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Study of the Impact of the Skeletal Facial Type on the Electromyographic Masseter / Temporal Ratio

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Abstract: ***Aim**: To evaluate the impact of the craniofacial architecture according to the ANB angle corrected by Miralles on the EMG activity of the masseter (Ms) and anterior temporal (Ta) muscles. **Method**: 62 individuals aged ranged 18 - 23 years, distributed by gender (24 men, 38 women), were studied. The facial morphology, according to Miralles, was determined from a lateral radiograph. All individuals underwent bilateral EMG examinations for the Ms and Ta muscles. **Results**: In the total sample, Ms presented a significant difference in voltage amplitude (p <0.001) greater than that of Ta on both sides. When distributing the sample among different facial skeletal types (normo, disto, and mesio), the dominance of the Ms was greater in the normo group. The Ms/Ta ratio also preserves the predominance of Ms in the normo group (1.74–1.54) on the left and right sides, respectively, without showing significant asymmetry. The vertex of the polynomial linear regression of the Ms/Ta ratio and the voltage amplitude is compatible with the normo group (approx. 1.69–1.45). The percentage of dominance of Ms (Ms/Ta ratio > 1) reached 80% in the normo group. This percentage was lower in disto and mesio groups. **Conclusions**: The ANB angle, EMG, and the Ms/Ta voltage ratio represent useful tools to explore the function of Ms and Ta in different skeletal types. The Ms/Ta ratio is close to 1.5, which represents the synergistic working ratio between the Ms and Ta muscles for the normo group.***

Keywords: ANB, EMG, SNA

1. Introduction

Cephalometry, which began in 1940 by Broadbent, became a valuable tool that facilitated the classification of different skeletal facial types, based on angular measurements[1]. Downs described points A and B in 1948. Thanks to the work of Cecil Steiner, Cephalometry in Clinical Practice[2], the SNA, SNB, and ANB angles became universally diffused in the dental community.

The arithmetic difference between SNA and SNB angles determines the ANB angle. However, this angle can vary by changing the position of the maxilla (SNA) and the rotation of the mandible (SN-Go-Gn). Miralles corrects the ANB with maxillary and mandibular adjustment and, based on this correction, determines three skeletal types: Normo, Mesio, and Disto, which can be distributed linearly[3]. Given the plethora of cephalometric analysis, various authors have tested the ANB angle and have concluded that it has, so far, a high standard[4] and that it is valid and reliable[5]

Another useful tool used in dentistry is surface electromyography (EMG), which allows us to study the bioelectric properties of muscles that are related to the stomatognathic system[6, 7]

The neuromusculature of the stomatognathic system adapts to efficiently fulfill functions like chewing, swallowing, and phonation, among others[8]. These functional adaptations should be expressed in the bioelectrical characteristics of the masseter (Ms) and temporal anterior (Ta) muscles in the different skeletal types[9, 10, 11]

2. Method and Patients

Sixty-two (62) patients were studied, all students from the University of Concepción with an age range of 18–23 years (male=24; female=38). All subjects underwent a lateral skull radiograph and a bilateral surface EMG on the Ms and Ta muscles.

Exclusion criteria

1) Present similar anthropological characteristics (age, weight, and height).
2) Present complete dental formula (except third molars)
3) Clinical absence of mandibular disorders such as clicking, crepitus of the TMJ, and pain on palpation of the chewing muscles.
4) They must not present systemic muscular pathologies.
5) Must not be subjected to orthodontic treatment.
6) Dental restorations in good condition
7) Absence of periodontal pathologies
8) Should not be subjected to pharmacological treatment.

All underwent the examination with informed consent according to the Helsinki protocol.

This research had the approval of the Ethics, Bioethics, and Biosafety Committee of the Vice-Rectory and Development of the University of Concepcion (role n ° 575).

Lateral skull x-ray

The radiographs were taken with Soredex teleradiography equipment, Crane Tome Ceph model year 2001 (Orion Corporation Soredex, Helsinki, Finland), operating at 70 kV and 10 mA. Exposure times were adjusted according to the physical constitution of the patient, from 1.0 to 1.2 seconds maximum.

The patients were placed on the cephalostat of the radiographic unit with supports in each ear canal and a nasal support to maintain the Frankfort plane parallel to the horizontal. Each patient was instructed to maintain occlusal contact at maximum voluntary contraction (MVC).

Cephalometric tracing.

SNA and SNB angles were plotted according to Steiner (Clinical Practice Cephalometry, Steiner, 1959). Then the Steiner ANB angle was determined by the arithmetic difference of the SNA and SNB angles.

ANB according to Mirralles[3]

The Steiner ANB angle value was adjusted according to Freeman by subtracting or adding one degree to the ANB angle for every 2 degrees that the SNA angle exceeded or was below 81.5º, respectively. Then this adjusted ANB angle was modified with the SN-Go-Gn angle. This procedure consists of subtracting or adding 25% when the angle exceeds or falls 32º, respectively. When the corrected ANB varies between 0º and 4º the subjects are included in skeletal class I (normo), above 4º they are classified in skeletal class II (disto) and the subjects with negative values are classified as skeletal class III (mesio)

Electromyographic examination (EMG).

Surface electromyography was performed according to Ferrario[12] technique.

The patient, inside the grounded Faraday cage, was seated with the back straight and the Frankfort plane parallel to the floor.

Muscles Ms and Ta, on both sides were recorded simultaneously. The surface of the facial skin was cleaned with 90% denatured alcohol. Surface electrodes (3M, 2222) were used. The control electrode was placed in the most prominent part of the muscle belly at the moment it performs a maximum isometric contraction. The reference electrode was located about 1.5 cm from the center of the control electrode, following the line of the muscle fibers. The ground electrode was placed ipsilaterally on the chin.

The capture of electrical signals was performed with a frequency of 5,000 Hz in a band of 30–500 Hz and with an amplification of 1000; professional Biopac equipment was used with an analog-digital mp5 converter. These electrical signals were converted into numbers, and the electromyogram was displayed using the software.

Four records were taken, and the best one was chosen. From this register, 1 second was selected, from which it was possible to analyze 5,000 events.

Statistical analysis

For the statistical analysis, the IBM SPSS program was used.

The Shapiro-Wilk test was performed to study the normal distribution of the sample.

t-test was performed for paired tests.

The one-way analysis of variance (ANOVA) was used to test more than two variables.

3. Results

Table 01

n	SNGoGn	ANBSteiner	ANBMiralles	n	SNGoGn	ANBSteiner	ANBMiralles
1	32,1	-5,5	-9,5	32	33,9	4,0	3,0
2	27,0	-1,0	-4,5	33	45,0	5,0	3,3
3	35,1	-2,0	-4,3	34	32,1	4,5	3,3
4	26,1	1,0	-3,8	35	27,0	7,0	3,5
5	36,0	-1,0	-3,3	36	41,1	5,5	3,5
6	32,1	-2,0	-3,3	37	24,0	4,0	3,5
7	33,9	-2,0	-2,3	38	41,1	6,0	3,5
8	45,0	6,0	-0,5	39	42,9	7,0	3,5
9	33,0	3,5	0,0	40	36,0	6,0	3,8
10	39,0	4,0	0,0	41	33,9	6,0	3,8
11	30,9	3,0	0,5	42	20,1	5,0	3,8
12	45,0	0,5	0,5	43	36,0	7,5	4,0
13	38,1	2,5	0,5	44	35,1	7,0	4,0
14	48,0	4,5	0,5	45	51,9	8,5	4,0
15	36,0	2,0	0,8	46	48,9	8,0	4,0
16	30,9	4,0	1,0	47	39,9	5,5	4,0
17	36,0	5,0	1,0	48	35,1	8,0	4,0
18	30,0	4,5	1,0	49	33,0	4,5	4,3
19	33,9	6,0	1,3	50	36,0	4,5	4,5
20	33,9	3,0	1,3	51	42,9	5,0	4,8
21	29,1	4,0	1,5	52	39,9	7,5	5,0
22	29,1	4,5	1,8	53	32,1	6,0	5,0
23	36,0	4,0	2,0	54	30,0	4,0	5,3
24	41,1	2,0	2,3	55	24,0	5,5	5,3
25	26,1	4,0	2,3	56	44,1	9,5	5,3
26	27,0	5,0	2,3	57	47,1	7,0	5,5
27	45,0	6,0	2,5	58	45,0	9,0	5,5
28	32,1	4,0	2,5	59	44,1	8,0	5,8
29	26,1	2,5	2,5	60	35,1	8,5	5,8
30	45,0	5,0	2,5	61	41,1	9,5	6,0
31	38,1	7,0	2,5	62	39,9	11,5	9,8

Table 01
Values (degrees) of the ANB of Steiner, ANB corrected by Miralles, and SN-GoGn (Sella-Nasion-Gonion-Gnation) angles.

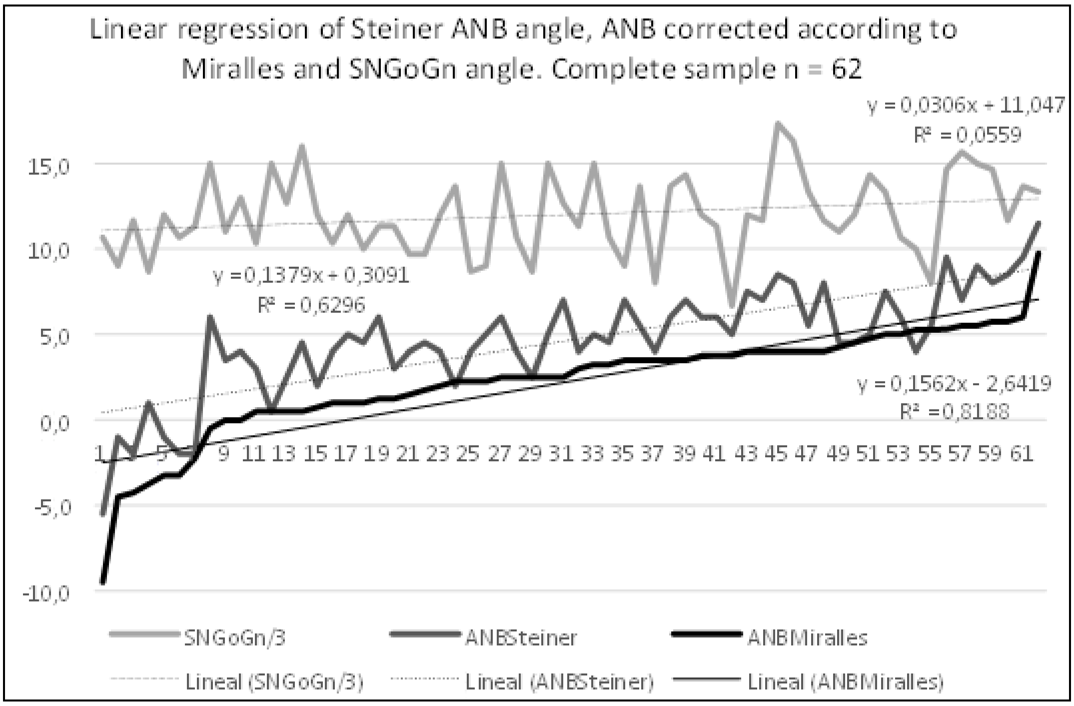

Figure 01

Figure 01
From the data in Table 01, the angles ANB of Steiner, ANB corrected by Miralles and SN-GoGn were plotted, and then a linear regression was performed for each one.

The ANB angle corrected by Miralles presents the coefficient of determination closest to 1 (0.8 over 0.6 of Steiner's ANB). Both curves have a similar slope. The SN-GnGn angle shows high dispersion.

Table 02

Muscle	n	Mean age ± SD (years)
Male	24	19,5 ± 1,3
Female	38	20,2 ± 1,5
Total	62	20,0 ± 1,5

Table 02
Mean±SD of age (years) all individuals, distributed by gender, sample range (18-23 years) (n=62)
NS difference Male - Female

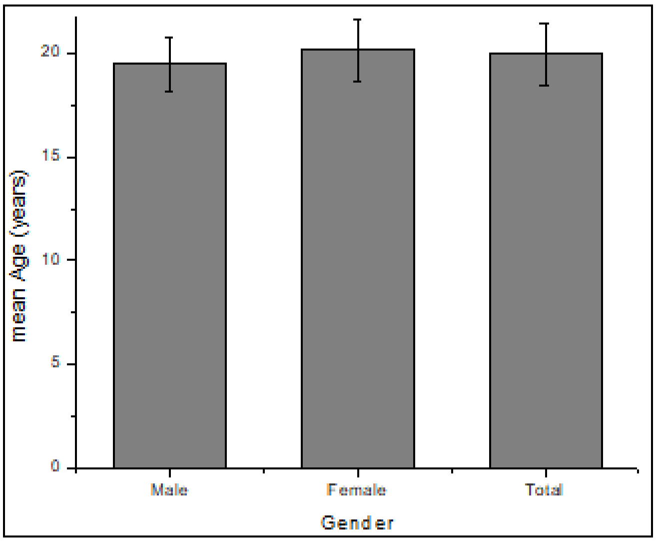

Figure 02

Figure 02
Mean±SD of age (years) all individuals, distributed by gender, sample range (18-23 years) (n=62)

Mean Amplitude EMG (µVolt)		
Muscle	Left Side	Right Side
Ms	235,0 ± 81,6*	224,5 ± 81,1**
Ta	175,4 ± 77,2	186,8 ± 81,0

Table 03
Mean ±SD. of voltage amplitude (µVolt) Ms and Ta muscles, all sample (n=62)
Paired t-test for Ms and Ta on both sides
* Statistically significant difference between Ms and Ta, left side p < 0,0001

**Statistically significant difference between Ms and Ta, right side $p < 0,0001$

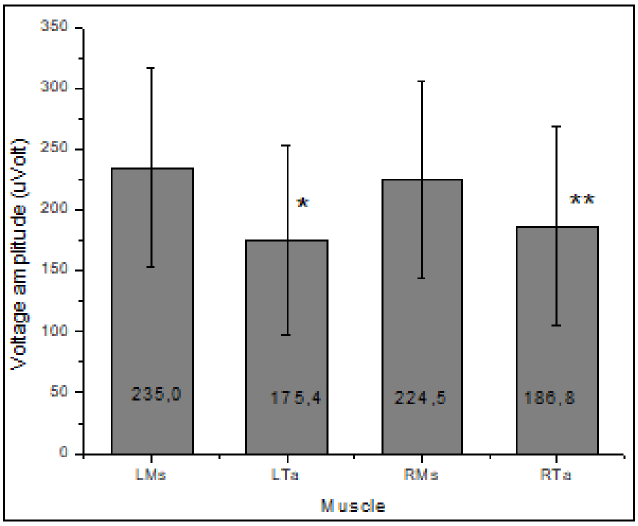

Figure 3

Figure 03
Mean ±SD. of voltage amplitude (µVolt) Ms and Ta muscles, all sample (n=62)

Table 04

		Muscle EMG (µVolt)			
		Ms		Ta	
Gender	n	Left	Right	Left	Right
Male	24	273,0 ± 79,6	257,4 ± 79,8	195,1 ± 72,5	229,6 ± 73,3
Female	38	211,0 ± 74,3	203,8 ± 75,8	163,0 ± 78,5	159,9 ± 74,4

Table 04
Mean ± SD of voltage amplitude (µVolt) by gender (M=24; F=38) all sample (n=62)

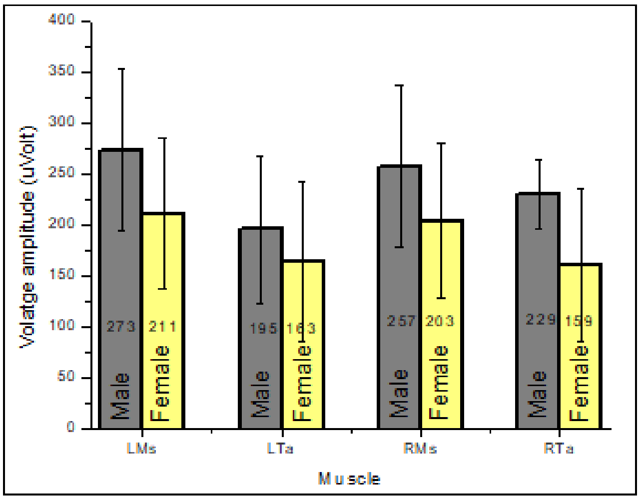

Figure 04

Figure 04
Mean ± SD of voltage amplitude (µVolt) by gender (M=24; F=38) all sample (n=62)

Table 05

		Muscle EMG (µVolt)			
		Ms		Ta	
Type	n	Left	Right	Left	Right
Normo	40	247,4 ± 69,4	237,4 ± 78,0	166,7 ± 75,6	178,5 ± 85,2
Disto	14	226,6 ± 93,6	207,9 ± 86,5	210,2 ± 85,4	202,6 ± 79,9
Mesio	8	187,4 ± 106,4	189,6 ± 81,2	158,1 ± 57,9	201,3 ± 61,3

Table 05
Mean voltage amplitude ± SD (µVolt) vs the craniofacial architecture (Skeletal type) according to Miralles, all sample (n=62)
The ANOVA test does not present differences in voltage amplitude between the different skeletal types for any muscle

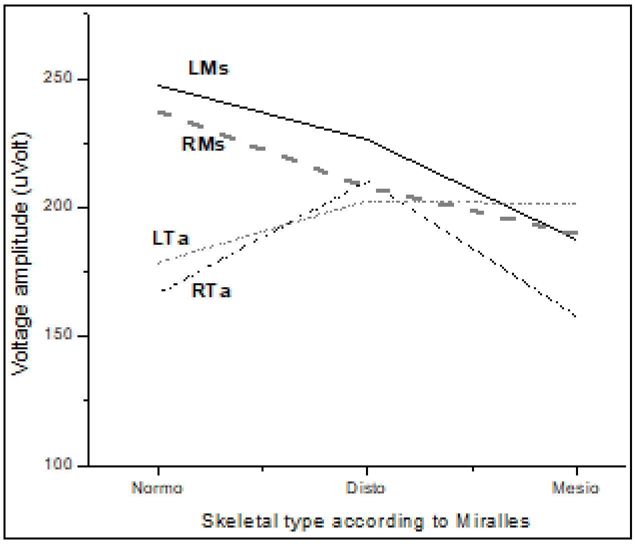

Figure 05

Figure 05
Mean voltage amplitude ± SD (µVolt) vs the craniofacial architecture (Skeletal type) according to Miralles, all sample (n = 62). In this figure, we clearly observe that the greatest difference in voltage between Ms and Ta are in the normo group. The Ms presents a descending linear voltage pattern for each skeletal type, normo, disto, and mesio, respectively.

Table 6

Ms/ Ta ratio all sample, n= 62	
Left Side	Right Side
1,51 ± 0,76	1,37 ± 0,63

Table 06
Mean±SD of Ms/Ta ratio, right and left side, all sample (n=62)
NS difference left-right side

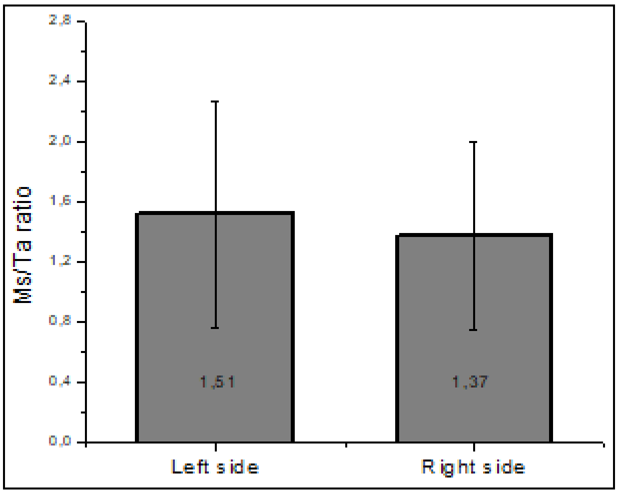

Figure 6

Figure 06
Mean±SD of Ms/Ta ratio, right and left side, all sample (n=62)

Table 7

		Ms/ Ta ratio	
Type	n	Left Side	Right Side
Normo	40	1,74 ± 0,83	1,54 ± 0,66
Disto	14	1,05 ± 0,28	1,12 ± 0,49
Mesio	8	51,16 ± 0,47	0,95 ± 0, 28

Table 07
Mean Ms/Ta ratio ± SD both sides, in the different skeletal types (n=62)

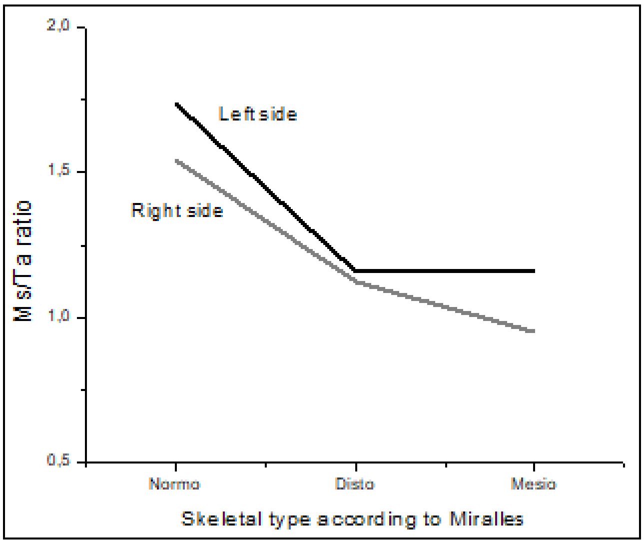

Figure 07

Figure 07 Mean Ms/Ta ratio ± SD both sides, in the different skeletal types (n=62). In this figure we clearly observe that the Ms/Ta ratio shows an ostensible dominance in the normo group. The Ms/Ta ratio presents a descending linear pattern for each skeletal type, normo, disto, and mesio, respectively.

* ANOVA, HSD Tukey Left side →**Normo** and **Disto** statistically significant difference
** ANOVA, HSD Tukey Right side →**Normo** and **Mesio** statistically significant difference

Table 8

		Left Side (%)		Right Side (%)	
Type	n	Domains Ms	Domains Ta	Domains Ms	Domains Ta
Normo	40	80,0	20,0	77,5	22,5
Disto	14	57,1	42,9	50,0	50,0
Mesio	8	50,0	50,0	37,5	62,5

Table 08
Mean percentage (%) of muscular dominance on both sides, in the different skeletal types (n = 62)

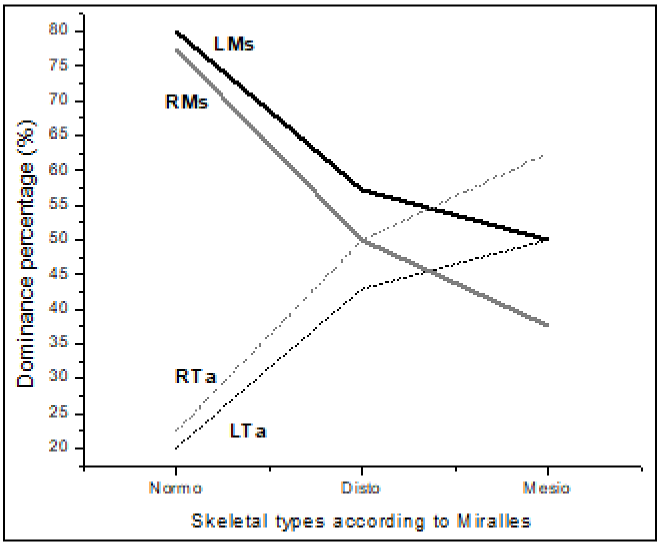

Figure 08

Figure 08 Mean percentage (%) of muscle dominance (Ms/Ta ratio >1) on both sides, in the different skeletal types (n = 62). This figure is really amazing, although it is presented in percentage; you can clearly see the synergy between the Ms and Ta muscles. It shows a very high domain difference for Ms in the normo group. (LMs= left masseter muscle, RMs= right masseter muscle, LTa=left temporal anterior muscle, RTa=right temporal anterior muscle)

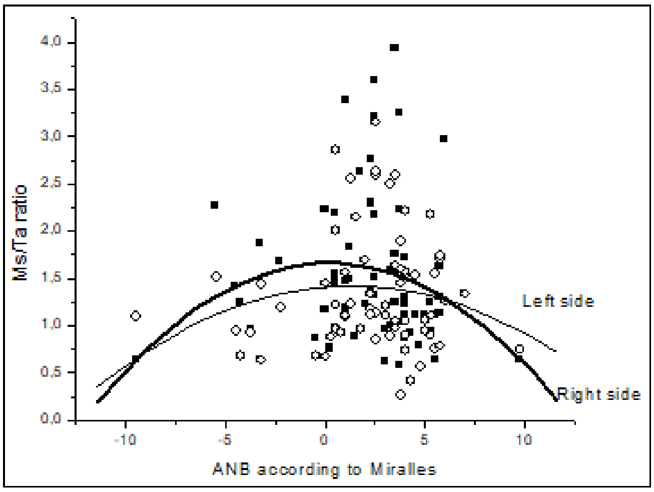

Figure 09

Figure 09
Polynomial regression Ms/Ta ratio vs ANB according to Miralles (n=62). This shows us that both sides (right and left) present a convex curve for the values of the Ms/Ta ratio with respect to the ANB angle corrected according to

Miralles. The largest number of individuals is distributed between the values of 0 to 5 of the ANB angle, that is, the skeletal type in which the Ms has a predominance in its work with respect to the Ta, compatible with the normo group. Thus, the normo group could represent a central tendency. It is interesting to note that the curve at the point of its maximum convexity (vertex) reaches an approximate value of 1,69 -1,44 for the Ms/Ta ratio left and right respectively, which would represent the ideal working relationship between Ms and Ta in the normo group.

Right curve $y= -0{,}008X^2+0{,}022X+1{,}44$
Left curve $y= -0{,}013X^2+0{,}018X+1{,}69$

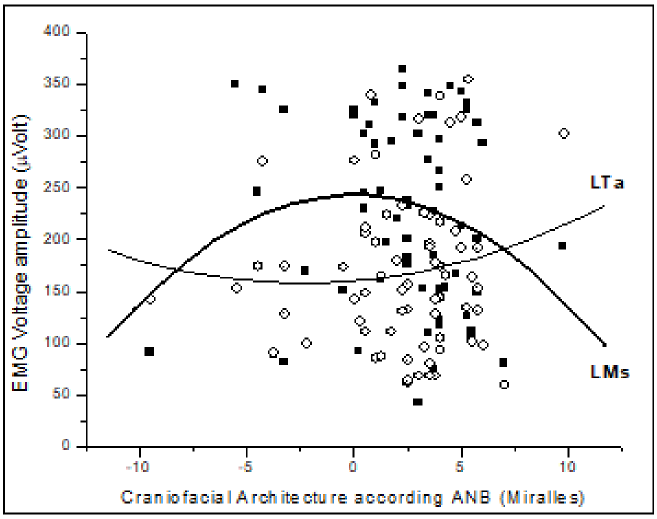

Figure 10

Figure 10
Voltage vs ANB according to Miralles (Left)
Polynomial regression of the voltage values for Ms and Ta. Both curves show axial symmetry. Ms/Ta ratio =1,53
Curve for Ta $y= 0{,}56X^2+2{,}81X+160{,}6$
Curve for Ms $y= -1{,}24X^2+2{,}89X+246{,}6$

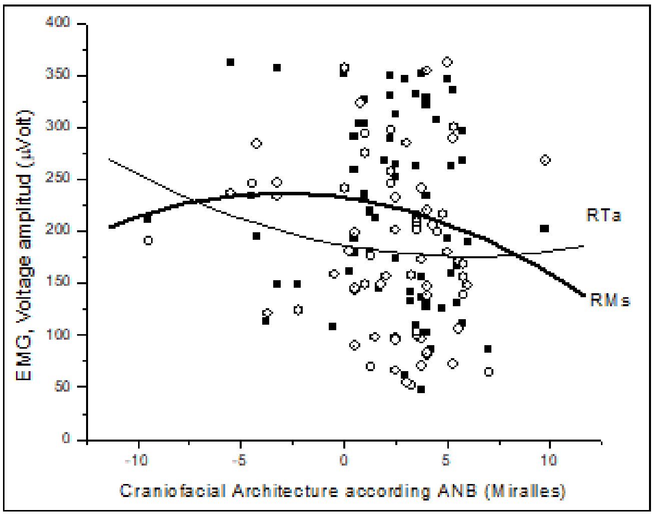

Figure 11

Figure 11
Voltage vs ANB according to Miralles (Right)
Polynomial regression of the voltage values for Ms and Ta. Both curves show axial symmetry. Ms/Ta ratio =1,26
Curve for Ta $y= 0{,}43X^2+2{,}37X+185{,}8$
Curve for Ms $y= -0{,}62X^2+0{,}07X+233{,}9$

4. Discussion

Undoubtedly, the ANB angle corrected by Miralles represents a reliable parameter to represent the different skeletal types. In our sample, we can see that it presents less dispersion than Steiner's ANB (Table and figure 1)

The mean age of the sample was 20 years (Table and figure 2). At this age, the muscles have their greatest functional potential, expressed in the maximum tension developed in the isometric contraction. The variables that contribute to determining this tension are mass, anabolic hormones, glycolytic enzymes, etc.[13, 14, 15, 16, 17,18]

From the EMG recordings, the voltage amplitude of the Ms and Ta muscles was determined, showing that Ms plays a leading role, with a statistically significant difference concerning to Ta, both ipsilateral and contralateral (Table and figure 3). This same trend is observed when analyzing them by gender, where the Ms muscle presented a greater amplitude of voltage (Table and figure 4). These observations agree with other authors[19, 20, 21, 22, 23, 24]

When analyzing the voltage amplitude in the different skeletal types according to Miralles, we observe that Ms presents the highest mean voltage in the normo group. This observation is essentially qualitative since we did not find a significant difference in the voltage amplitude with the mesio and disto groups (Table and figure 5). Here, we can notice that the Ms presents a normo, mesio, and disto descending voltage pattern, respectively. It can also be observed that the greatest voltage difference of Ms concerning Ta occurs in the normo group.

Several authors have related the craniofacial architecture with the electrical activity of the mandibular elevator muscles[3, 25, 26]. They have found no differences. The contribution of our work is to use the Ms/Ta ratio as a tool to study the synergy between these muscles. This ratio makes it possible to study the work synergy of both muscles, regardless of the voltage amplitude of each individual. We must say that our results do not find spectacular differences, but we do find trends that have an important qualitative relevance. Tecco[25] uses only the SN-GoGn angle to determine the skeletal type, based on mandibular divergence (in our sample, it presents a high dispersion). Melo[26] works with an index that is not radiographic, measuring only the width and height of the face. Regardless the methodology to determine the craniofacial shape, these authors did not venture to analyze the synergy between both muscles.

The Ms / Ta ratio (Table and figure 6) in the complete sample is close to 1.5-1.4, left and right respectively, and separated by skeleton types (Table and figure 7), the normo group shows a relationship close to (1.7-1.5) that is, the role of the Ms is reinforced. To corroborate this phenomenon, all the Ms / Ta ratios greater than 1 were separated, that is, with a predominance of Ms (Table and figure 8). Here it is observed that the predominance of Ms reaches almost 80% in the normo group.

Linear polynomial voltage regressions are also helpful in establishing the function of Ms concerning Ta. The Ms/Ta ratio vs ANB (Figure 09) shows the vertex of each curve 1.7–1.4, respectively compatible with the normo group. Voltage vs ANB (Figures 10 and 11) show an axial symmetry whose vertex is 1.5–1.4, left and right, respectively, compatible with the normo group.

Mean and regressions lead us to similar magnitudes of the Ms/Ta ratio, in which Ms is predominant in the normo group.

Why does Ms present this predominance?

This could be because Ms has a kind of functional reserve. Van Eijden[27]describes a force index for each mandibular elevator muscle that is determined from the cross-sectional area and the length of the muscle fiber. This index is higher for Ms

According to Farella[8], we can say that the stomatognathic system is redundant, that is, each muscle will be able to respond to the infinite biomechanical requirements to achieve homeostasis. Each muscle will occupy its reserve potential in relation to its requirements in pursuit of function. The Ms mainly provides the force, and the Ta the stabilization in the normo group, both being antigravitational.

The relationship between the musculature and the bone structure is a biunivocal mathematical function, that is, the bone influences the musculature and the musculature influences the bone, both structures having high plasticity, undergoing constant change seeking a metastable balance[28, 29, 30]

5. Conclusion

By distributing all sample in skeletal types according to the Miralles corrected ANB angle, the synergistic working relationship between Ms and Ta, according to the Ms/Ta ratio is approximately 1.5 in the normo group.

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