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Effects of interceptive orthodontics on orbicular muscle activity: A surface electromyographic study in children

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ABSTRACT

The purpose of this study was to assess by surface electromyography (sEMG) the changes in upper and lower orbicular oris (OO) muscles produced by a preformed functional device in subjects with Class II, division 1 malocclusion, deep bite, and labial incompetence.

Twenty-eight subjects were selected: 13 subjects (mean age 9 ± 1.5 years) with Class II malocclusion, deep bite, and labial incompetence were treated with a preformed functional device, while 15 subjects (mean age 9.5 ± 0.8 years) with normal occlusion were used as control.

Inclusion criteria for both groups were: presence of mixed dentition, no previous orthodontic treatment, and absence of speech disturbance.

sEMG recordings were taken at the time of the first visit (T0), and after 3 (T1) and 6 months (T2) for the treated group, and at T0 and T2 for the control group.

The sEMG recording was performed at rest, and while kissing, swallowing, opening the mouth, clenching the teeth, and during protrusion of the mandible, by placing electrodes at the area of muscle contraction.

At T0, except during swallowing, the treated group always showed a lower sEMG activity of the lower OO muscle with respect to the control group, with significant differences at rest and during mandibular protrusion ($p < 0.05$).

In the treated group, a significant increase in muscle tone was observed for the lower OO muscle from T0 to T1, but only at rest. The upper OO muscle showed a significant increase during the protrusion of the mandible from T1 to T2.

No significant change was observed in the control group during the follow-up.

Muscular contractility of treated patients at T2 reached the same values as that of the control group at T2.

Interceptive orthodontics seems to improve the form and function of the orofacial muscle structure. Improvement in muscle contraction after treatment was demonstrated by sEMG.

1. Introduction

Correction of neuromuscular function (functional therapy) is essential for a successful treatment of malocclusion, and it should always be a supplement to conventional therapies.

Several reports in literature (Schopf, 2003; Tausche et al., 2004) address the problem of controlling interferences with dentofacial growth caused by abnormal muscle function in the mixed dentition period. The goal of orthodontic/functional therapy is to correct abnormalities in muscle behavior (Gross et al., 1989) as follows: (a) recovering muscle tone and mobility; (b) recovering antagonist muscle strength; (c) recovering correct posture in various regions, including the tongue, mandible, and lips; (d) education in swallowing, phonation, chewing, and breathing; and (e) eliminating defective posture and/or movements. Functional therapy is basically effective during the growth period, affecting the epigenetic regulation of craniofacial growth. The optimal timing of therapy is during rapid sutural growth (prepubertal stages of development).

Perioral muscles and labial posture are considered the most important factors responsible for the position of teeth and the dental arch form because of their moderate but steady activity. (Lowe and Takada, 1984; Moss, 1997a,b) Unfortunately, this complex process is only partially understood, and consequently, definitive data on treatment is not yet available.

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[1] These authors contributed to the study as principal investigators, as they gave the same contribute to the protocol, the analysis of data and the preparation of the manuscript.

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Monitoring muscular activity during the course of functional treatment can be helpful in guiding the therapy.

Surface electromyography (sEMG) is a practical tool to study muscle activity. In the present study, sEMG was applied to evaluate the tone of the upper and lower orbicular oris (OO) muscles in subjects with Class II malocclusion, deep bite, and labial incompetence after application of a preformed orthodontic/functional device. This group of patients was compared with a control group with normal occlusion.

2. Subjects and methods

2.1. The sample

Thirteen white Caucasian patients (nine males and four females) with Class II malocclusion (end to end or a more severe Class II relationships at the first permanent molars and deciduous canines), deep bite, overbite greater than 4 mm, and labial incompetence treated consecutively with a preformed orthodontic/functional device (Occlus-o-Guide™Ortho-Tain Inc. – Toa Alta, Puerto Rico) were included in this study (treated group) (Fig. 1a–c). The mean age was 9.0 ± 1.5 years. The treatment was performed after obtaining informed consent from the parents. The patients were instructed to wear the device during sleep. During daytime, they were invited to wear the device for 2 h, make a moderate pressure for 1–2 min, then relax for 10–20 s without opening the mouth, and then start again.

Fifteen children (nine males and six females) with normal occlusion (Class I occlusion without crowding, with good relationship between the upper and the lower dental arches) were recruited as control group. The mean age was 9.5 ± 0.8 years. Inclusionary criteria for both groups were: presence of mixed dentition, no previous orthodontic treatment, and absence of speech disturbance. Exclusionary criteria for both groups were: presence of caries, dental anomalies, and craniofacial syndromes.

None of the patients included in this study showed any oral habits, and none could be defined as an oral breather.

About the dental formula of the enrolled subjects, we did not observe relevant differences in the development of the dental formula, during the six months of follow-up for the subjects, between the study and the control groups.

The electric potential of the OO muscle was investigated by electromyography during the rest position, kissing, swallowing, opening of mouth, clenching of teeth, and protrusion of mandible in the treated and control groups at T0 (before therapy for the treated group), and also after three (T1) (only for the treated group) and six (T2) months of treatment for the study and the control group.

2.2. Electromyographic recording

The OO muscle tone was measured by an 8-channel Bio-pak EMG (BIOEMG 800™, Bio research Assoc. Inc., USA), pass-band 25–1500 Hz, interfaced with a kinesiograph and a cephalostat (Siemens), with a piezoelectric transducer for surface recording of vibrations produced by the movement of temporomandibular joints. The median frequency and 25th and 75th percentiles (measured in Hz) of condylar vibration, during the opening and closing phases, were measured to assess the absence of any abnormal vibrations.

The EMG assessment was performed using Myo Tronic Duo-Trode bipolar surface rectangular electrodes (10 mm × 5 mm), with a fixed interelectrode gap of 10 mm. The bipolar derivation is the most frequently used sensor for recording surface EMG signals from the muscles of the mandible (Castroflorio et al., 2008).

During the EMG examination, the patient was seated in a usual position on a dental chair; (Cram, 1997) the patient was invited to assume a "natural head position" to avoid undesired inclinations of the head. As mentioned earlier, this is a standardized orientation for studying facial morphology, which was obtained in this study by having the subjects look straight ahead at a small mirror at eye level, as described above (Riolo et al., 1974). The subjects were asked to make themselves comfortable, to relax their arms by their sides, and to look straight ahead and make no head or body movements during the test. With this arrangement, unintentional movements from other parts of the body were eliminated or reduced.

Electromyographic recordings of the upper and lower fascicles of the OO muscle were used to evaluate muscle activity during

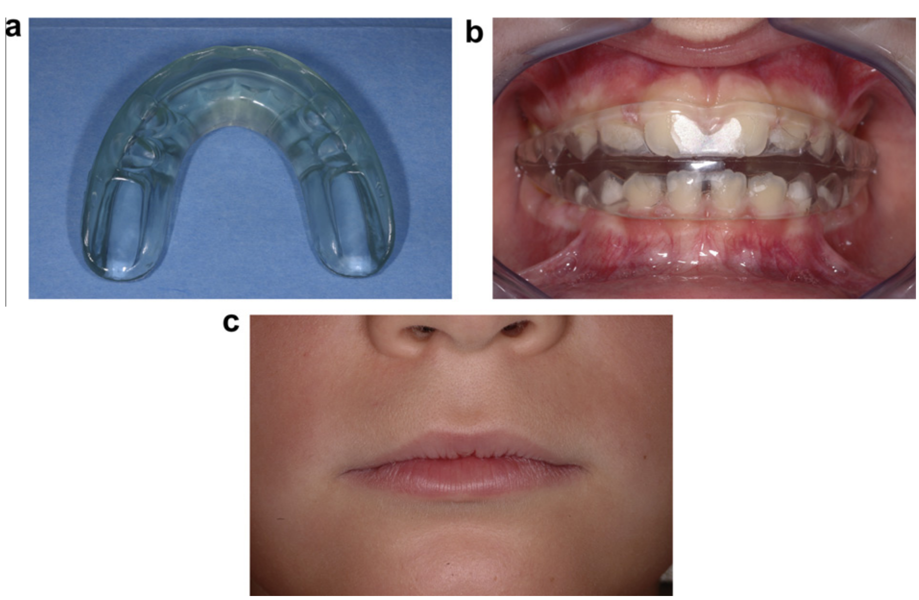

Fig. 1. a–c Images of the appliance used in this investigation (a) the appliance, a preformed orthodontic/functional device (Occlus-o-GuideOrtho-Tain Inc. – Toa Alta, Puerto Rico); (b) the appliance inserted in the mouth; (c) the labial seal during the wearing of the appliance.

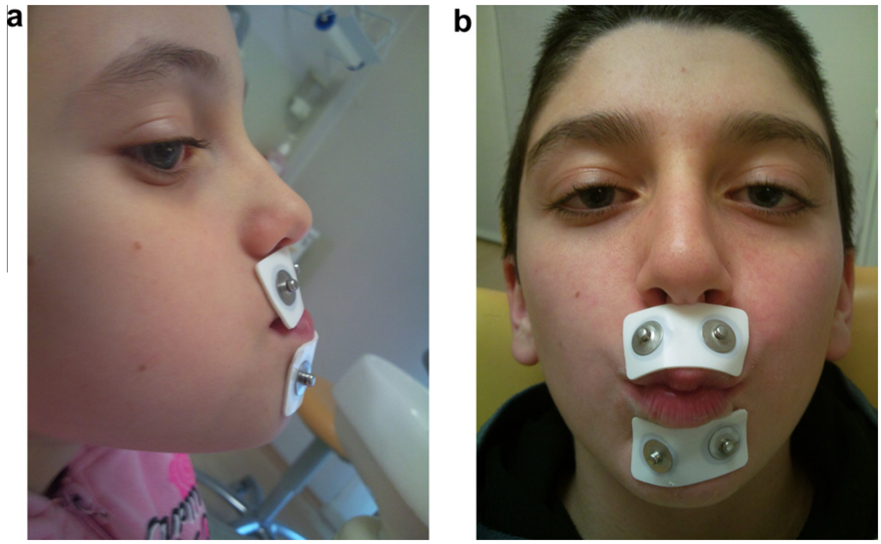

Fig. 2. (a and b) Kissing and mandibular protrusion.

situations that involved effective lip participation. Prior to performing the movements, patients were given instructions and practice, imitating the examiner.

In particular, the starting point of the recording was in habitual occlusion; the swallowing was on command and with saliva in mouth; also, "kissing," protrusion, clenching, and opening of the mouth were on command. (Fig. 2a–b).

The rest position was included to evaluate the basal electric potential of the OO muscle; swallowing was included to evaluate the existence of the labial seal associated with the activation of the OO muscle; kissing was included to study the electric potentials of the OO muscle, during its activity; opening of mouth, clenching of teeth, and protrusion of mandible were included to evaluate the OO muscle tone during movements that are not expected to involve the OO muscle.

Before the examination, the skin was prepared with ethyl alcohol, and then the electrodes were applied according to the direction of the muscle fiber.

The electrodes were positioned centrally and parallel to the direction of the fiber bundles of each fascicle of the OO muscle. The skin was cleaned with alcohol to decrease impedance.

All the sEMG recordings were performed without the device in the mouth and by the same operator (author M.S.).

The recordings were made at rest and during muscle exercises, such as opening and closing of the lips, swallowing, protrusion of the mandible, and kissing. Movement patterns were conducted for at least three repetitions to ascertain stability, according to the protocol developed by Donaldson (1990).

The first movement pattern was eliminated as the "learning" sequence because it was demonstrated to be very frequently dissimilar with respect to the other two repetitions (Christensen and Hutching, 1992). The third movement is generally considered the most stable. In a single subject, all sEMG data were the arithmetic means of these last two surface sEMG recordings. The sEMG recording time for each analysis was at least 15 s, and the values were expressed in millivolt per sec (mV s^{-1}). This was performed in an attempt to reduce the effects of the non-stationary nature of sEMG signals (Christensen and Hutching, 1992).

Among the different exercises, about 1 min of relaxation passed, so a total of 10 min were necessary for the whole examination, not considering the time employed for the study of repeatability, for which other electrodes were employed.

The computerized system allows a raw data to be displayed on the screen, permitting a preliminary analysis of the waveform.

2.3. The repeatability of examination (electrode positioning and recording protocol)

The repeatability of the recording protocol was investigated for the test conditions, by asking the selected subjects to repeat the sEMG recording two times, with a gap of 15 min between the two recordings. We asked the subjects to stay relaxed during this 15 min break once the electrodes were removed from their muscles and to walk around the laboratory if they needed to. The results of the first and second set of experiments showed a repeatability of measurements. Table 1 shows the results of the method error study.

The repeatability of electrode positioning was maintained by using a standard procedure for positioning the electrodes. The criteria about the positioning of the electrodes were strictly followed to ensure consistent positioning for all the subjects. The EMG channels were applied on the upper and lower OO muscles, while a single ground electrode was applied over the skin of the hand.

To assure standard results and repeatability of electrode positioning with the sEMG examination, the electrodes were placed accurately at the area of contraction of the muscle belly (Tecco et al., 2008).

In particular, for the positioning of the electrodes, to assure the positioning in the areas of contraction, the movement performed by the patients consisted of the "kissing movement" for the puckering role of OO muscles in this movement. The electrodes were then connected to the amplified control unit.

2.4. Data analysis

The data derived by the preliminary study on method error result normally distributed. So we performed the method analysis using parametric paired *t* test and indicate them as mean and standard deviation in Table 1.

The data derived by the tests are provided in the form of the median, minimum and maximum values, and interquartile range. Final values were obtained by calculating the mean of the two recordings.

The Kruskal–Wallis test was used to evaluate differences in movements at different observation times within the treated and control groups. When the Kruskal–Wallis test was significant ($p < 0.05$), the Wilcoxon signed-rank test, corrected with the Bonferroni method for multiple comparisons, was used to test the significance between the different time periods.

Table 1
sEMG data of the study on method error (mV s^{-1}).

Type of movements	Muscle	Evaluation 1	Evaluation 2	Mean difference	Statistical comparison (paired *t* test)
		Mean ± SD	Mean ± SD	Mean ± SE	
At rest	Upper orbicolar	9.2 ± 4.2	8.2 ± 3.1	1.1 ± 1.5	*t*: 1.014; *P*: 0.315
	Lower orbicolar	6.3 ± 4.1	6..5 ± 3.5	2.8 ± 0.9	t: −0.196; *P*: 0.845
Swallowing	Upper orbicolar	26.2 ± 10.1	30.2 ± 13.5	5.2 ± 2.5	*t*: −1.255; *P*: 0.215
	Lower orbicolar	24.2 ± 12.2	24.1 ± 10.5	0.4 ± 2.3	*t*: 0.033; *P*: 0.974
Kissing	Upper orbicolar	33.4 ± 18.2	32.3 ± 14.2	1.3 ± 3.2	*t*: 0.252; *P*: 0.802
	Lower orbicolar	50.1 ± 32.4	45.3 ± 24.2	5.3 ± 7.2	*t*: 0.628; *P*: 0.533
Opening of the mouth	Upper orbicolar	54.1 ± 35.2	53.1 ± 35.2	1.1 ± 0.2	*t*: 0.106; *P*: 0.916
	Lower orbicolar	52.3 ± 29.1	51.2 ± 28.3	1.2 ± 1.4	*t*: 0.143; *P*: 0.887
Clenching of the teeth	Upper orbicolar	21.2 ± 19.1	22.5 ± 14.2	1.7 ± 5.2	*t*: −0.288; *P*: 0.774
	Lower orbicolar	44.3 ± 26.5	44.3 ± 25.6	0.6 ± 1.2	*t*: 0.00; *P*: 1
Protrusion of the mandible	Upper orbicolar	38.4 ± 21.5	41.4 ± 20.3	3.5 ± 1.3	*t*: −0.537; *P*: 0.594
	Lower orbicolar	39.8 ± 25.6	36.2 ± 26.3	3.2 ± 1.2	*t*: 0.519; *P*: 0.606

Table 2
sEMG activity (mV s^{-1}) of the monitored muscles at T0, T1, and T2 for the treated group.

		Treated group (T0)				Treated group (T1)				Treated group (T2)				Statistical comparisons (Kruskal Wallis test) and Wilcoxon signed rank test with Bonferroni correction)		
		Median	Min	Max	IQ range	Median	Min	Max	IQ range	Median	Min	Max	IQ range	T0 Vs. T1	T0 Vs. T2	T1 Vs. T2
At rest	Upper orbicolar	2.3	0.1	28.1	8.2	3.5	1.1	14.9	6.2	3.1	2.1	22.2	9.2	NS	NS	NS
	Lower orbicolar	1.7	0.2	11.4	6.3	3.5	7.1	20.1	6.2	4.1	2.1	10.6	3.2	*P* = 0.004	NS	NS
Swallowing	Upper orbicolar	25.9	1.4	42.7	12.5	14.8	1.6	38.6	15.7	15.4	4.1	78.6	31.2	NS	NS	NS
	Lower orbicolar	22.4	2.6	55.3	26.5	35.1	9.48	82.6	31.2	42.1	3.4	177.4	70.2	NS	NS	NS
Kissing	Upper orbicolar	33.9	1.0	68.5	27.6	54.7	16.1	142.8	65.3	37.5	17.6	66.3	20.1	NS	NS	NS
	Lower orbicolar	43.6	15.8	110.3	35.2	69.7	31.8	127.1	48.2	113.4	5.4	143.1	60.3	NS	NS	NS
Opening of the mouth	Upper orbicolar	10.2	2.2	150.6	68.3	23.5	3.4	179.2	65.4	11.5	8.4	44.3	32.3	NS	NS	NS
	Lower orbicolar	38.3	3.07	139.5	51.2	57.1	4.7	252.7	120.2	58.5	9.1	296.4	65.2	NS	NS	NS
Clenching of the teeth	Upper orbicolar	15.9	2.8	42.1	16.5	10.5	3.9	97.3	40.4	17.4	4.1	73.4	30.3	NS	NS	NS
	Lower orbicolar	17.7	3.6	111.1	46.5	13.1	4.1	122.5	52.3	32.1	2.8	145.1	60.4	NS	NS	NS
Protrusion of the mandible	Upper orbicolar	23.9	2.0	83.7	35.2	19.3	2.8	172.7	70.2	28.5	17.6	172.7	75.2	NS	NS	*P* = 0.004
	Lower orbicolar	31.9	2.07	119.1	51.5	44.4	3.8	105.5	45.2	44.8	5.5	121.9	50.3	NS	NS	NS
TMJ vibration (Frequency, Hz)																
		Median	25th P.le	75th P.le												
Opening		45	40.5	49.5												
Closing		46	40	49												

Table 3
sEMg activity (mV s^{-1}) in the control group at T0 and T2. At the end of follow-up, control patients showed no statistically significant differences in muscle activity compared to the data at T0.

Type of movements	Control group at T0					Control group at T2				Statistical comparison (Wilcoxon siged rank test test)
	Muscle	Median	Min	Max	Interquartile range	Median	Min	Max	Interquartile range	
At rest	Upper orbicolar	2.3	1.3	8.5	5.5	2.4	1.1	8.7	2.5	NS
	Lower orbicolar	3.1	2.1	22.2	9.2	3.2	1.9	22.3	9.5	NS
Swallowing	Upper orbicolar	12.1	1.9	88.2	35.3	13.2	1.7	89.3	35.5	NS
	Lower orbicolar	19.9	2.9	54.8	23.5	21.3	3.1	55.4	26	NS
Kissing	Upper orbicolar	31.1	17.1	76.6	25.5	29.2	16.5	77.5	28.2	NS
	Lower orbicolar	43.8	13.5	96.3	38.2	40.5	14.5	98.6	35.6	NS
Opening of the mouth	Upper orbicolar	13.1	2.1	111.5	56,8	13.5	2.3	113.5	45.2	NS
	Lower orbicolar	50.8	4.6	186.7	80.2	52.9	4.7	187.2	40.5	NS
Clenching of the teeth	Upper orbicolar	8.8	3.2	73.3	33.5	8.9	3.3	74.5	32.5	NS
	Lower orbicolar	33.8	4.8	137.1	65.5	34.5	5.0	136.5	60	NS
Protrusion of the mandible	Upper orbicolar	17.1	2.5	115.5	65.2	16.5	2.4	114.7	55.3	NS
	Lower orbicolar	52.1	3.5	138.6	65.2	501	3.5	139.5	50.2	NS
TMJ vibration (Frequency, Hz)										
		Median	25th P.le	75th P.le						
Opening		46	41	50						
Closing		46	42.5	50						

NS: Not significant.

In addition, the Mann–Whitney U test was used to compare the sEMG values in the treated group versus the control group at T0 and T2.

The level of significance was set at $p < 0.05$.

3. Results

The repetition of the main experiment confirmed the repeatability of electrode positioning, as well as the entire protocol.

With regard to the positioning of subjects in the "natural head position" we did not perform a study on metho error; however we you used a method that is considered one of the most repeatable, especially in adults (data about children are not so clear).

Tables 2 and 3 shows the descriptive statistics of the treated and control groups at T0.

The treated group showed statistically significant lower values in the muscle tone of the lower OO muscle, both at rest and during protrusion of the mandible with respect to the control group.

The control subjects did not show any significant difference between T0 and T2.

Tables 2 and 3 also report the frequency spectrum produced in normal subjects by condylar movements that were recorded simultaneously in the right and the left sides.

Table 2 presents the descriptive statistics and statistical comparisons at T0, T1, and T2 for the treated group. In the treated group, a significant increase in muscle tone was observed at rest for the lower OO muscle from T0 to T1. The upper OO muscle showed a significant increase during protrusion of the mandible from T1 to T2. For all the other movements, both the upper and lower OO muscles showed an increase in the values of muscle tone (though not statistically significant levels) from T0 to T2. The only exception was the upper OO muscle during swallowing which exhibited a decrease in muscle tone from T0 to T2, without statistical significance.

After treatment, the patients reached a muscular contraction activity similar to the control group, as there was no significant difference between the treated patients and the control subjects at T2; control subjects did not experiment any change in their sEMG activity from T0 to T2 (Table 3).

4. Discussion

Myofunctional therapy and interceptive orthodontics are re-educational methods intended to achieve equilibrium of the orofacial muscles and correct stomatognathic functions, such as swallowing, phonation, chewing, and respiration. Its use in growing patients, in combination with conventional orthodontic therapy, is an important aid in achieving harmonious orofacial development.

It is now well recognized that most dentomaxillofacial dysmorphoses have a multi-factorial etiology. Among the environmental factors, uneven pressures caused by behavioral and structural anomalies of the orofacial muscle structure are recognized as a dynamic cause. Correction of these anomalies may therefore be helpful in eliminating dysmorphoses. Myofunctional therapy acts on muscle function, which is a crucial factor in determining the way in which the jaws develop (Meyer, 2000; Grabowski et al., 2007; Stahl et al., 2007; Grippaudo et al., 2008; Grabowski et al., 2007).

In the orofacial area, form and function are strictly correlated and have reciprocal effects. A correct function leads to trouble-free jaw development, whereas an impaired function may adversely influence the form of the jaws and dental arches. Conversely, the function will also adapt to a correct or impaired structural form (Porticelli et al., 2009).

Like functional orthodontic therapy, myofunctional treatment, which actually consists of a physiotherapy of the orofacial muscle structure, is based on the principle of neuromuscular re-education and muscle exercise, achieved by using biological forces naturally present in the stomatognathic system. The combination of these two forms of treatment allows correction of the growth of the skeletal and dental arch structures. Interceptive orthodontics can therefore improve the form and function of orofacial muscle structure (Christensen, 1989). Knowledge of myofunctional methods for both diagnosis and treatment is essential for every orthodontist, as a means of identifying any dysfunction, which may cause alterations of the occlusion and impaired craniofacial growth. sEMG is a useful aid for monitoring the correct evolution of these types of therapy.

In the present study, we evaluated the electric potentials of the upper and lower OO muscles in subjects with Class II malocclusion, deep bite, and labial incompetence, before and after application of a preformed orthodontic/functional device by sEMG.

This group of patients was compared to a control group with normal occlusion

In this study, we also used a piezoelectric transducer capable of recording bilateral sounds of the TMJ in conjunction with mandibular movements, displaying frequency of TMJ vibration during opening and/or closing jaw movements. This analysis was included as a criterion to exclude the presence of TMJ abnormal sounds during the mandibular opening and closing (American Academy of Craniomandibular Disorders. Guidelines for Evaluation, 1990). In this study, this examination was evaluated only at T0. None of the subjects showed TMJ abnormal frequencies of vibration because the ranges observed in our sample respected the limits of normal values observed in literature (Ioi and Counts, 2004).

In this study, the sEMG recordings were obtained with the subjects in a standardized orientation for studying facial morphology, called the "natural head position," clinically obtained by asking the patients to look at a small mirror at eye level (called the "mirror position"), as described above (Moorrees, 1994). The "natural head position" is a craniofacial reference system used mainly because of its good intraindividual reproducibility to a true horizontal, confirmed in literature (Moorrees and Kean, 1958; Madsen et al., 2008).

The "mirror position" was used because the Frankfurt line has been demonstrated to be an inappropriate plane to individuate the gravity horizontal plane in lateral view (Petricevic et al., 2006).

During the 6 month treatment with the functional device, myofunctional therapy seemed to partly alter the muscle tone, at least for the lower OO muscle at rest and for the upper OO muscle during mandibular protrusion, as shown by our study.

In this study, the treated group showed a statistically significant increase in contractility of the lower OO muscle at rest and for the upper OO muscle during mandibular protrusion (Table 2). As the protrusion of the mandible is a movement that habitually does not involve the upper OO muscle, the significant increase can be interpreted as an increase of its basal tone. Also, we observed an increase in the other conditions, but not significant.

The effect size is a measure of the strength of the relationship between two variables in a statistical population, or a sample-based estimate of that quantity.To evaluate the effect size we considered its amplitude, respect to the method error (Perinetti and Contardo, 2009).

In this study, sEMG passed from 5.2 ± 5.0 to 13.2 ± 5.5 for the lower orbicolar at rest in the test group; in this case the mean difference was 8.3 ± 5 (higher than 2.8 ± 0.9 of difference between the first and the second evaluation for the method error).

For the upper orbicular during mandibular protrusion it passed from 43.1 ± 33.2 to 44.3 ± 35.1 from T1 to T2, with a mean difference of 1.2 ± 2.1 (lower than 3.5 ± 1.3 the mean difference observed between the first and the second evaluation for the method error).

Several hypotheses could explain these findings in treated patients. It can be the result of the continuous pressure by the lip shields that are present in the functional device (Occlus-o-Guide). Furthermore, these patients underwent a true perioral muscular exercise that could increase the strength of the upper and lower OO muscles.

The presence of the device could have a stabilization effect on the occlusion, probably because of changed information from the periphery, because of the tooth contact on a soft silicone device.

5. Limits of the study

This study is limited because of the small number of subjects and can be considered only a pilot study in this field.

Missing from the study is an untreated group of children with similar defects measured over the same period of time.

Moreover, in this study we did not perform the normalization of data, relating results obtained by clenching on occlusal surfaces of teeth, to data obtained from clenching on two 10 mm-thick cotton rolls positioned on the mandibular first molars of each patient, as recently proved (Ferrario et al., 2006), to remove most of the biological and technical noise (De Luca, 1997). The normalization was not performed in order to avoid the children to learn the procedure for a correct normalization. Thus, clinical comparisons of data among the different test conditions are not possible with our limited data.

6. Conclusions

Although there are some limits, we can conclude that the use of sEMG to study muscular activity represents quite an important instrument in understanding these phenomena. Further, studies with a larger number of patients are needed to confirm the usefulness of sEMG in patients undergoing myofunctional therapy. sEMG could also be useful in monitoring the appropriate development of these types of therapy.

Our findings suggest that the use of a preformed functional device in interceptive orthodontics induces a significant increase of the sEMG activity of the lower OO muscle at rest and of the upper OO muscle during mandibular protrusion.

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