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sEMG activity of masticatory, neck, and trunk muscles during the treatment of scoliosis with functional braces. A longitudinal controlled study

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ABSTRACT

Background: Studies on the relationship between occlusal problems and the spine are of increasing interest. In this study, we monitored the sEMG activity of masticatory, neck, and trunk muscles during the treatment of scoliosis in young patients, and compared the data with a control of untreated group.
Subjects and methods: Twelve white Caucasian patients (nine males and three females; mean age of 8.0 ± 1.5 years) with scoliosis and Class I occlusion (without crowding) were included in this study (study group). Fifteen healthy subjects (nine males and six females; mean age of 9.5 ± 0.8 years) were recruited as control group. The subjects were visited before they underwent the treatment of scoliosis, as well as after 3 (T1) and 6 months (T2) of their treatment for scoliosis. The patients were instructed to wear the device during sleep and during the day, according to the protocol given by their orthopedic.
Results: The treated group showed statistically significant changes in the sEMG activity of masticatory, neck, and trunk muscles, both at rest and during MVC of the mandible with respect to T0. The masseter and the anterior temporalis showed a significant improvement in the asymmetry index from T0 to T2. On the other hand, subjects in the control group did not register much change.
Conclusion: Our findings suggest that the use of a functional device for the treatment of scoliosis induces a significant reduction in the asymmetry index of the trunk muscles, as well as a significant increase in the contractility of masticatory muscles.

1. Introduction

Scoliosis is defined as a spinal curve or curves of 10 degrees or more. The major types of non-idiopathic scoliosis are congenital scoliosis, due to malformation or faulty segmentation of the vertebrae, and neuromuscular scoliosis, due to muscular imbalance.

Different factors have been suggested cause this condition. Among them, the following must be highlighted: deviation from the standard growth pattern, neuromuscular or conjunctive tissue alterations, asymmetric growth of the limbs and trunk, alterations in the sagittal configuration of the spine, and environmental factors (Alden et al., 2006; White and Panjabi, 1990). Non-congenital scoliosis has many etiologies. The hereditary musculoskeletal disorders, such as osteogenesis imperfecta, Marfan syndrome, Stickler syndrome, Ehlers-Danlos syndrome, and muscular dystrophies, can each exhibit scoliosis as a manifestation. Neuromuscular diseases, such as cerebral palsy and myelomeningocele, are associated with the development of scoliosis secondary to muscle imbalance. Furthermore, paralytic disorders resulting from polio or spinal trauma may lead to a progressive scoliosis (Trobisch et al., 2010). In dentistry, the studies on the relationship between occlusal problems and spine are of increasing interest (Visscher et al., 2001).

The assumption underlying this research is that treatment of scoliosis with bust can change the electromyographic (EMG) activity of trunk muscles, as well as the activities of masticatory muscles. The working hypothesis of this research is that EMG variations of masticatory muscles are expected as a consequence of the treatment of scoliosis, based on the general principle that in the body, form and function are strictly correlated and have reciprocal effects: a correct function leads to trouble-free development, whereas an impaired function may adversely influence the form; conversely, the function will also adapt to a correct or impaired structural form.

The EMG changes are expected due to functional connection among the trunk muscles, related to the spine alignment, neck

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muscles, and masticatory muscles. The cervical spine provides the morphological basis for an extensive relationship between masticatory muscles and trunk muscles, and serves as a bridge for numerous blood and lymphatic vessels and nerves, linking head, trunk, and upper limb.

There are several conditions that impede normal trunk alignment in the frontal plane, and it appears interesting to investigate whether such conditions also affect dental occlusion, suggesting that a possible treatment for scoliosis can also have consequences on the dental occlusion as well as on the functional activity of masticatory muscles, which is the hypothesis of this research.

In 1970, Fonder, (Hitchcock, 1969) a dentist, presented a case history evidence of a causal relationship between occlusion and scoliosis, and vice versa, as he underlined the relationship of dental malocclusions to various skeletal problems, such as scoliosis, kyphosis, and other postural defects.

For the treatment of scoliosis, bracing is normally done when the patient exhibits bone growth and is generally implemented to hold the curve and prevent it from progressing to the point where surgery is recommended. The latest standard of brace construction is with CAD/CAM technology. With the help of this technology, it has been possible to standardize the pattern specific to brace treatment. A recent development is the SpineCor Dynamic brace, developed by a research team at the St. Justine Hospital in Montreal, Canada. This brace works using a treatment approach different from rigid bracing. Rather than trying to force the spine straight using three points of pressure, SpineCor uses a corrective movement. The regions of the body – shoulders, rib cage, lumbar spine, and pelvis – are guided to a postural position, obtained through influencing the muscular function, which is the inverse of the scoliotic posture. As the spine is connected to the body, the trunk muscles must move when the body is repositioned by the corrective movement. Hence, through the coupling of muscular and spinal position, it is possible to affect the geometry of the scoliotic curve. The advantages of SpineCor are that it is flexible and allows dynamic movement, stimulating the correction of muscular functions, thereby eliminating the muscle-weakening side effects observed with rigid bracing. The fact that it works as both a muscular rehabilitation device and a brace signifies that corrections made in the brace are sustained by muscular activity over the long term in 95.7% of the cases (Pećina et al., 1991; Ben-Bassat et al., 2006).

In view of the postural approach to correct scoliosis, contemporary monitoring of muscular activity can be considered in line with the actual principles, based on the muscular and postural correction of scoliotic treatment.

In the present study, we have evaluated the electric potentials of the upper and lower trapezious muscles, sternocleidomastoid muscle, and masticatory muscles (masseter and anterior temporalis) in subjects with scoliosis and good occlusion, before and after 6 months of treatment of scoliosis with a functional brace. To our knowledge, there are not previous studies focused on the EMG changes of masticatory muscles after the treatment of scoliosis with brace.

This group of patients was compared with a control group without scoliosis and normal occlusion.

2. Subjects and methods

2.1. The sample

Twelve white Caucasian patients (nine males and three females) with scoliosis and Class I occlusion (without crowding) were included in this study (study group). They were selected among children who visited an orthopedic for their scoliosis. They were visited before undergoing the treatment of scoliosis and after 3 and 6 months of treatment for their scoliosis.

The mean age was 8.0 ± 1.5 years.

Among 12 subjects, seven showed levoscoliosis (Cobb's angle: mean value 30; SD 5; range 18°–40°) and five demonstrated destroscoliosis (Cobb's angle: mean value 28; SD: 4; range: 2°–41°).

The study was performed after obtaining informed consent from parents

The patients were instructed to wear the device during sleep and during the day, according to the protocol given by their orthopedic.

Fifteen children (nine males and six females) with a mean age of 9.5 ± 0.8 years, without scoliosis and with normal occlusion (Class I occlusion without crowding, with good relationship between the upper and lower dental arches) were recruited as control group.

Among a group of 45 children with scoliosis, only those with a good occlusion were included in this evaluation to avoid the effect of malocclusion on EMG activity of masticatory muscles. The inclusion criteria for both the groups were: presence of mixed dentition, no previous orthodontic treatment, and absence of speech disturbance. The exclusion criteria for both the groups were presence of caries, dental anomalies, and craniofacial syndromes.

None of the patients included in this study showed any bad oral habits (such as atypical swallowing, thumb sucking, and lip interposition between the teeth), and none could be defined as an oral breather.

With regard to the dental formula of the enrolled subjects, we did not observe relevant differences in the development of the dental formula during the 6 months of follow-up between the study and the control groups.

The electric potential of the masticatory muscles (masseter and anterior temporalis) was investigated through EMG during the rest position, opening of mouth, clenching of teeth, and protrusion of mandible in the treated and control groups at T0 (before therapy for the treated group) as well as after three (T1) (for the treated group) and six (T2) months of treatment in the study and the control group.

For the "rest position" task, the patient was asked to relax his/her muscles avoiding contacts between the upper and lower teeth, soon after a movement of swallowing.

For the "opening of mouth" task, the patient was asked to fully open his/her mouth and then to return to habitual occlusion.

For the "clenching of teeth" task, the patient was asked to close his/her teeth as forcefully as possible during the entire period.

For the "protrusion of mandible" task, the patient was asked to protrude his/her mandible, maintaining the contact between the upper and lower teeth until the maximal possible protrusion, and then to return to the habitual position.

2.3. EMG recording

The masticatory muscles' sEMG potentials of masseter and anterior temporalis were measured by an 8-channel Key-Win EMG (Biotronic, San Benedetto del Tronto, Italy), with a pass-band of 25–1500 Hz, interfaced with a kinesiograph and a cephalostat (Siemens). The EMG assessment was performed using Myo Tronic Duo-Trode bipolar surface rectangular electrodes (10×5 mm), with a fixed interelectrode distance 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 patients were asked to stand and look ahead; (Cram and Kasman, 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 previously (Riolo et al., 1974). The subjects were asked to make themselves comfortable, relax their arms by their sides, and 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. EMG recordings of the masseter and anterior temporal muscles were used to evaluate muscle activity during maximal voluntary clenching (normalized activity) and mandibular rest position. Prior to performing the movements, the patients were given instructions and practice, imitating the examiner. 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 skin was cleaned with alcohol to decrease impedance. The electrodes were positioned parallel to the direction of the fiber bundles of each muscle. All the sEMG recordings were performed by the same operator.

The recordings were made at rest and during maximal voluntary clenching. Movement patterns were repeated at least thrice to ascertain stability, according to the protocol developed by Donaldson and 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 was generally considered as the most stable. In a single subject, all the sEMG data were the arithmetic means of these last two surface sEMG recordings.

The repeatability of the recording protocol was investigated for the test conditions, by asking the selected subjects to repeat the sEMG recording twice, with a gap of 15 min between the two recordings, as reported in previous researches (intra-operator method error) (Tecco et al., 2008; Tecco et al., 2011; Saccucci et al., 2011). 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 wanted to. The results of the first and second set of experiments showed a repeatability of measurements. We also calculated the Intraclass Correlation Coefficient (ICC). 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 for the positioning of the electrodes were strictly followed to ensure consistent positioning for all the subjects. The EMG channels were applied on the 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, 2011; Saccucci et al., 2011).

In particular, for the positioning of the electrodes, to ensure the positioning in the areas of contraction, the movement performed by the patients consisted of clenching the teeth. The electrodes were then connected to the amplified control unit.

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 nonstationary nature of sEMG signals (Christensen and Hutching, 1992; Tecco et al., 2008, 2011; Saccucci et al., 2011; Moorrees, 1994).

Among the different exercises, about 1 min of relaxation passed, and thus, a total of 3 min was 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.

2.4. Data analysis

The data derived from the preliminary study on method error result were normally distributed.

To assess the consistency or reproducibility of quantitative measurements made by different observers measuring the same quantity, we calculated the ICC (Table 1).

We also performed a method analysis using parametric paired *t*-test, which are indicated as mean and standard deviation in Table 1. The RMS data derived by the tests were provided in the form of median, minimum and maximum values, and interquartile range. The final values were obtained by calculating the mean of the two recordings.

The asymmetry index between the right and left sides was calculated as percentage with respect to the higher value, using the formula:

$$\frac{[\text{the higher value (right or left)} - \text{the lower value (right or left)}] \times 100}{\text{the higher value}}$$

Table 1
sEMG data on method error and Intraclass Correlation Coefficient (ICC).

Type of movements	Muscle	Evaluation 1 Mean ± SD	Evaluation 2 Mean ± SD	Mean difference Mean ± SE	Statistical comparison (paired *t*-test) and ICC
At rest	Masseter (right)	3.42 ± 0.4	3.42 ± 0.3	0.1 ± 0.4	*t* = 0; *p* = 1; ICC = 0.83
	Masseter (left)	4.07 ± 0.7	3.72 ± 0.7	0.3 ± 0.8	*t* = 1.25; *p* = 0.24; ICC = 0.88
	Anterior temporalis (right)	6.74 ± 1	6.91 ± 0.93	0.17 ± 1.48	*t* = −0.36; *p* = 0.72; ICC = 0.98
	Anterior temporalis (left)	6.3 ± 2.5	7.6 ± 1.4	−1.27 ± 3.57	*t* = −1.06; *p* = 0.32; ICC = 0.89
	SCM (right)	8.1 ± 0.9	8.8 ± 0.59	−0.71 ± 1.4	*t*:−1.4; *p* = 0.18; ICC = 0.91
	SCM (left)	9.1 ± 1.2	9.2 ± 0.7	−0.1 ± 1.06	*t*:−0.47; *p* = 0.65; ICC = 0.94
	Upper trapezious (right)	15.9 ± 1.4	17.01 ± 3.1	−1.03 ± 2.99	*t*:−1.04; *p* = 0.33; ICC = 0.94
	Upper trapezious (left)	18.7 ± 1.5	18.2 ± 3.69	0.46 ± 3.79	*t*:0.36; *p* = 0.73; ICC = 0.94
	Lower trapezious (right)	16.3 ± 2.4	18.2 ± 3.8	−1.8 ± 4.1	*t*:−1.37; *p* = 0.21; ICC = 0.98
	Lower trapezious (left)	19.2 ± 2.3	17.4 ± 3.8	1.7 ± 4.8	*t*:1.09; *p* = 0.31; ICC = 0.91
MVC	Masseter (right)	24.5 ± 4.3	26.7 ± 7.4	−2.2 ± 6.6	*t* = −1.01; *p* = 0.34; ICC = 0.89
	Masseter (right)	24.6 ± 3.05	24.03 ± 5.9	0.57 ± 4.04	*t* = 0.42; *p* = 0.69 ICC = 0.91
	Anterior Temporalis (right)	26.3 ± 2.89	26.7 ± 6.9	−0.39 ± 8.6	*t* = −0.14; *p* = 0.97; ICC = 0.98
	Anterior Temporalis (left)	29.1 ± 5.4	29.04 ± 8.3	0.12 ± 7.9	*t* = 0.05; *p* = 0.96; ICC = 0.96
	SCM (right)	11.3 ± 3.9	12.8 ± 4.04	−1.5 ± 5.9	*t* = −0.76; *p* = 0.47; ICC = 0.92
	SCM (left)	14.8 ± 3.8	18.1 ± 6.1	−3.31 ± 4.4	*t* = −2.23; *p* = 0.06; ICC = 0.91
	Upper trapezious (right)	20.03 ± 2.67	20.23 ± 5.34	−0.2 ± 5.7	*t* = −0.1; *p* = 0.92 ICC = 0.88
	Upper trapezious (left)	22.5 ± 4.07	24.1 ± 6.2	−1.58 ± 8.4	*t* = −0.56; *p* = 0.59; ICC = 0.91
	Lower trapezious (right)	26.6 ± 3.22	25.4 ± 6.6	1.24 ± 7.4	*t* = 0.5; *p* = 0.63; ICC = 0.88
	Lower trapezious (left)	28.1 ± 3.5	25.6 ± 7.08	2.58 ± 7.8	*t* = 0.98; *p* = 0.36; ICC = 0.91

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

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 (Table 1).

With regard to the positioning of the subjects in the "natural head position," we did not perform a study on method error; however, we used a method that is considered as one of the most repeatable, especially in adults (data about children are not so clear). We used this method in another study that investigated the facial morphology in relation to the sEMG activity of masticatory, neck, and trunk muscles (Tecco et al., 2011).

Tables 2 and 3 show the descriptive statistics of the treated and control groups at T0, T1, and T2.

The descriptive statistic for the control group at T0, T1, and T2 is reported in Table 3.

The treated group showed statistically significant changes in the sEMG activity of the masticatory, neck, and trunk muscles, both at rest and during MVC of the mandible with respect to T0.

The masticatory muscles exhibited several changes, both at rest and during maximal voluntary clenching (Table 2).

Also, the masseter and anterior temporalis showed a significant improvement in the asymmetry index from T0 to T2 (Table 4).

In addition, the asymmetry index was significantly reduced with respect to T0.

No changes were observed in the sEMG activity in the control group as shown in Table 3.

The data on the asymmetry index are reported in Table 4 for all the muscles.

The control subjects did not show any significant difference in T0, T1, and T2.

All the neck and trunk muscles generally showed a decrease in the values of the asymmetry index from T0 to T2. The only exception was the lower trapezious muscle during MVC and at rest, which exhibited an increase in the asymmetry index from T0 to T2, without statistical significance.

After treatment, the treated patients exhibited a more symmetric muscular contraction activity than the control untreated subjects, as there were significant differences between the treated patients and the control subjects at T2 in the asymmetry index; the control subjects did not exhibit any change in their sEMG activity from T0 and T1 to T2 (Table 3).

4. Discussion

The functional brace is a re-educational method intended to achieve equilibrium of the trunk muscles and correct the cerebral-column curvatures.

Its use in pediatric patients is an important aid in achieving harmonious development and correction of scoliosis.

It is now well recognized that scoliosis has a multi-factorial etiology.

Different factors have been suggested to cause this condition. Among these, deviation from the standard growth pattern, neuromuscular alterations, asymmetric growth of the limbs and trunk, alterations in the sagittal configuration of the spine, and environmental factors are noteworthy (Alden et al., 2006; White and Panjabi, 1990).

In the body, form and function are strictly correlated and have reciprocal effects. A correct function leads to trouble-free development, whereas an impaired function may adversely influence the form. Conversely, the function will also adapt to a correct or impaired structural form.

The functional treatment of scoliosis, which actually consists of physiotherapy of the muscle structure, is based on the principle of neuromuscular re-education and muscle exercise, achieved by using biological forces naturally present in the trunk muscles.

The exercises and functional brace allow correction of the growth of the skeletal structures.

Knowledge of sEMG activity of muscles during this treatment is essential for the identification of any dysfunction, which may cause alterations in the vertebral-column alignment and impaired muscular function. Consequently, sEMG is a useful aid for monitoring the correct evolution of these types of therapy.

During the 6-month treatment with the functional device, the therapy seemed to partly alter the muscle tone of the trunk muscles, improving the asymmetry indices, as shown in our study (Table 2).

This was also evident during teeth clenching (Table 2), and also the muscle sternocleidomastoid showed a significant increase in its contractility during teeth clenching (Table 2).

Also, the masticatory muscles showed significant increases in contractility after the treatment of scoliosis (Table 2).

However, all these changes were not observed in the control group (Table 3).

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 with respect to the method error (Perinetti and Contardo, 2009).

In this study, the changes observed in the sEMG were all higher than the differences between the first and the second evaluation for the method error. This was also observed for the masticatory muscles, suggesting that the treatment of scoliosis through a functional brace could also modify the function of the stomatognathic area.

Scoliosis is one of the notorious symptoms of masticatory muscle because the misalignment of the body puts more pressure on one side of the jaw.

Although the question of correlations occurring between posture, locomotion apparatus, and dentition has been debated since the beginning of the 20th century, this issue has gained only scant attention in subsequent researches (Huggare, 1998). The results from experimental animal studies, also conducted by the same research group of this evaluation, (D'Attilio et al., 2005) suggest that alterations in the occlusion evoke changes in many other regions of the body (Azuma et al., 1999). Occlusion has an impact on the spinal-column alignment. Recently, a scoliotic curve has been developed after insertion of a unilateral bite plane in rats (D'Attilio et al., 2005). In all the rats, the evoked changes were observed within 1 week of unilateral manipulation and normalized after harmonization of the occlusal plane. To investigate the possible effects of orthopedic asymmetric disorders on dentofacial development and head posture, interdisciplinary clinical studies have been conducted on patients with scoliosis or torticollis. The statistically elevated prevalence of a unilateral cross-bite in those subjects amounted to 26–55% (Pećina et al., 1991). The cervical spine provides the morphological basis for an extensive freedom of head movement; it serves as a bridge for numerous blood and lymphatic vessels and nerves, linking head, trunk, and upper limb. In our study, the developed physiotherapeutic treatment system uses isometric and other exercises to

Table 2
sEMG data of the treated group at T0, T1 and T2.

		Treated group (T0)				Treated group (T1)				Treated group (T2)				Statistical comparisons (Friedman 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	Masseter (right)	3.2	0.2	16.5	6.5	3.6	0.3	16.5	9.2	3.5	0.2	13.5	6.5	NS	NS	NS
														Friedman test: Chi-square 1.6; $p = 0.45$		
	Masseter (left)	6.6	0.3	9.3	5.2	6.2	1.2	20.1	6.2	3.5	0.3	10.2	5.4	$P = 0.004$	$P = 0.002$	NS
														Friedman test: Chi-square 10.9; $p = 0.001$		
	Anterior temporalis (right)	7.5	0.5	37.9	26.5	7.3	1.5	41.5	21.3	8.5	3.4	37.5	25.2	NS	NS	NS
														Friedman test: Chi-square: 5.71; p = 0.06		
	Anterior temporalis (left)	8.5	0.6	49.5	25.3	5.8	0.3	55.5	39.4	5.5	0.5	25,4	15.3	$P = 0.004$	$P = 0.002$	$P = 0.003$
														Friedman test: Chi-square: 12.8; $p = 0.001$		
	SCM (right)	13.5	2.1	55.4	40.5	10.4	1.1	56.5	45.5	15.5	0.5	50.5	33.6	NS	NS	NS
														Friedman test: Chi-square: 0; $p = 1$		
	SCM (left)	10.5	0.1	60.5	45.8	15.4	0.3	59.5	47.6	15.9	0.2	65.5	48.7	NS	NS	NS
														Friedman test: Chi-square: 5.4; $p = 0.07$		
	Upper trapezious (right)	40.5	3.6	115.6	60.9	55.5	5.5	122.5	60.5	50.6	2.9	149.5	70.9	NS	NS	NS
														Friedman test: Chi-square: 1.4; $p = 0.5$		
	Upper trapezious (left)	47.5	3.2	139.5	80.5	59.8	5.9	139.5	70.6	69.6	3.5	81,5	40,2	NS	$P = 0.04$	$P = 0.03$
														Friedman test: Chi-square: 6.8; $p = 0.03$		
	Lower trapezious (right)	50.5	4.6	130.6	70.5	66.6	4.9	130.3	69.8	45.5	6.6	86,2	50,5	NS	$P = 0.04$	$P = 0.03$
														Friedman test: Chi-square: 10.4; $p = 0.01$		
	Lower trapezious (left)	40.5	9.9	140.4	80.5	50.5	10.5	130.9	69.9	69.5	15.2	150.5	70.2	NS	$P = 0.04$	$P = 0.04$
														Friedman test: Chi-square: 10.2; $p = 0.01$		
MVC	Masseter (right)	85.5	30.5	120.5	60.9	90.3	13.4	110.2	75.4	70.2	15.8	130.5	75.5	NS	NS	NS
														Friedman test: Chi-square: 1.4; $p = 0.5$		
	Masseter (left)	68.2	25.3	135.7	68.2	78.4	7.2	150.8	59.3	86.4	13.2	150.3	71.2	**NS**	$\mathbf{P = 0.002}$	$P = 0.03$
														Friedman test: Chi-square: 11.4; $p = 0.001$		
	Anterior temporalis (right)	70.3	5.2	148.7	69.2	75.4	6.7	80.6	65.3	80.5	13.8	90.3	60.3	NS	NS	NS
														Friedman test: Chi-square: 4.2; $p = 0.12$		
	Anterior Temporalis (left)	72,5	15.6	110,3	60.5	86,2	30.4	149.9	70.5	90,5	37,9	140.8	40.8	NS	$P = 0.04$	$P = 0.03$
														Friedman test: Chi-square: 14.6; $p = 0.001$		
	SCM (right)	20.6	3.2	60.8	40.2	35.6	1.1	69.7	43.2	32.3	7.5	70.2	39.8	$P = 0.04$	NS	NS
														Friedman test: Chi-square: 5.6; $p = 0.06$		
	SCM (left)	9.3	0.2	40.5	25.6	20.4	0.9	75.4	45.2	23.5	6.2	75.6	45.2	$P = 0.03$	$P = 0.04$	NS
														Friedman test: Chi-square: 5.6; $p = 0.06$		
	Upper trapezious (right)	43.2	10.5	90.2	40.3	40.4	9.2	85.5	39.2	43.3	15.2	85.3	35.6	NS	NS	NS
														Friedman test: Chi-square: 2.5; $p = 0.28$		
	Upper trapezious (left)	32.4	12.2	46.3	25.2	43.3	8.7	90.2	36.5	46.7	13.5	83.2	55.6	$P = 0.01$	$P = 0.04$	NS
														Friedman test: Chi-square: 11.4; $p = 0.001$		
	Lower trapezious (right)	40.3	3.5	129.4	65.2	65.3	14.2	129.3	45.2	70.2	13.7	130.2	61.2	$P = 0.04$	$P = 0.04$	NS
														Friedman test: Chi-square: 16.2; $p = 0.001$		
	Lower trapezious (left)	40.3	10.2	113.5	70.2	66.2	15.6	125.2	43.5	72.4	16.5	135.2	60.2	$P = 0.03$	$P = 0.04$	NS
														Friedman test: Chi-square: 20; $p = 0.001$		

strengthen or lengthen the asymmetrical muscles in a scoliotic body to halt the progression of abnormal spinal curvature, and in the best case, to reverse the curves. All scoliosis cases involve asymmetrical muscles. A scoliotic spine twists abnormally due to strength and bulk imbalances among the muscle groups in the back and elsewhere (such as lower extremities), which are supposed to be equal. Owing to unknown reasons, some muscles on one side of the back grow stronger than the opposing group on the other side and pull harder. The weaker ones cannot maintain the balance, and thus, the scoliosis cycle begins and gradually worsens under the asymmetrical loads. Nevertheless, knowing how the spine initially began to twist (whether due to muscle degenerative disease or unknown causes) is less important than recognizing the imbalances. Identifying the imbalances is the only method to treat this problem. In this case, sEMG is helpful to recognize the asymmetry. The therapist designs a program to restore the normal balance. Each person's scoliosis deformity is somewhat unique, and hence, a therapist tailors the scoliosis exercises individually. Some exercises that greatly benefit one patient may be counterproductive for another who has a different abnormal spinal configuration, and some are bad for all scoliotics. The regimen of muscle-strengthening and stretching exercises aims to derotate and elongate the spine back to its normal position. The patient must perform the scoliosis exercises for about half-an-hour daily. Patient compliance is extremely important and hard work is essential. However, the benefits are significant. The method gives a patient the knowledge and tools to control his/her own postural health, lifelong, which can be the result of continuous stimulation by exercises and using brace to increase the strength of trunk muscles and influence masticatory muscles. The presence of the device could have a stabilization effect on the trunk muscles, probably because of changed conformation from the periphery, because of the different posture of the trunk.

4.1. Limits of the study

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

However, the study lacks 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, to remove most of the biological and technical noise. The normalization was not performed 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.

Table 3
sEMG data in the control group.

		Control group (T0)				Control group (T1)				Control 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	Masseter (right)	2.2	0.1	10.3	5.5	2.5	0.3	16.2	8.4	2.6	0.1	14.3	5.8	NS	NS	NS
														Friedman test: Chi-square 2.6; $p = 0.27$		
	Masseter (left)	3,5	0.2	10.5	5.2	3.6	0.6	13.2	7.3	3.6	0.6	13.5	4.7	NS	NS	NS
														Friedman test: Chi-square 2.7; $p = 0.2$		
	Anterior Temporalis (right)	6.6	1.5	30.2	35.4	8.9	2.6	35.7	36.5	8.9	5.5	39,7	38.7	NS	NS	NS
														Friedman test: Chi-square 1.6; $p = 0.45$		
	Anterior Temporalis (left)	8.2	2.4	69.8	40.2	8.5	1.6	69.8	45.5	9.8	2.5	69.7	41.2	NS	NS	NS
														Friedman test: Chi-square 5.6; $p = 0.06$		
	SCM (right)	20.3	3.4	66.5	35.7	25.6	5.4	58.2	40.3	24.3	0.3	56.2	40.1	NS	NS	NS
														Friedman test: Chi-square 0.6; $p = 0.74$		
	SCM (left)	12.2	3.1	65.4	36.2	13.5	4.3	61.3	38.7	13.5	0.6	55.4	43.4	NS	NS	NS
														Friedman test: Chi-square 0.2; $p = 0.9$		
	Upper trapezious (right)	35.7	5.4	130.4	50.5	47.8	13.5	120.4	65.5	45.5	3.2	129.3	68.7	NS	NS	NS
														Friedman test: Chi-square 0.6; $p = 0.7$		
	Upper trapezious (left)	22.3	1.1	85.5	60.4	32.5	6.9	129.2	65.5	43.3	3.2	119.2	70.4	$P = 0.04$	NS	NS
														Friedman test: Chi-square 7.8; $p = 0.02$		
	Lower trapezious (right)	56.3	6.5	118.2	65.4	50.2	6.7	120.2	60.4	59.2	6.7	130.2	61.3	NS	NS	NS
														Friedman test: Chi-square 0.6341,2; $p = 0.73$		
	Lower trapezious (left)	41.2	6.8	139.2	65.3	35.6	1.1	129.8	69.8	36.2	19.3	139.4	70.3	NS	NS	NS
														Friedman test: Chi-square 0.2; $p = 0.9$		
MVC	Masseter (right)	45.4	13.8	90.5	65.4	55.6	7.6	113.2	67.8	59.8	9.2	110.3	65.7	NS	NS	NS
														Friedman test: Chi-square 1.4; $p = 0.5$		
	Masseter (left)	43.4	10.2	87.5	68.5	49.3	13.2	99.5	65.5	53.2	11.2	99.8	65.7	NS	NS	NS
														Friedman test: Chi-square 1.4; $p = 0.5$		
	Anterior Temporalis (right)	60.2	13.4	99.5	71.3	67.3	11.4	110.2	78.7	68.9	3.6	110.2	68.9	NS	NS	NS
														Friedman test: Chi-square 1.7; $p = 0.41$		
	Anterior Temporalis (left)	66.5	15.2	110.2	65.5	69.8	15.4	113.5	76.2	73.4	12.5	108.3	65.4	NS	NS	NS
														Friedman test: Chi-square 0.36; $p = 0.84$		
	SCM (right)	26.5	5.5	59.8	35.6	35.4	6.9	63.5	38.9	36.7	7.6	66.7	38.9	NS	NS	NS
														Friedman test: Chi-square 3.2; $p = 0.2$		
	SCM (left)	27.5	7.6	69.8	35.8	36.5	13.2	71.3	43.2	39.8	11.2	73.4	45.6	NS	NS	NS
														Friedman test: Chi-square 4.2; $p = 0.12$		
	Upper trapezious (right)	43.4	9.5	65.6	35.6	48.7	15.5	97.8	55.4	49.8	13.2	98.7	60.2	NS	NS	NS
														Friedman test: Chi-square 1.4; $p = 0.5$		
	Upper trapezious (left)	46.7	13.2	71.3	45.6	51.4	16.5	87.9	50.4	55.2	16.7	93.4	55.6	NS	NS	NS
														Friedman test: Chi-square 3.2; $p = 0.2$		
	Lower trapezious (right)	43.6	13.2	110.3	70.9	49.7	15.4	110.4	65.8	58.9	11.3	86.5	55.2	NS	NS	NS
														Friedman test: Chi-square 4.2; $p = 0.1$		
	Lower trapezious (left)	47.6	15.4	99.2	56.7	41.2	18.7	115.6	55.6	43.6	15.4	125.7	69.8	NS	NS	NS
														Friedman test: Chi-square 0.36; $p = 0.84$		

Table 4
Asymmetry index for the muscles calculated at T0 and T2 in the treated and the control group.

	Treated group	Control group	Treated versus Control (T0) p	Treated group	Control group	Treated versus Control (T1) p
	Asymmetry index (Mean and SD) (%)	Asymmetry Index (Mean and SD) (%)		Asymmetry index (Mean and SD) (%)	Asymmetry Index (Mean and SD) (%)	
	T0			T1		
At rest						
Masseter	40 (±14)	20 (±7)	t = 15.26 p = 0.001	25 (±12) (*)	25 (±5)	NS
Anterior Temporalis	20 (±5)	30 (±2)	NS	30 (±3) (*)	32 (±3)	NS
SCM	35 (±5)	75 (±6)	t = –19.6 p = 0.001	10 (±5) (*)	80 (±5)	t = –19.7 p = 0.001
Upper trapezious	20 (±7)	20 (±5)	NS	5 (±6)	25 (±5)	t = –9.7 p = 0.001
Lower trapezious	20 (±6)	27 (±2)	NS	20 (±5)	27 (±6)	NS
MVC						
Masseter	25 (±7)	23 (±7)	NS	15 (±7) (*)	27 (±5)	t = –9.4 P = 0.001
Anterior Temporalis	15 (±5)	26 (±5)	t = –9.33 P = 0.001	7 (±3) (*)	29(±6)	t = –12.6 p = 0.001
SCM	33 (±5)	28 (±3)	NS	27 (±5)	26(±4)	NS
Upper trapezious	40 (±13)	33 (±7)	NS	10 (±6) (**)	29(±7)	t = –10.4 p = 0.001
Lower trapezious	5 (±3)	26(±3)	t = –15p = 0.001	8 (±4)	26(±5)	t = –15 p = 0.001

5. Conclusions

Although there are some limits, we can conclude that the use of sEMG to study muscular activity represents 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 scoliosis therapy. In addition, sEMG could also be useful in monitoring the masticatory muscles during postural treatment of scoliosis.

Our findings suggest that the use of a functional device for the treatment of scoliosis induces a significant reduction in the asymmetry index of trunk muscles as well as a significant increase in the contractility of masticatory muscles.

References

Alden KJ, Marosy B, Nzegwu N, Justice CM, Wilson AF, Miller NH. Idiopathic scoliosis: Identification of candidate regions on chromosome 19p13. Spine 2006;31:1815–9.

White AA, Panjabi MM. Clinical Biomechanics of the Spine. 2nd ed. New York: Lippincott; 1990.

Trobisch P, Suess O, Schwab F. Idiopathic Scoliosis. Dtsch Arztebl Int. 2010;107:875–84.

Visscher CM, Lobbezoo F, de Boer W, van der Zaag J, Naeije M. Prevalence of cervical spinal pain in craniomandibular pain patients. Eur. J. Oral Sci. 2001;109:76–80.

Hitchcock HP. Treatment of malocclusion associated with scoliosis. Angle Orthod. 1969;39:64–8.

Pećina M, Lulluć-Dukić O, Pećina-Hrncević A. Hereditary orthodontic anomalies and idiopathic scoliosis. Int. Orthop. 1991;15:57–9.

Ben-Bassat Y, Yitschaky M, Kaplan L, Brin I. Occlusal patterns in patients with idiopathic scoliosis. Am. J. Orthod. Dentofac. Orthop. 2006;130:629–33.

Castroflorio T, Bracco P, Farina D. Surface electromyography in the assessment of jaw elevator muscles. J. Oral Rehabil. 2008;35:638–45.

Cram J.R., Kasman G.S. Introduction to Surface Electromyography. Gaithersburg, MD: Aspen Publishers, 1997:102–15.

Riolo M.L., Moyers R.E., McNamara J.A. Jr. An Atlas of Craniofacial Growth: Cephalometric standards from the University of Michigan. Craniofacial Growth Series. Ann Arbor Center for Growth and Development. The University of Michigan, 1974.

Donaldson S, Donaldson M. Multi-channel EMG assessment and treatment techniques. In: Cram JR, editor. Clinical EMG For Surface Recording. 2nd ed. Nevada City, CA: Clinical Resources; 1990. p. 143–74.

Christensen LV, Hutching MO. Methodological observations on positive and negative work (teeth grinding) by human jaw muscles. J. Oral Rehabil. 1992;19:399–411.

Tecco S, Epifania E, Festa F. An electromyographic evaluation of bilateral symmetry of masticatory, neck and trunk muscles activity in patients wearing a positioner. J. Oral Rehabil. 2008;35:433–9.

Tecco S, Crincoli V, Di Bisceglie B, Caputi S, Festa F. Relation between facial morphology on lateral skull radiographs and sEMG activity of head, neck, and trunk muscles in Caucasian adult females. J. Electromyogr. Kinesiol. 2011;21(2):298–310.

Saccucci M, Tecco S, Ierardoa G, Luzzi V, Festa F, Polimeni A. Effects of interceptive orthodontics on orbicular muscle activity: A surface electromyographic study in children. J. Electromyogr. Kinesiol. 2011;21(4):665–71.

Moorrees CFA. Natural head position – a revival. Am. J. Orthod. Dentofacial Orthop. 1994;105:512–3.

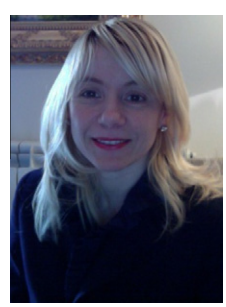
Perinetti G, Contardo L. Posturography as a diagnostic aid in dentistry: a systematic review. J. Oral Rehabil. 2009;36:922–36.

Huggare J. Postural disorders and dentofacial morphology. Acta Odontol. Scandinav. 1998;56:383–6.

D'Attilio M, Filippi MR, Femminella B, Festa F, Tecco S. The influence of an experimentally-induced malocclusion on vertebral alignment in rats: a controlled pilot study. J. Craniomandib. Pract. 2005;23:119–29.

Azuma Y, Maehara K, Tokunaga T, Hashimoto M, Ieoka K, Sakagami H. Systemic effects of the occlusal destruction in guinea pigs. In Vivo 1999;13:519–24.

Pećina M, Lulić-Dukić O, Pećina-Hrnčević A. Hereditary orthodontic anomalies and idiopathic scoliosis. Int. Orthop. 1991;15:57–9.



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