached to the skin with adhesive washer to provide same impedance during all EMG recordings. Therefore, the effect of the impedance can be ignored because it is nearly same for all recording section. The common ground electrodes were adhered onto the forehead of the subject and the active electrodes are placed on the muscles.

Bipolar silver/silver chloride disk surface electrodes were placed over the right and left anterior temporal and superficial masseter muscles. The site on the anterior temporal muscle was defined by palpation during clenching of the mandible (Gay *et al.*, 1994) and the electrodes were placed 1–1.5 cm from the anterior border of the muscle (Leung and Hägg, 2001). The electrode site on the superficial masseter was defined as an area midway along a line connecting the inferior border of the zygomatic arch at the zygomaticotemporal suture to the gonial angle. The electrodes were placed centrally, about 1 cm distal to the anterior border of the muscle and inter-electrode distance was 20 mm and they have 4 mm recording diameter.

Electrodes for recording the orbicularis oris muscles were placed symmetrically above and below the vermilion border of the lips. The EMG signals for each patient are also recorded from mentalis muscle. The position of the electrodes at the first session was marked on each patient's chart, and the chart was used as a guide at each subsequent recording session. Photographs were taken at the first session as reference for future electrode placement. Additionally, EMG records were taken several same-day repetitions (three times for each person) and used the mean values of these records instead of relying on only one measuring interval.

The silver/silver chloride or Ag/AgCl electrode is many electrochemists' reference electrode of choice. It is stable and quite robust (Watson and Yee, 1969). The electrodes were filled with an electrode gel thus uniformity for electrode impedance was provided.

EMG recording

The EMG recordings are made at the initial stage of the appliance placement and at the end of the POT therapy (mean treatment period: 7.43 ± 1.06 months). EMG records from the control sample were taken approximately 7–8 months later from the first records, similar to the treatment group (mean observation period: 8.13 ± 2 months).

The EMG recordings were made of maximal clench in centric occlusion (four clenches), swallowing of saliva (two swallows), and sucking on an empty straw (six suckings; Tallgren *et al.*, 1998). Each participant was informed of the research protocol prior to the first EMG recording session. They were instructed to avoid protruding their jaw or tongue during recordings. No visual feedback was provided to the subjects, who were closely monitored during the recording procedure.

The swallowing recordings were made when the patient indicated that a sufficient amount of saliva had accumulated. To produce the sucking recordings, the patient was instructed to suck on a plastic straw, keeping it in front of the teeth and shield with one finger closing the open end of the straw. During the recording procedure, the patient was seated in a dental chair in an upright relaxed position with the head unsupported and in its natural balance.

The EMG signal acquisition was conducted by Biopac-MP150 unit (BIOPAC Systems Inc., Goleta, California, USA). The EMG-100C Biopac was used as an amplifier with 2000 gain. Its high-pass filter was set to 1.0 Hz and low-pass filter was set to 500 Hz. The serial output of EMG recorder device unit was sampled at 5000 samples/second and then sent to a PC via an Ethernet card.

EMG analysis

The power spectral density (PSD) is a function commonly used for frequency domain analysis of surface EMG. Analysis of the PSD can provide information about spatial and temporal recruitment of motor unit (Blinowska *et al.*, 1979). PSD of the surface EMG signals results from a summation of the spectral characteristics of the motor unit action potentials. Therefore, maximum value of the PSD was chosen as a parameter in order to evaluate the effects of the POT. Maximum PSD value expresses amplitude of the largest spectral line. EMG signals were recorded while the muscular activity was onset and PSD calculation that was made using Welch method was done for these signals. Hanning window of 256 samples with an overlap of 128 samples are used in the Welch method. We made the spectral estimate with Welch's Method, which can be derived from Cheng and Lan (2003) and Kara *et al.* (2006).

Statistical analysis

All statistical analyses were performed using the Statistical Package for Social Sciences (Windows, version 13.0; SPSS Inc., Chicago, Illinois, USA). Arithmetic mean and standard deviation (SD) were calculated for each measurement.

The Shapiro–Wilks normality test and the Levene's variance homogeneity test were applied to the EMG data. The data showed non-normal distribution, and there was no homogeneity of variances between the groups. Thus, the statistical evaluation of EMG values between test groups was performed using non-parametric tests

Wilcoxon test was used to test the significance of the mean differences of the EMG variables between the observation stages. To compare the mean differences of the EMG variables for four investigated muscles during several activities of the jaws and lips, Mann–Whitney *U*-test at the 95 per cent confidence interval ($P < 0.05$) was used.

Results

The EMG changes and statistically evaluations of the samples at the pre- and post-treatment and pre- and post-observation periods and statistical comparisons of the mean difference of treatment and control groups are showed in Table 1.

Anterior temporal muscle

During the POT treatment, statistically significant difference was only found in clenching activity ($P < 0.001$) for this muscle (Table 1). EMG activity during clenching at the beginning of the treatment was significantly higher than the post-treatment activity. The control group's EMG activity during clenching was increased at the sixth month of observation ($P < 0.05$).

Treatment and control group comparisons showed that statistically significant differences were observed during sucking ($P < 0.05$) and clenching ($P < 0.001$) activities. During sucking, EMG activity was decreased in treatment group and not changed in controls. However, during

Table 1 The electromyography changes and statistically evaluations of the samples at the pre- and post-treatment and pre- and post-observation periods and statistical comparisons of the mean difference of treatment and control groups. *n*, sample size; SD, standard deviation.

Muscles	Functions	Trainer group (n = 20)								Control group (n = 15)								Statistical comparison of trainer and control group	
		Pre-treatment			Post-treatment			Difference (T2−T1)	Wilcoxon test	Pre-observation			Post-observation			Difference (T2−T1)	Wilcoxon test	Mean difference	Mann–Whitney *U*-Test
		Mean (dB/Hz)	SD	SEM	Mean (dB/Hz)	SD	SEM			Mean (dB/Hz)	SD	SEM	Mean (dB/Hz)	SD	SEM				
Anterior tempoaralis	Swallowing	0.155	0.387	0.087	0.038	0.065	0.015	−0.117	NS	0.083	0.131	0.037	0.161	0.255	0.071	0.078	NS	0.195	NS
	Sucking	0.040	0.091	0.020	0.003	0.003	0.001	−0.037	NS	0.002	0.002	0.001	0.002	0.002	0.001	0.000	NS	0.036	*
	Clenching	0.610	0.645	0.144	0.201	0.444	0.099	−0.409	***	1.560	1.500	0.417	1.890	1.660	0.460	0.330	*	0.739	***
Mentalis	Swallowing	0.104	0.188	0.042	0.074	0.076	0.017	−0.030	NS	0.096	0.096	0.027	0.976	0.138	0.038	0.880	NS	0.910	NS
	Sucking	0.249	0.296	0.066	0.297	0.393	0.088	0.047	NS	0.233	0.202	0.056	0.240	0.203	0.056	0.006	NS	−0.041	NS
	Clenching	0.958	0.232	0.052	0.538	0.593	0.133	−0.420	*	0.019	0.027	0.007	0.028	0.033	0.009	0.009	NS	0.429	*
Orbicularis oris	Swallowing	0.048	0.053	0.012	0.093	0.135	0.030	0.045	NS	0.104	0.104	0.029	0.142	0.188	0.052	0.038	NS	−0.007	NS
	Sucking	0.288	0.456	0.102	0.407	0.463	0.103	0.119	*	0.362	0.252	0.070	0.207	0.186	0.052	−0.155	*	−0.274	**
	Clenching	0.016	0.215	0.005	0.144	0.060	0.013	0.128	**	0.014	0.209	0.006	0.041	0.083	0.023	0.027	NS	−0.101	NS
Masseter	Swallowing	0.044	0.103	0.023	0.006	0.014	0.003	−0.038	NS	0.033	0.072	0.020	0.114	0.298	0.083	0.081	NS	0.119	**
	Sucking	0.124	0.360	0.081	0.015	0.057	0.013	−0.109	NS	0.015	0.026	0.007	0.017	0.030	0.008	0.002	NS	0.111	**
	Clenching	0.781	0.863	0.193	0.185	0.353	0.079	−0.596	**	1.080	1.480	0.409	1.880	1.890	0.524	0.800	**	1.396	***

NS, not significant. *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

clenching, EMG activity was decreased in treatment and increased in control group.

Mental muscle

The effect of the treatment with POT during sucking and swallowing on the EMG activity of pre- and post-treatment values are identical, as seen in Table 1. However, after using the appliance for approximately 6 months, EMG values during voluntary clenching was decreased and this difference was found statistically significant when compared to control ($P < 0.05$). During the observation period, no significant differences were determined in mental muscle for all investigated activities in the control group.

Orbicularis oris muscle

During the POT treatment, statistically significant differences were found in sucking ($P < 0.05$) and clenching ($P < 0.01$) activities for orbicularis oris muscle. The EMG values were increased in both sucking and clenching activities at the end of the treatment period. The control group's EMG activity during sucking was decreased at the end of observation and the difference was found statistically significant ($P < 0.05$).

Intergroup comparisons showed that statistically significant difference was observed during sucking ($P < 0.05$) activity. The EMG activity was increased in treatment and decreased in control group during sucking ($P < 0.01$).

Masseter muscle

All EMG values were decreased in the treatment and increased in the control groups. However, statistically significant changes were only determined during voluntary clenching activity for both treatment and control groups ($P < 0.01$). Treatment and control group comparisons showed that statistically significant differences were determined during swallowing ($P < 0.01$), sucking ($P < 0.01$), and clenching ($P < 0.001$) activities.

Discussion

This follow-up study of a sample of 40 subjects (25 subjects for treatment and 15 for control group) with Class II division 1 malocclusion was designed to evaluate the EMG activity of treatment with the POT appliance. Five non-cooperative patients were excluded from the study. The size of the sample may seem small but analysis undertaken to determine sample size showed adequate power. Moreover, a longitudinal analysis is statistically much more sensitive than an analysis of changes based on a cross-sectional sample.

During treatment or observation period, the growth potential of the masticatory and facial muscles that affect the EMG should be taken into consideration (Möller, 1966;

Ahlgren *et al.*, 1985; Dahlström, 1989). The observed EMG changes during treatment reflect the combined effects of treatment and individuals' growth and development. Ideally, a matched or at least comparable control group should be included for identifying the changes due to the normal growth (Usumez *et al.*, 2004). Therefore, to eliminate possible differences in growth pattern, a control group consisting of longitudinal data for untreated Class II division 1 malocclusion subjects was used in this study.

Similar to the therapeutic position used in activator treatment, the POT appliance is constructed with the mandible in a lightly anterior position for Class II patients (Usumez *et al.*, 2004). For oral screen treatment, Graber (1979) reported that the construction bite cannot be as protrusive as that with an activator and the appliance is of value mainly in cases of mild Class II malocclusions. A study concerning the POT appliances combined with the straight wire system was published (Mahony, 2002). Usumez *et al.* (2004) evaluated the effects of POT appliance on dentoskeletal structures by lateral cephalometry in a group of Class II division 1 cases and determined no significant morphological changes by use of POT. A review of the literature presents no information on whether the POT appliance can actually improve the EMG activity of a patient with Class II malocclusion or not. Although the use of myofunctional appliances such as the oral/vestibular screen in the primary and mixed dentitions are mentioned in the literature (Tallgren *et al.*, 1998; Usumez *et al.*, 2004); only two studies have been published concerning the EMG changes induced by these procedures in the early occlusal developmental stages (Tallgren *et al.*, 1998; Schievano *et al.*, 1999).

Masticatory muscles and facial soft tissues not only have an impact on bone growth but also influence the process of treatment and stability of orthodontic treatment. The EMG is the primary tool for the registration of these functional processes and for the objective of growth modifying pressure and traction effects on the skull (Eckardt *et al.*, 1997). Therefore, appropriate application of non-invasive EMG can provide more information about effect of the treatment and usage of appliances, such as POT.

The EMG recordings are the measurements of the electrical activity of muscles and not a measure of bite force. The use of multiple electrodes permits maximum voluntary isometric contraction recordings from groups of muscles but cannot be used to compare the relative forces developed by individual muscles nor is the data appropriate for indicating whether a muscle is contracting isometrically or isotonically (Leung and Hägg, 2001). The myofunctional therapy acted on the musculature, posture, and functions. Therefore, the muscular electrical activity request was supposed to decrease during closure of the lips, which is the desired posture during rest (Schievano *et al.*, 1999).

During recordings, factors such as age, gender, composition and shape of the face, connective tissue, and fat content may all affect the type and magnitude of signals recorded (Schanne and Chaffin, 1970). Thus, subjects with similar age, gender, dentoalveolar, and physical characteristics were included to both study and control groups.

In the current study, the effects of myofunctional treatment on orofacial muscle activity were studied from EMG recordings of three different oral functions: swallowing, sucking, and clenching. The reliability of the EMG measurements of elevator and facial muscle activity during various oral activities has been evaluated in previous studies (Möller, 1966; Tallgren *et al.*, 1998; Schievano *et al.*, 1999).

The marked anterior temporal activity changes during maximal clenching, which averaged 0.409 µV during the initial and 6 months stages, showed a significant decrease after 6 months use of the POT. Tallgren *et al.* (1998) reported similar changes during myofunctional appliance treatment for anterior temporal muscle. Whether the decrease in temporal activity was influenced by the POT treatment or possibly associated with occlusal changes related to the growth in the mixed dentition cannot be determined by the present data.

Stavridi and Ahlgren (1992) carried out an EMG study of the masseter, buccinator, and mentalis muscles to evaluate the myofunctional changes that occur during orthodontic treatment with functional appliances constructed with vestibular screen elements. During swallowing, they found statistically significant decrease in mental muscle activity by EMG. Usumez *et al.* (2004) showed anterior rotation and sagittal growth of the mandible and increased lower incisor proclination in patients with treated POT. These changes may be effects the mentalis muscles position and activities. In the current study, it was determined after POT treatment that lip pads decreased mentalis activity during clenching but not changed during swallowing and sucking.

In the present research, we determined that POT treatment increased orbicularis oris activity during sucking and clenching, but it remained unchanged during swallowing. Usumez *et al.* (2004) showed retroclination of upper incisors and overjet reduction when patients treated with POT appliance. Upper lip and orbicularis oris muscles effects because of the retroclination of upper incisors and these can cause increasing EMG activity. Schievano *et al.* (1999) evaluated orbicularis oris muscle before and after myofunctional therapy and found that the electrical activity was increased significantly at the 5 per cent level. This activity was within the normal range. They thought that myofunctional therapy influenced perioral muscles because the muscular activity requested to hold lips together decreased after therapy. During the myofunctional appliance treatment, Tallgren *et al.* (1998) determined significant decreases in sucking activity of the lips observed at the 6 month and 1 year stages. This finding indicated a decrease of the marked initial lip activity and may suggest a favourable effect of the shield treatment.

In the literature, only few data were existing regarding to the activity of masseter muscle during myofunctional appliance treatment. Lower and upper incisors inclinations changes and overjet reduction showed at the end of POT treatment (Usumez *et al.*, 2004). The number of teeth in occlusal contact influences the muscle activity during chewing and biting (Ahlgren, 1966). In this study, all EMG values of masseter muscle were decreased during the treatment period and significant changes were observed during clenching. Different from the present findings, no statistically significant difference in EMG for masseter muscle during clenching by vestibular screen treatment was determined (Stavridi and Ahlgren, 1992).

Ralston (1961) indicated that the recording electrodes removing and replacing may entirely invalidate the EMG results. Regional specialization and asynchronous activity in measured muscles contribute further to the complexity of EMG analyses. Consequently, we can say that all EMG studies are flawed in one way or another. Yet EMG can help quantify complex dynamic relationships and it can provide a better understanding of muscles changes.

Conclusion

The results from the present EMG follow-up study of a sample with Class II division 1 malocclusion with incompetent lips indicated that treatment with POT appliance showed a positive influence on the masticatory and perioral musculature when compared to control.

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