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Relationship between the inclination of the coronoid process of the mandible and the electromyographic activity of the temporal muscle in skeletal Class I and II individuals

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Abstract: **The aim of this study was to verify the relationship between the inclination of the coronoid process of the mandible, and electromyographic activity of the anterior part of the temporal muscle in skeletal Class I and II individuals. Forty-seven volunteers (mean age 24.5 ± 3.9 years) were subdivided into two groups, according to angle ANB: Class I (n = 25) and II (n = 22). Two radiographic examinations were performed; one lateral cephalogram to measure angle ANB, and one frontal cephalogram to measure the inclination of the coronoid process. Electromyographic (EMG) examination of the anterior part of the subjects' temporal muscles was performed. Statistical analysis of the data showed that Class II individuals presented lower electromyographic activity of the anterior part of the temporal muscle. Based on the results obtained, it was concluded that the skeletal classes analyzed had no influence on the inclination of the coronoid process. The inclination of the coronoid process was not influenced by the electromyographic activity of the anterior part of the temporal muscle in Class I and II individuals; however, the lower electromyographic activity of the anterior part of the temporal muscle could be influenced by the skeletal class in Class II individuals.**

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Introduction

The relationship between bone morphology and muscular function has been studied extensively since the XIXth century. The interaction between these two factors was determined by the theory of Wolff (1), who affirmed that bone morphology and architecture depend on the tension applied to the bone by the muscle inserted in it. The musculoskeletal system in the craniofacial region is complex due to this morpho-functional relationship (2). The mandible is formed by distinct morphogenetic and functional units, such as the mandibular body, alveolar process, gonial region, condyle, and coronoid process (3).

The largest portion of the temporal muscle is inserted in the middle part of the coronoid process of the mandible, and these elements show morpho-functional dependence, right from the embryonic period in human beings (2). Differentiation and development of the coronoid process of the mandible during this period are linked to the differentiation of the temporal muscle. Observation of regression or complete absence of this process after surgical removal of the temporalis in newborn rats, suggests that this relationship of dependency persists during the postnatal period (4,5). These findings indicate that the growth and morphology of the coronoid process of the mandible in this period is also completely dependent on the presence of a functioning temporal muscle. In addition to the reduction in size, alterations in the inclination of this process were also observed after removal of the temporal muscle in cats and dogs (6,7).

When elevating the mandible, the anterior part of the temporal muscle draws the coronoid process upward and laterally, because of the direction of contraction of its fibers (8). It has also been clarified that the tension exerted by this muscle can distinctly influence the growth and morphology of the coronoid process in different skeletal classes (9).

Differences between the growth patterns of Class I and II individuals could be explained by alterations in the inclination or spatial position of the mandibular ramus, which can change the inclination of the coronoid process located in its superior portion (11).

Inclination of the coronoid process in the lateral direction has been analyzed in different skeletal classes. Class II individuals did not present a significant variation in this inclination, indicating uniformity of the group with regard to this parameter (9).

Electromyographic activity (EMG) of the anterior part of the temporal muscle was analyzed in individuals of different skeletal classes. Comparison between Class I and II subjects showed that during maximum voluntary isometric and simultaneous bilateral contraction, the bite force and temporal muscle activity were lower in Class II individuals, indicating that the force of muscular contraction is lower in this group. At rest, the electromyographic record of this muscle was higher in the Class II group (12-15).

The aim of the present study was to verify whether there was a possible relationship between the inclination of the coronoid process of the mandible and electromyographic activity of the anterior part of the temporal muscle in skeletal Class I and II individuals.

Materials and Methods

Sample selection

The study population consisted of 47 volunteers (18 women and 29 men, mean age 24.5 ± 3.9 years), who were subdivided into two groups, according to angle ANB (16): Class I (n = 25) and II (n = 22). Volunteers who satisfied the following criteria were selected: complete permanent dentition; absence of previous orthodontic and orthopedic treatment or history of orthognathic surgery; absence of signs and symptoms of temporomandibular dysfunction; absence of anterior and posterior reverse articulation (crossbite) or anterior open occlusal relationship (open bite); and no use of analgesic, antiinflammatory or myorelaxant medications during the experimental period. The research was approved by the Ethics Committee of the State University of Campinas (UNICAMP).

Radiographic examination

Lateral and frontal cephalograms were taken for the purpose of determining the skeletal class and the values relative to inclination of the coronoid processes, respectively. The radiographic images were obtained using a Quint Sectograph Linear Tomography Unit (Denar Corp., Anaheim, CA), belonging to the Radiology area of UNICAMP (Piracicaba, Brazil).

For the skeletal classification, the subjects were subdivided into two groups, based on the values of angle ANB (16): Class I ($0° \leq ANB \leq 4°$) and Class II ($ANB > 4°$).

To measure the inclination of the coronoid process on the frontal cephalograms, the image of the most anterior point of the frontozygomatic suture and the image of the medial edge of the coronoid process were used as references. The most anterior point of the frontozygomatic suture was marked bilaterally, and a horizontal line joining these two points was traced, generating a plane of reference. A second line was traced bilaterally, tangential to the image of the medial edge of the coronoid process, crossing the first line traced. The angle formed between the two traced lines was measured bilaterally, and the inclination of the coronoid process was thus recorded by means of the values expressed by this angle (Figs. 1 (17) and 2).

All the measurements were made by means of an acetate sheet fixed to the radiographs, by the same observer, on three different days, with an interval of one week between measurements.

Electromyographic examination

To record the electromyographic signal, the Myosystem I appliance (Prossecon, Uberlândia, Brazil) with 12 channels was used, 8 for the electromyograph and 4 for supporting channels. The electromyographic signals were conditioned through programmable instrumentation amplifiers with software and 20-Hz high pass analog filters and 500-Hz low pass filters. Digitization was performed at a sampling frequency of 4,000 Hz, with 12-bit resolution and simultaneous sampling of the signals. Signal visualization and processing were performed with Myosystem I version 2.22 software (Prossecon).

The electromyographic examinations were performed in the Electromyography Laboratory of UNICAMP (Piracicaba, Brazil), in accordance with the protocol of this laboratory (18). To capture the action potentials of the muscles, simple differential active electrodes (Lynx

Tecnologia Eletrônica Ltda., Uberlândia, Brazil) were positioned on the skin in the region corresponding to the location of the muscular venter of the anterior part of the temporal muscle (Fig. 3). A reference electrode, composed of stainless steel and coated with water-based gel at its interface, was placed in the region corresponding to the manubrium of the sternal bone to eliminate acquisition noises.

The electromyographic examination was performed with the subjects seated in an upright position with the Frankfurt Horizontal Plane parallel to the ground, without visualizing the records on the computer monitor.

The electromyographic records were made during simultaneous bilateral contraction, in accordance with the following protocol:

Simultaneous bilateral contraction for 10 seconds with Parafilm M® (American National Can TM, Chicago, IL, USA): this acquisition was made to the rhythm of a metronome calibrated to 60 cycles (Figs. 4 and 5).

This task was performed three times in the same session with an interval of one minute between recordings.

The software Myosystem Br-1 version 2.22 was used to process the electromyographic data. The raw myographic signal was used to derive the electromyographic amplitude values obtained through the calculation of the integral electromyographic values (4th order Butterworth and 10 Hz). The integral electromyographic values were normalized by the mean value of the electromyographic

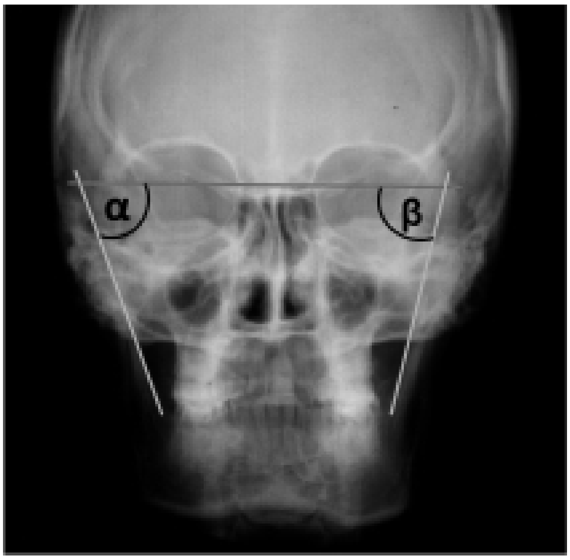

Fig. 2 Diagrammatic representation of the measurement of the inclination of the coronoid process on the radiograph on the right (angle α) and left sides (angle β).

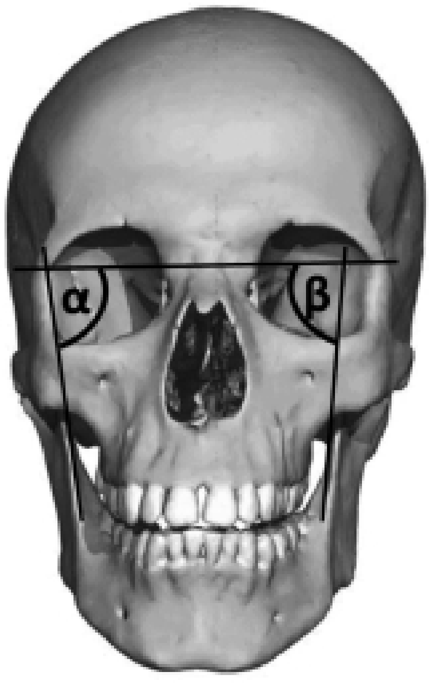

Fig. 1 Diagrammatic representation of the measurement of the inclination of the coronoid process on the cranium on the right (angle α) and left sides (angle β). Source: Kindersley (15).

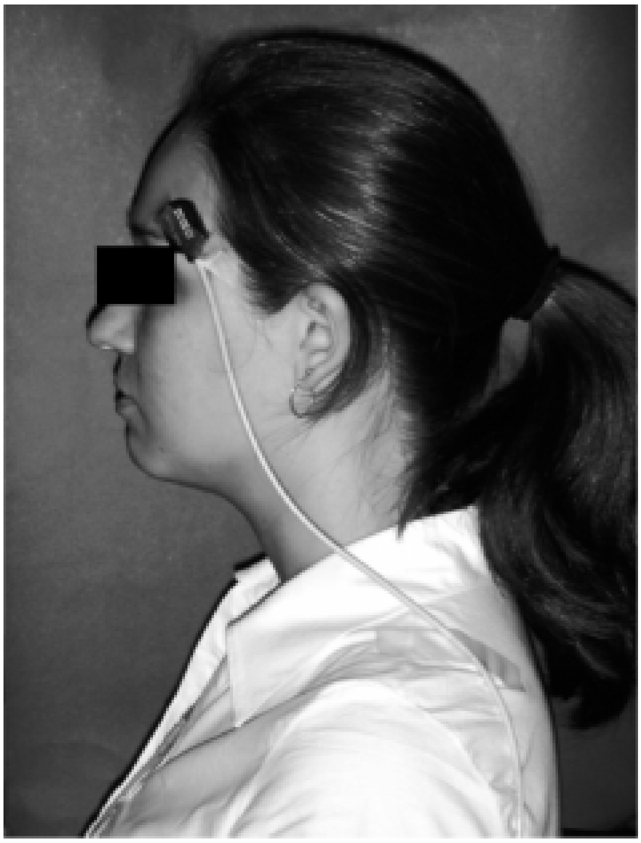

Fig. 3 Photograph of the electrodes in place.

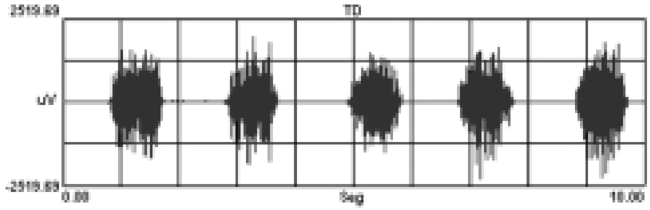

Fig. 4 Electromyographic signal of anterior part of the right temporal muscle

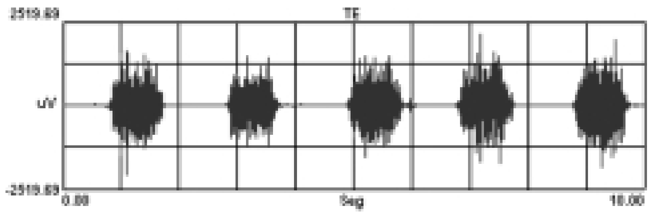

Fig. 5 Electromyographic signal of anterior part of the left temporal muscle

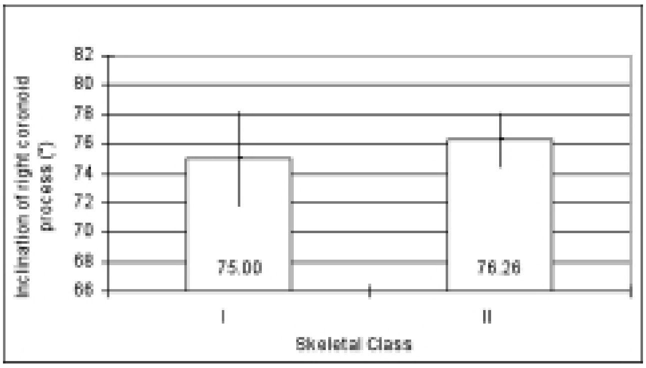

Fig. 6 Means and confidence intervals (95%) of the inclination of the right coronoid process in Class I and II.

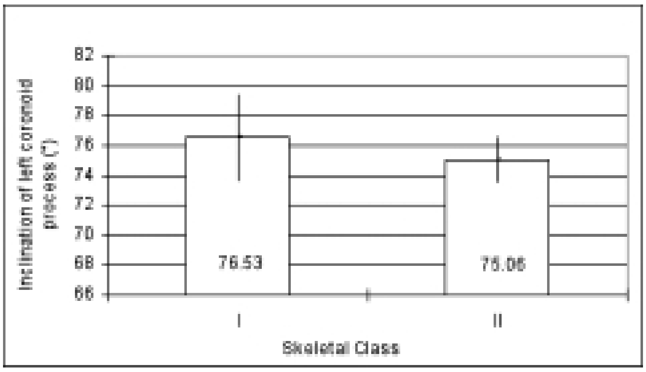

Fig. 7 Means and confidence intervals (95%) of the inclination of the left coronoid process in Class I and II.

amplitude, which presented a lower coefficient of variation.

The following statistical tests were used: analysis of variance (one-way ANOVA), the Pearson test, and the coefficient of intra-class correlation (ICC) (19); significance was determined at a level of 5%. The mean, standard deviation and 95% confidence interval limits were used to describe basic characteristics. The ICC values were above 0.95 for all measurements.

Results

The relationship between the inclination of the coronoid process and skeletal class was negative for both groups analyzed ($P > 0.05$), indicating that there was no correlation between these two factors. The mean values for the two groups were similar, and the intra-class variability was significant (Figs. 6 and 7).

The relationship between electromyographic activity

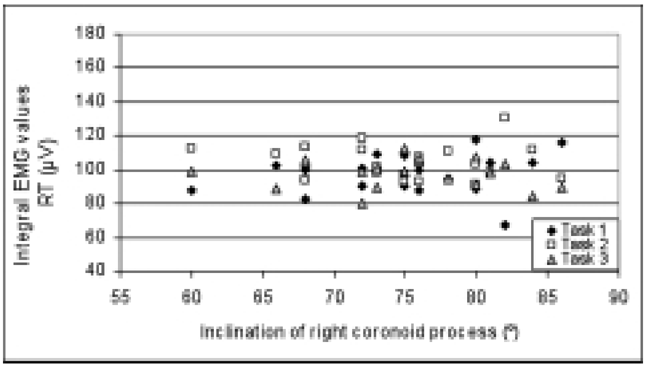

Fig. 8 Association of the integral electromyographic (EMG) values of the right temporal muscle (RT) in the three task performances with the inclination of the right coronoid process in skeletal Class I.

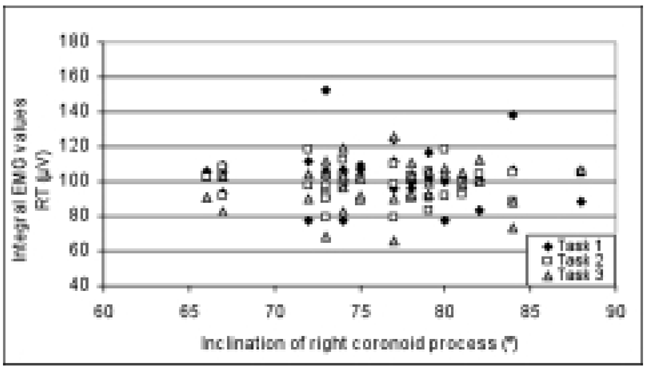

Fig. 9 Association of the integral electromyographic (EMG) values of the right temporal muscle (RT) in the three task performances with the inclination of the right coronoid process in skeletal Class II.

of the anterior part of the temporal muscle and inclination of the coronoid process was not statistically significant in the two groups studied ($P > 0.05$), indicating that in these two groups there is no correlation between these two factors (Figs. 8-11).

Class II individuals have lower electromyographic activity of the anterior part of the temporal muscle ($P < 0.05$) compared to Class I individuals (Figs. 12 and 13).

Discussion

Alterations in muscular tension can influence the morphology and internal architecture of the already developed bone. Its structure and shape are altered in order to adapt to its new function (1). From the phylogenetic point of view, it is accepted that bone morphology reflects muscular function, and a variation in the mandibular morphology among species reflects a variation in their requirements (20).

The mandible undergoes morphological and spatial alterations during the growth of the craniofacial complex, and these alterations vary, depending on the maxillo-mandibular relationship of the individual (9,11,21). Analysis of the correlation between the inclination of the coronoid process and activity of the anterior part of the temporal muscle in different skeletal classes shows the influence of the alterations inherent to these classes, as undergone by the mandible, on the morpho-functional relationship between the coronoid process and the temporal muscle.

The negative relationship between inclination of the coronoid process in both skeletal classes analyzed and the intra-group variability observed in this study suggest that factors other than the skeletal class may influence the inclination of the coronoid process.

Although the relationship between the morphology of

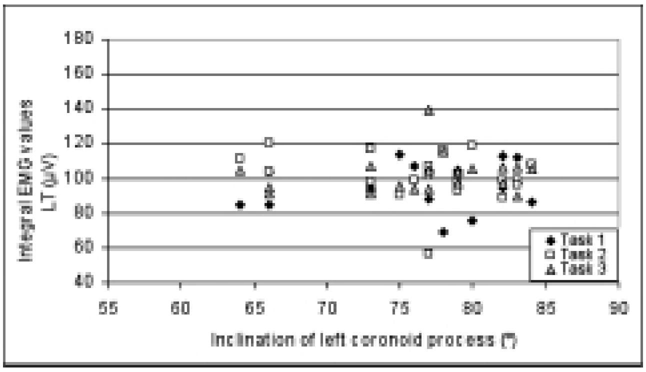

Fig. 10 Association of the integral electromyographic values (EMG) of the left temporal muscle (LT) in the three task performances with the inclination of the left coronoid process in skeletal Class I.

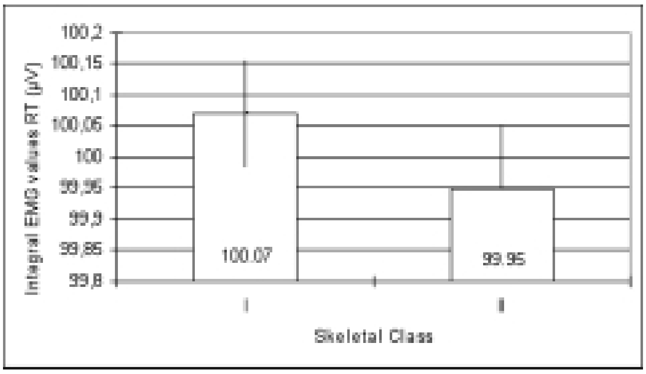

Fig. 12 Means and confidence intervals (95%) of the integral electromyographic values of the right temporalis (TD) in Class I and II.

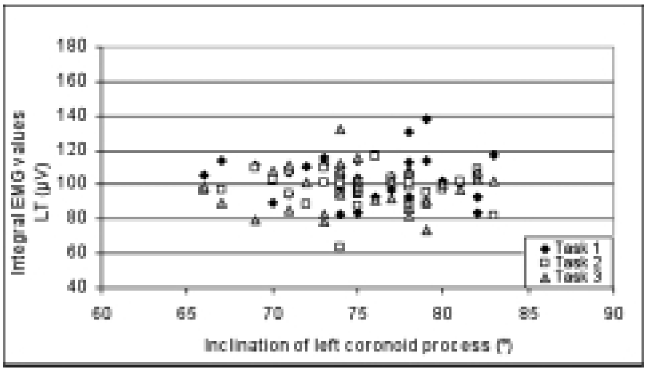

Fig. 11 Association of the integral electromyographic values (EMG) of the left temporal muscle (LT) in the three task performances with the inclination of the left coronoid process in skeletal Class II.

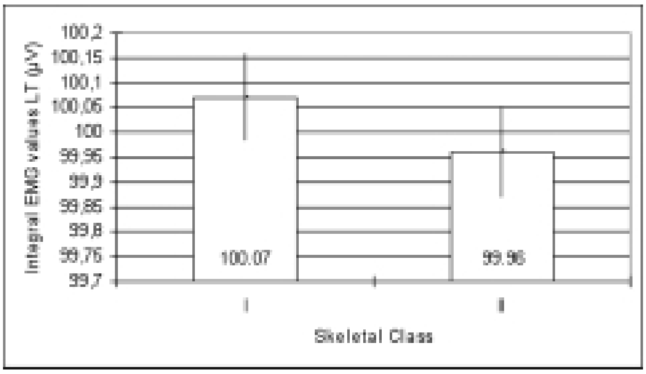

Fig. 13 Means and confidence intervals (95%) of the integral electromyographic values of the left temporalis (TE) in Class I and II.

the coronoid process and tension exerted by the temporal muscle has been described previously (4-7,20), several studies have demonstrated that muscular tension in isolation is not sufficient to alter this process morphologically. Resection of the motor portion of the trigeminal nerve, which is responsible for the innervation of the temporal muscle, did not result in atrophy of the coronoid process, due to auxiliary innervation mechanisms of the muscle (22). Vascularization of the coronoid process region has also been pointed out as a factor responsible for maintaining the size and morphology of the coronoid process, based on research that compared this process in pigs with and without removal of the blood supply. Reduction or elimination of muscular tension caused no morphologic alteration in the coronoid process of the animals whose blood vascularization in the region was maintained. The results of this research suggest that alterations in muscular activity alone do not interfere in the morphology of the coronoid process. This could explain the absence of differences in the inclination of this process in the skeletal classes analyzed, even though they presented different electromyographic patterns.

The face and cranium represent a complex mixture of counterbalanced regional imbalances. Class I individuals have a prominent tendency towards skeletal Class II or III, that is, they present morphological characteristics inherent to one of these classes. The difference between Class I and Class II individuals, for example, is the extent of the imbalances and the number and extent of the compensatory characteristics. If the compensatory characteristics are adequate, the result is the relationship of skeletal Class I, and should these characteristic fail partially or completely, the result is a maxillomandibular discrepancy that could vary from slight to severe (11). Therefore, the extent of the imbalances and compensatory characteristics may vary in the same skeletal class, explaining the variability in the inclination of the coronoid process found in the present study.

Based on the results, it is assumed that the inclination of the coronoid process, due to its variability in the classes analyzed, cannot be used to determine skeletal class, making their use unfeasible as a diagnostic aid in skeletal Class II individuals.

Analysis of the relationship between electromyographic activity of the anterior part of the temporal muscle and skeletal class demonstrated that, in Class II individuals, this activity was significantly lower compared to Class I individuals. These results are in agreement with previous studies which affirmed that masticatory efficiency, bite force and electromyographic activity of the temporal muscle during simultaneous bilateral contraction and maximum voluntary isometric contraction was lower in Class II individuals (12-15).

Occlusal stability is related to muscular performance, and represents the functional equilibrium of the stomatognathic system. Occlusal alterations, such as the presence of premature contact, may alter this equilibrium, and consequently, muscular function. Thus, individuals with occlusal stability presented shorter muscular contraction time and higher electromyographic potentials during mastication than individuals with compromised occlusal stability (24). Electromyographic alterations express proprioceptive disorders in the activity of the masticatory muscles, and in Class II individuals, muscular alterations may contribute to the severity of characteristic occlusal alterations, inhibiting possible mechanisms of occlusal equilibrium (8). Irregular masticatory patterns observed in Class II individuals reflect this occlusal imbalance (25).

The masticatory muscles function as a unit during mandibular movements, and patients with mandibular retrognathism have different patterns of muscular recruitment when compared with normal individuals. Differences in mandibular position and rotation inherent to skeletal classes are factors capable of determining a change in the axis of muscular action with a reduction in the gravitational component, and consequent reduction in the neuromuscular stimulation of the elevator muscles. These factors may reflexively cause a decrease in the electromyographic activity of these muscles, which could explain the lower activity found in the anterior portion of the temporal muscle in Class II individuals (14).

The variability found in the values of the inclination of the coronoid process in Class II individuals did not interfere in the determination of lower electromyographic activity in this muscle, that is, these two factors are independent. Electromyographic activity of the anterior part of the temporal muscle is lower in these individuals, but its influence is not sufficient to determine an alteration in the inclination of the coronoid process, which may justify the variability of this inclination.

Characterization of the electromyographic profile of Class II individuals, and the differences found between the two classes analyzed, enables the use of electromyographic examination as an auxiliary aid in the diagnosis of these individuals.

Based on the results of the present study, it was concluded that the tension exerted by the anterior portion of the temporal muscle is insufficient to influence the inclination of the coronoid process in different skeletal classes, showing that this morpho-functional relationship is not exclusively due to these two factors. Although there are differences between the electromyographic activities of the temporal muscle in the two skeletal classes analyzed, it is probable that factors such as accessory innervation and vascularization of the region may maintain the form and size of the coronoid process, being preponderant in muscular tension. Measurement of the coronoid process inclination may not be a useful tool for characterizing skeletal class, since no differences were found between the classes. Electromyographic examination for analyzing the activity of the anterior portion of the temporal muscle may aid in the diagnosis of skeletal Class II individuals.

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