

Evaluation of the muscular activity and myodynamic balance in children with physiological dental occlusion

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Abstract

Objective

The objective was to evaluate the homogeneous myoelectric activity of the maxillofacial area and to identify the myodynamic musculature balance in children of different ages with a physiological dental occlusion.

Materials and methods

Sixty children, 30 aged 7–9 years and 30 aged 10–12 years, with an Angle Class I relationship and

who had no clinical symptoms, temporomandibular disorders, cross bite, deep bite or open bite, and were not bruxers underwent a surface electromyographic examination. The bioelectric potentials of the left and right temporalis, masseter, suprahyoid and sternocleidomastoid muscles were evaluated in maximum clenching.

Results

The electroactivity of the muscles measured with root mean square and average rectified value did not present statistically significant differences between the groups, even though different values in relation to age were found. Among the 7- to 9-year-olds, the root mean square index in maximum clenching for the masticatory muscles was $256.5 \pm 9.0 \mu\text{V}$ on the right and $254.0 \pm 7.3 \mu\text{V}$ on the left and for the suprahyoid muscles was $27.3 \pm 3.2 \mu\text{V}$ and $31.6 \pm 3.7 \mu\text{V}$, respectively. In the group of 10- to 12-year-olds, the values were $374.8 \pm 15.5 \mu\text{V}$ and $354.0 \pm 16.4 \mu\text{V}$, respectively, for the masticatory muscles and $23.4 \pm 1.9 \mu\text{V}$ and $22.4 \pm 2.1 \mu\text{V}$, respectively, for the suprahyoid muscles.

Conclusion

Any deviation from the values reported in the present study suggests the presence of occlusal and/or postural problems.

Keywords

Clinical research protocol; clinical trial; randomized controlled trial; dental occlusion; stomatognathic system; masticatory system; orthodontics

Introduction

Surface electromyography (sEMG) is an objective information tool of the functional state of the neuromuscular system of the masticatory apparatus.¹ Technological progress has made it possible to extend the scope of measurement tools in stomatology; the development

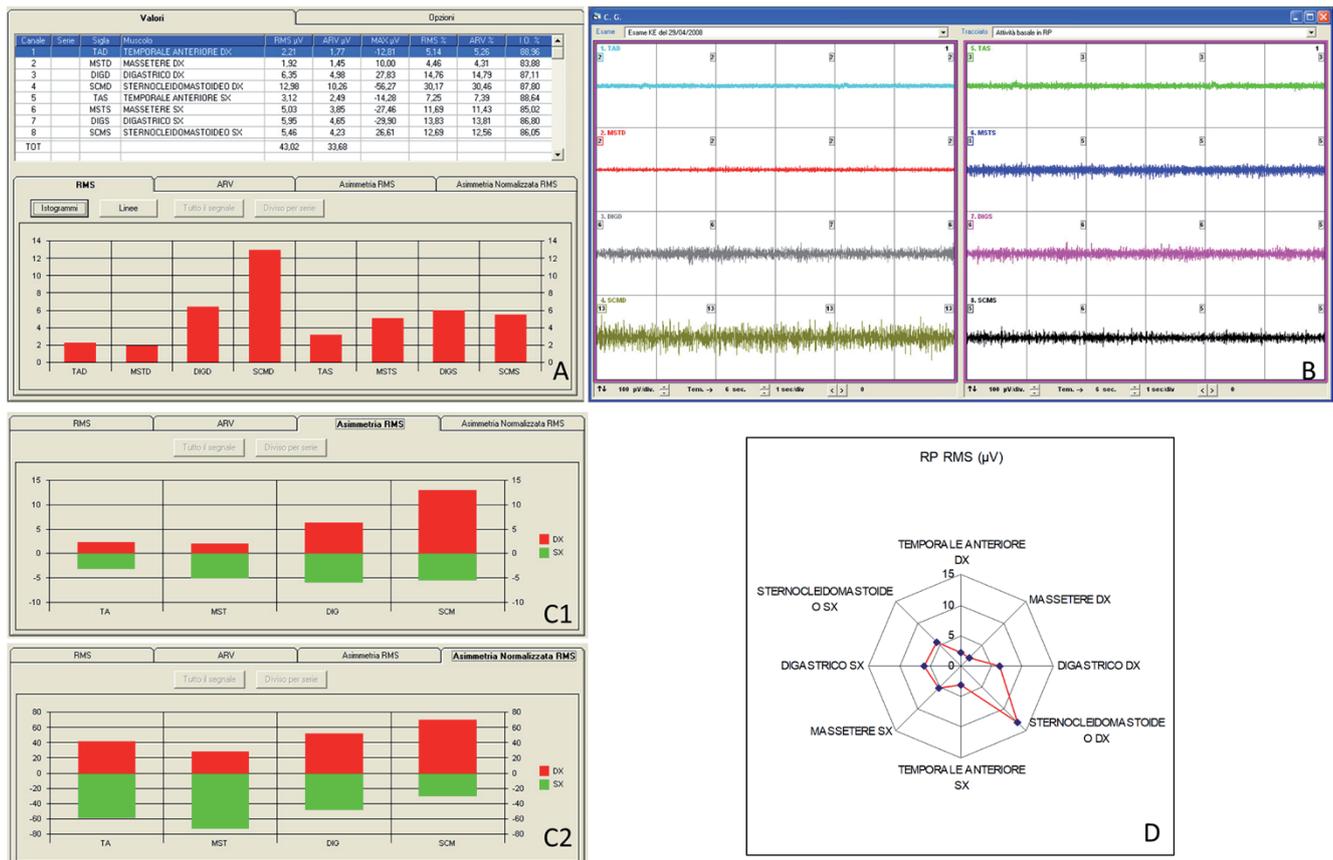


Fig. 1

of digital techniques has allowed the creation of surface electromyographs that combine analog equipment and computers. The latter receives the signals detected by the surface electromyograph in digital and then processes and displays them in tables, histograms and other graphs (Fig. 1).

The use of surface electromyographs requires precise information on the normal average values of average normality of different age groups and of the muscular biopotentials, both for agonist and antagonist muscles, with particular reference to the temporalis, masseter, suprahyoid and sternocleidomastoid muscles. Several studies have compared the outcomes of adults with adults,²⁻⁶ children with adults⁷ and children with children,⁸⁻¹³ showing in every case different occlusal diseases. To date, the muscular activity of the masticatory complex in healthy children of different ages with a physiological dental occlusion has not been considered.

The present study was aimed at evaluating the homogeneous myoelectric activity of the maxillofacial area and at identifying the myodynamic muscu-

lature balance (masseter, temporalis and suprahyoid muscles) in children of different ages with a physiological dental occlusion. Physiological dental occlusion was regarded as an Angle Class I relationship and no clinical symptoms, temporomandibular disorders, cross bite, deep bite, open bite or bruxism. The null hypothesis was that myoelectric activity in children is associated with age, which is the reason 2 age groups were selected.

Materials and methods

Sixty children, 30 aged 7–9 years and 30 aged 10–12 years, with physiological dental occlusion, underwent an electromyographic examination. The bioelectric potentials of the left and right temporalis, masseter, suprahyoid and sternocleidomastoid muscles were evaluated with the BioKeyNet surface electromyograph (Bioket, San Benedetto del Tronto, Italy). The biopotentials of the muscles were recorded using single-use surface electrodes, taking into account the recommendations of various authors.^{1, 14, 15}

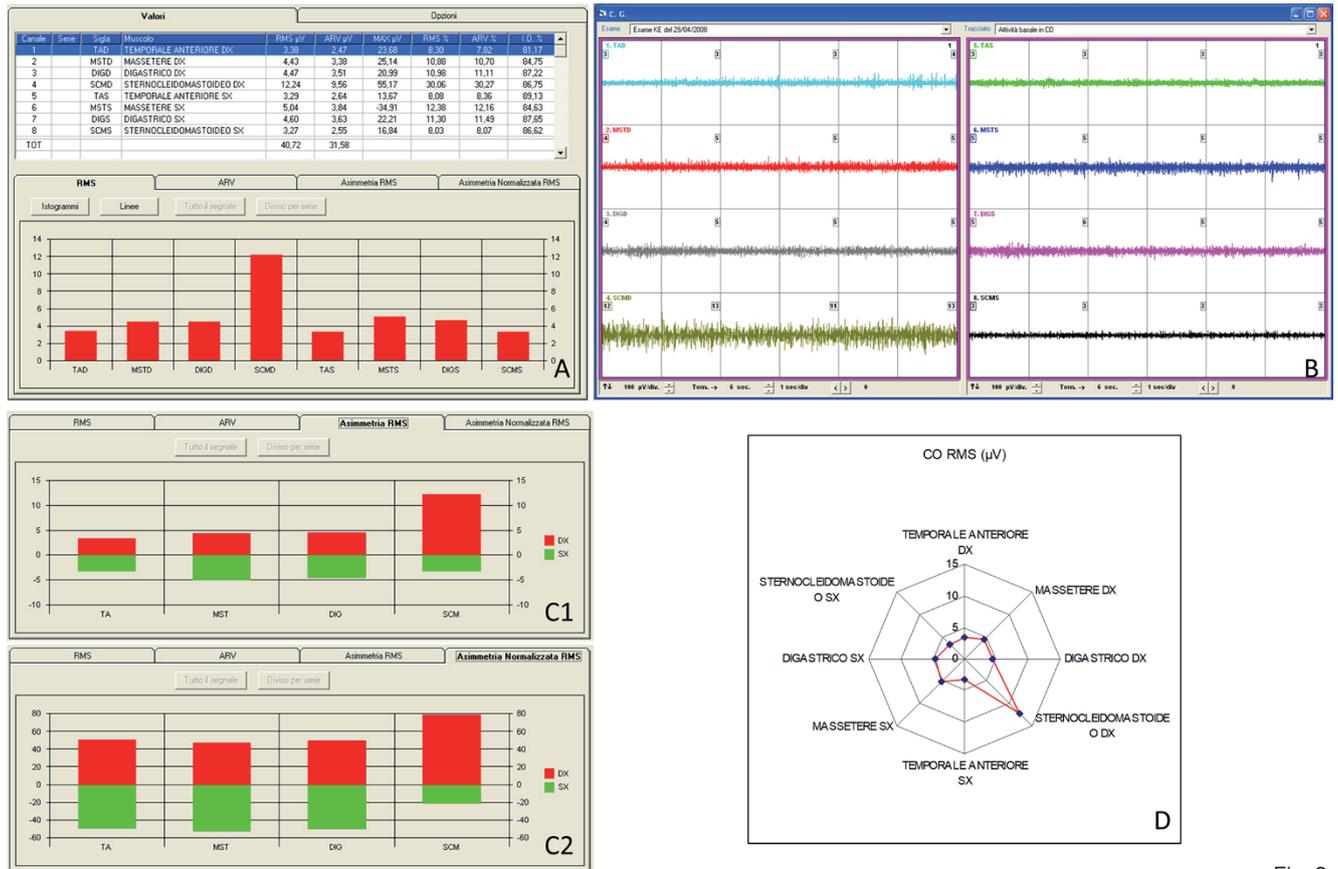


Fig. 2

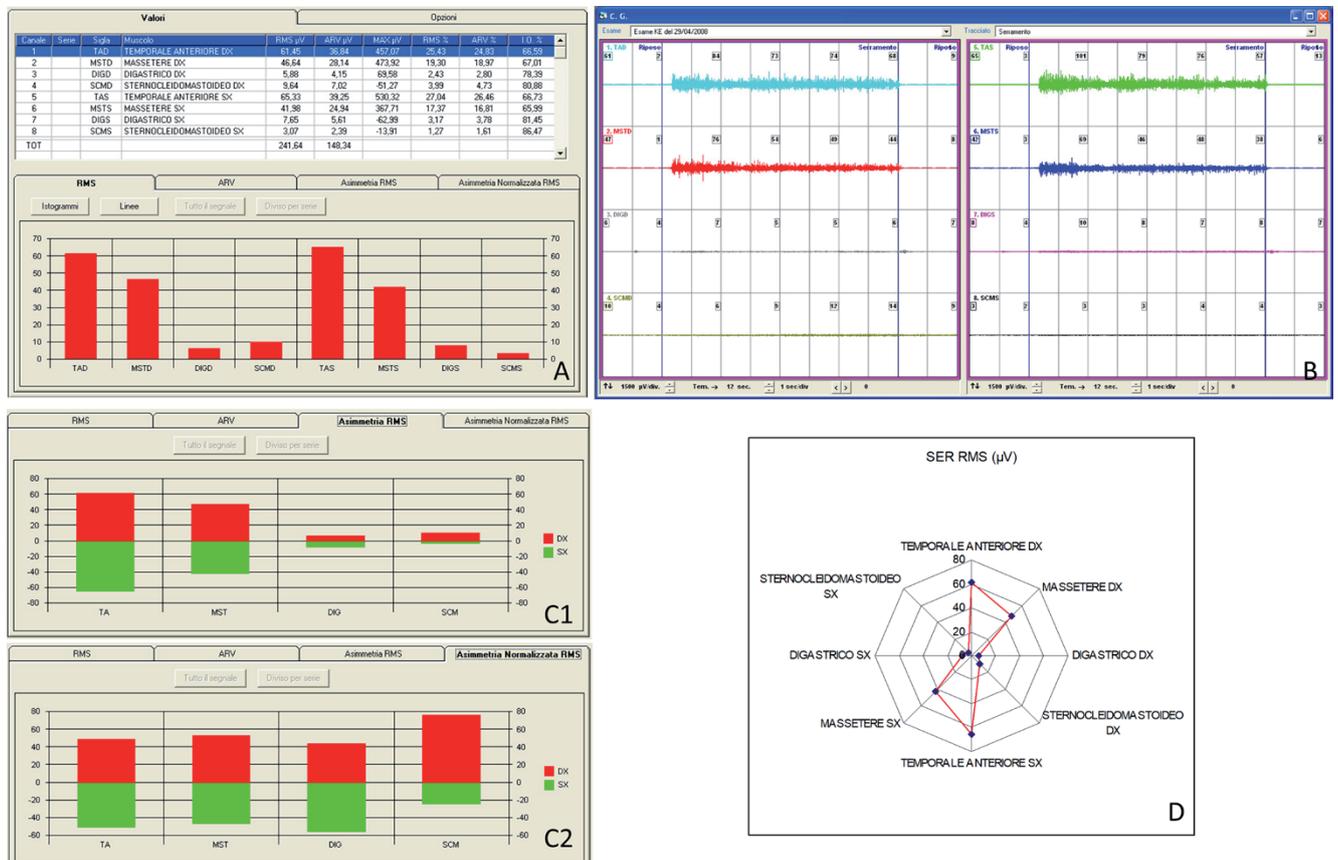


Fig. 3

Muscle ratio	RMS		P value
	Right	Left	
Temporalis + masseter	256.5 ± 9.0	254.0 ± 7.3	> 0.05
Suprahyoid	27.3 ± 3.2	31.6 ± 3.7	> 0.05
Ratio ϕ mass.tempor./ ϕ suprahyoid	9.4	8.0	N/A
Sternocleidomastoid	23.4 ± 4.2	19.7 ± 3.2	> 0.05
Muscle ratio	ARV		P value
	Right	Left	
Temporalis + masseter	156.1 ± 5.0	156.7 ± 4.1	> 0.05
Suprahyoid	19.0 ± 2.6	23.8 ± 3.0	> 0.05
Ratio ϕ mass.tempor./ ϕ suprahyoid	8.2	6.6	N/A
Sternocleidomastoid	8.5 ± 0.9	10.9 ± 1.1	> 0.05

ϕ Mass.tempor. = total value of biopotentials of temporalis and masseter muscles.
 ϕ Suprahyoid = mean values of biopotentials of the suprahyoid muscles.

Table 1:
Myodynamic balance of maxillofacial muscles at the time of dental clenching at maximum effort in 7- to 9-year-old children 7-9 years old with physiological occlusion (RMS and ARV in μ V).

Muscle ratio	RMS		P value
	Right	Left	
Temporalis + masseter	374.8 ± 15.5	354.0 ± 16.4	> 0.05
Suprahyoid	23.4 ± 1.9	22.4 ± 2.1	> 0.05
Ratio ϕ mass.tempor./ ϕ suprahyoid	16.0	15.8	N/A
Sternocleidomastoid	24.3 ± 2.9	22.9 ± 3.5	> 0.05
Muscle ratio	ARV		P value
	Right	Left	
Temporalis + masseter	242.7 ± 11.7	226.7 ± 10.2	> 0.05
Suprahyoid	15.8 ± 1.3	15.4 ± 1.5	> 0.05
Ratio ϕ mass.tempor./ ϕ suprahyoid	15.3	14.7	N/A
Sternocleidomastoid	15.3 ± 2.1	16.2 ± 1.8	> 0.05

ϕ Mass.tempor. = total value of biopotentials of temporalis and masseter muscles.
 ϕ Suprahyoid = mean values of biopotentials of the suprahyoid muscles.

Table 2:
Myodynamic balance of maxillofacial muscles at the time of dental clenching at maximum effort in 10- to 12-year-old children with physiological dental occlusion (RMS and ARV in μ V).

On the skin in the motor area of the muscle under examination, pre-gelled self-adhesive electrodes based on silver chloride were fixed parallel to the muscular fibers, with an interelectrode distance of 22 mm. The configuration of the input channels of the surface electromyograph is of the differential type: (i) the poten-

tial difference between the positive electrode and the negative electrode is detected; (ii) a reference electrode (ground) is placed in a zone nonelectrically connected to the points to be monitored. The bioelectric signal arising from the muscle fibers, when the skin is reached, is detected by the electrodes and then ampli-

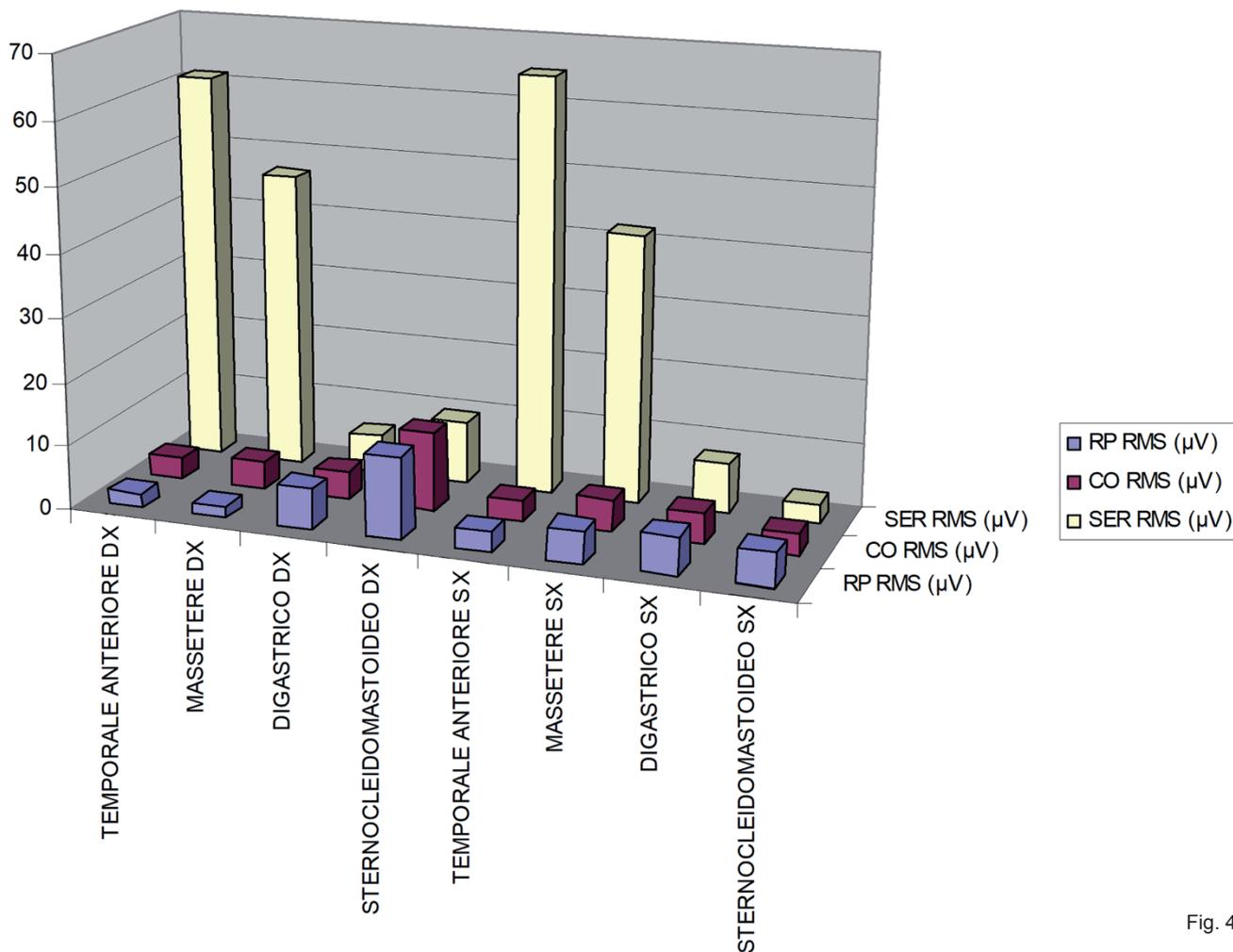


Fig. 4

Indexes	RMS		ARV	
	Right	Left	Right	Left
Muscles				
Temporalis	125.4 ± 9.8	143.1 ± 7.3	91.4 ± 6.5	93.6 ± 4.5
Masseter	131.1 ± 9.2	111.0 ± 7.5	64.7 ± 3.9	63.1 ± 3.8
Suprahyoid	27.3 ± 3.2	31.6 ± 3.7	19.0 ± 2.6	23.8 ± 3.0
Sternocleidomastoid	23.3 ± 4.2	19.7 ± 3.2	8.5 ± 0.9	10.9 ± 1.1

Table 3: Myodynamic balance of maxillofacial muscles at the time of dental clenching at maximum effort in 7- to 9-year-old children with physiological dental occlusion (RMS and ARV in μV).

Indexes	RMS		ARV	
	Right	Left	Right	Left
Muscles				
Temporalis	144.6 ± 13.7	144.9 ± 15.2	94.5 ± 9.0	92.7 ± 9.9
Masseter	230.2 ± 22.7	209.6 ± 18.2	148.2 ± 14.7	134.0 ± 11.7
Suprahyoid	23.4 ± 1.2	22.4 ± 2.2	15.8 ± 1.3	15.4 ± 1.5
Sternocleidomastoid	24.3 ± 2.9	22.9 ± 3.5	15.3 ± 2.1	16.3 ± 1.8

Table 4: Myodynamic balance of maxillofacial muscles at the time of dental clenching at maximum effort in 10- to 12-year-old children with physiological dental occlusion (RMS and ARV in μV).

fied and filtered (elimination of disturbances). The bioelectric signal is acquired, converted into digital form and transmitted to the computer for real-time display on the monitor.

The sEMG analysis was performed using the following functional tests:

1. mandible in relative physiological rest state, that is, teeth not in contact and lips just in contact (**Fig. 1**);
2. mandible in physiological position of occlusion, that is, teeth in contact (**Fig. 2**); and
3. mandible in voluntary clenching to the maximum effort (**Fig. 3**).

The main index of the functional state of a muscle is the value of the amplitude of its biological potential. Currently, 2 average amplitude indices, root mean square (RMS) and average rectified value (ARV), are mainly used. The maximum amplitude of the electromyographic signal is measured from the maximum positive peak to the maximum negative peak. The individual measured values can be processed to obtain the mean value of the absolute value with respect to the period. This index is the mean value of the adjusted signal (ARV), and it is usually expressed in μV .^{4, 5} The RMS index represents the value of a continuous voltage that develops a power equivalent to that of the electromyographic signal (alternating voltage). This index is calculated as the square root of the mean quadratic value of the electromyographic signal, and it is expressed in μV . Most of the other indexes, calculated according to the software, are derived from the ARV and RMS amplitude indices. The following electromyographic indices^{4, 5} were analyzed:

- RMS of biopotentials (expressed in μV);
- ARV of biopotentials (expressed in μV);
- total bioelectric activity (Total index, expressed in μV): the sum of all the ARV or RMS indices related to the bioelectric activity of the right and left muscles;
- participation in the bioelectric activity by each muscle in question expressed in % (calculated according to both the ARV and RMS indices)—the calculation of these participation indices was performed by dividing the bioelectric activity index of each muscle (in ARV or RMS) for the total index and subsequently multiplying by 100; and

- maximum amplitude of biopotentials index (Max; expressed in μV).

The results of the present study were statistically analyzed using BioStat software (AnalystSoft). An $\alpha < 0.05$ was used.

Results

Tables 1 and 2 show the sum parameters of the left and right temporalis, masseter, suprahyoid and sternocleidomastoid muscles (**Fig. 4**). These parameters have been taken from **Table 3** for **Table 1** and from **Table 4** for **Table 2**, respectively.

The data showed that, in 7- to 9-year-olds with physiological dental occlusion, the position of the mandible at the time of voluntary clenching at maximum effort can be normal only if the total value of the masticatory muscles (RMS; temporalis and masseter) is within the limits of $256.5 \pm 9.0 \mu\text{V}$ on the right and $254.0 \pm 7.3 \mu\text{V}$ on the left, and of the suprahyoid (digastric) muscles within $27.3 \pm 3.2 \mu\text{V}$ on the right and $31.6 \pm 3.7 \mu\text{V}$ on the left. The ratio of the temporalis and masseter muscles to the suprahyoid muscles was 9.4 times on the right and 8.0 on the left for the RMS index, and 8.2 and 6.6 times, respectively, for the ARV index. It should be noted that, in the case of normal posture, the biopotentials of the sternocleidomastoid muscles were within the limits of $23.4 \pm 4.2 \mu\text{V}$ on the right and $19.7 \pm 3.2 \mu\text{V}$ on the left.

The normal position of the jaw at the time of voluntary clenching at maximum effort in the 10- to 12-year-olds was possible when the total value of the temporalis and masseter muscles was within the limits of $374.8 \pm 15.5 \mu\text{V}$ on the right and $354.0 \pm 16.4 \mu\text{V}$ on the left, of the suprahyoid muscles was within $23.4 \pm 1.9 \mu\text{V}$ on the right and $22.4 \pm 2.1 \mu\text{V}$ on the left. The ratio of the temporalis and masseter muscles to the suprahyoid muscles was 16.0 times on the right and 15.8 times on the left for the RMS index, and 15.3 and 14.7 times, respectively, for the ARV index. In the 10- to 12-year-olds in normal posture, the biopotentials of the sternocleidomastoid muscles were within the limits of $24.3 \pm 2.9 \mu\text{V}$ on the right and $22.9 \pm 3.5 \mu\text{V}$ on the left. It should be noted that, in both age groups, no reliable differences were found between the parameters of the masseter, temporalis,

Age (years)	Coordination coefficient	
	Right	Left
7–9	$\frac{256.5 - 27.3}{256.5 + 27.3} = \frac{229.2}{283.8} = 0.81$	$\frac{254.0 - 31.6}{254.0 + 31.6} = \frac{224.4}{285.6} = 0.78$
10–12	$\frac{374.8 - 23.4}{374.8 + 23.4} = \frac{351.4}{398.2} = 0.88$	$\frac{354.0 - 22.4}{354.0 + 22.4} = \frac{331.6}{376.4} = 0.88$

Table 5: Coordination coefficient values in relation to the RMS index at the time of voluntary clenching at maximum effort in children aged 7–9 and 10–12 years with physiological occlusion.

suprahyoid and sternocleidomastoid muscles on the right and on the left, respectively.

Table 5 shows that the coordination coefficient for the maxillofacial area muscles evaluated at the time of voluntary clenching at maximum effort in the 7- to 9-year-olds was within the limits of 0.81 on the right and 0.78 on the left. In the 10- to 12-year-olds, at the end of the period of transition from primary dentition, the coordination coefficient was higher compared with the 7- to 9-year-olds, and it was the same (0.88) for both sides. This indicates that, toward the end of the replacement of the primary dentition, the muscles of the maxillofacial area on the left and on the right work in a homogeneous regimen.

Discussion

The present study evaluated the homogeneous muscular activity in the maxillofacial area and identified myodynamic balance in children with physiological dental occlusion. The mean biopotential values were identified of the masseter, temporalis and suprahyoid muscles, which participate directly in the retention of the physiological position of the resting jaw at the time of voluntary clenching at maximum effort. The mean values of the biopotentials of the muscles were assessed, as was the muscular myodynamic balance on the right and on the left. It was seen that the homogeneity of the muscular activity improves with age.

It is very important to establish the myodynamic balance of the muscles of the maxillofacial area between the right and left and compare them, since they condition the normal position (normognathic) of the jaw. In unbalanced conditions, the mandible may be

displaced either to the right or to the left, as well as in a distal or mesial direction. In addition, to study the myodynamic balance of the muscles of the maxillofacial area, it is necessary to have information on the

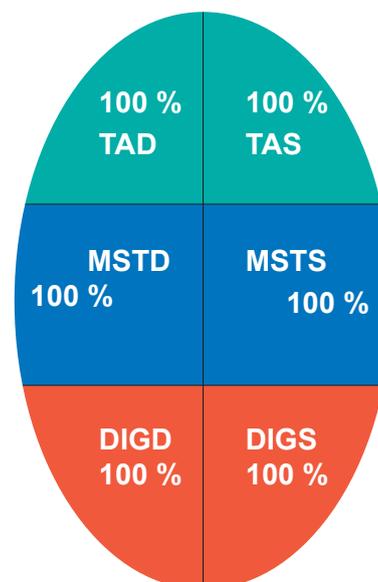


Fig. 5

homogeneous activity of the agonist and antagonist muscles, both in physiological or pathological conditions.

The coordination coefficient provides a value that expresses the balance of the muscles between the right and left in rest position and at maximum clenching. The myodynamic equilibrium and homogeneous muscular activity are illustrated in **Figure 5**, where the parameters of the masseter, temporalis and suprahyoid muscles in children with physiological dental occlusion are considered to be entirely normal. The intensity of the color changes according to the sEMG parameters and the deviation from the mean.

As mentioned before, previous studies on children compared patients with diseases. However, in those studies, the values in μV were assessed for dental clenching with cotton rolls and expressed as percentages of maximum voluntary clenching. This means that a direct comparison with the data from the present study is difficult. However, it should be considered that the use of cotton rolls during maximum clenching should increase the values in μV compared with maximum clenching without cotton rolls. Nevertheless, varying findings have been reported in several studies performed in children. In a clinical study,⁸ for example, the electromyographic activity and thickness of the right masseter, left masseter, right temporalis and left temporalis muscles and bite force in children with temporomandibular disorders were evaluated. The bite force was lower in the temporomandibular disorders group than in the control group. In another study,⁹ the electromyographic activity of the masseter and anterior portion of the temporalis muscles was evaluated in children with and without sleep bruxism. Children with sleep bruxism showed no significant difference in EMG of masticatory muscles at rest and in maximal intercuspal positions of the mandible compared with the control group.

In another study,¹⁰ the electromyographic activity of the temporalis and masseter muscles was evaluated in children with mixed dentition and a mean age of 8.6 years. All the children were undergoing rapid maxillary expansion with a bonded rapid maxillary expansion appliance. The electromyographic analysis showed that the activity of the temporalis and masseter muscles increased significantly when the expansion appliance was removed. During dental clenching with cotton rolls, the values in μV expressed as percentages of the maximum voluntary clenching increased from $\sim 112\text{--}113 \mu\text{V}$ to $143\text{--}149 \mu\text{V}$ for the masseter muscles and from $\sim 102 \mu\text{V}$ to $116\text{--}135 \mu\text{V}$ for the temporalis muscles. In the present study, in children with physiological dental occlusion, the data were higher during maximum voluntary clenching, $256.5 \mu\text{V}$ for the temporalis and masseter muscles. This might indicate that the removal of the rapid maxillary expansion appliance in the previously discussed study¹⁰ did not permit normal myoelectric activity of these muscles.

In conclusion, the present study provided the range of physiological function of the masticatory and ster-

nocleidomastoid muscles that children aged 7–9 and 10–12 should present in a myographic examination. Any deviation from these values suggests the presence of occlusal and/or postural problems, and an appropriate intervention to reach the values indicated in the present study should be considered.

Competing interests

The authors declare that they have no competing interests.

Legends

Fig. 1 – (A) Data acquired digitally and represented in the form of tables and histograms. Signal evaluated in relative physiological rest state. (B) Raw signal in relative physiological rest state. (C1) Histogram representation of asymmetrical root mean square signals in relative physiological rest state; (C2) signals normalized. (D) Further graphic representation of the mandible signals in relative physiological rest state.

Fig. 2 – (A) Representation in tables and histograms of the signal in the physiological position of occlusion (teeth in contact). (B) Raw signal in physiological dental occlusion position (teeth in contact). (C1) Histogram representation of asymmetrical root mean square signals in physiological dental occlusion position (teeth in contact); (C2) signals normalized. (D) Further graphic representation of the mandible signals in physiological dental occlusion position (teeth in contact).

Fig. 3 – (A) Representation in tables and histograms of the signal in voluntary clenching at maximum effort. (B) Raw signal in voluntary clenching at maximum effort. (C1) Histogram representation of asymmetrical root mean square signals in voluntary clenching at maximum effort; (C2) signals normalized. (D) Further graphic representation of the mandible signals in voluntary clenching at maximum effort.

Fig. 4 – Summary representation in a histogram of the functional tests performed.

Fig. 5 – Myodynamic equilibrium and homogeneous muscular activity. TAD = Right anterior temporalis; TAS = Left anterior temporalis; MSTD = Right masseter; MSTS = Left masseter; DIGD = Right digastric; DIGS = Left digastric. The intensity of the color

changes according to the sEMG parameters and the deviation from the mean. In the present diagram, the color intensity is 100% for each parameter.

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