

# Orthodontic-Surgical Treatment: Electromyographic and Electrognatographic Evaluation with Three Electromyographic Instruments

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## 1. Introduction

The introduction of electromyography in orthodontics determined the beginning of some studies about neuromuscular system's response to physiological and pathological oral alterations and the effect of masticatory muscles on facial morphology.<sup>1,2</sup>

Experimental studies demonstrated that a real change in muscular function causes morphology alterations.<sup>1</sup>

Several studies in literature, from Watt e Williams, who studied in 1951 the effect of masticatory bolus on mouse maxillary and mandibular development, to Avis who in 1961 showed how muscular function was important for gonial region development, connect morphology and function.<sup>3,4</sup>

In the last years masticatory muscles response to dento-skeletal discrepancies, alterations of breathing, swelling, speech and posture, to functional therapies, implant supported therapy and prosthetic rehabilitation has been studied.<sup>5</sup>

The definition of occlusion changed in time and it is now not based on mechanics theory but it includes functional aspects.<sup>6-10</sup>

In literature different positions about the compensatory muscular equilibrium in skeletal discrepancies can be found.

A correct diagnosis is based not only on clinical and radiographic examination, but it is also important to analyze informations obtaining from neuromuscular system.<sup>2</sup>

Knowing muscular action allows to obtain a correct diagnosis, prognosis and treatment planning and helps in avoiding failures.<sup>2</sup>

Electromyography allows to evaluate neuromuscular system and equilibrium, mandibular movements alterations and the effects of orthodontic therapy on stomathognathic system.<sup>7</sup>

Nowadays, different kind of electromyographic instruments are available, each of them constructed following specific protocols and with different aims.

It is well known that facial growth is influenced by both genetic and extrinsic factors and that muscle function exercises an important influence both on growth and on craniofacial morphology.<sup>11</sup>

Orthodontic-surgical treatment was born in order to reposition the skeletal bone basis in a normal position in subjects where their position was not correct.

Modifications of the facial skeleton have consequences on all masticatory muscles, even if the majority of studies in literature is referred to masseter and temporal muscle because these muscles are easy to study with surface analysis.<sup>12,13</sup>

Many studies in literature have tried to highlight the effect of orthognathic surgery on neuromuscular system.

Most authors explained that a first modification of the neuromuscular system can be seen during presurgical orthodontic phase besides Precious and Skulsky showed that maximum bite force is reduced after the beginning of the fixed orthodontic therapy.<sup>14</sup>

Also Dean, Throckmorton and Sinn showed that patients in orthodontic-surgical treatment were able to express a minor bite force in presurgical phase if compared to the one they could express before starting therapy.<sup>15</sup> Thomas et al affirmed that there was a reduction of the maximum mandibular opening movement and of its movement in vertical sense before and after the orthodontic phase, connected to the same protective mechanism which explains the maximum bite force reduction.<sup>16</sup> Moreover, during mandibular movements, there was a painful action of brackets on teeth and of orthodontics thread in soft tissues of cheek and lips, which limited the patient in executing normal movements.

Furthermore the presurgical orthodontic treatment contributed to reduce the possibility of mandibular movements and the consequent reduction of occlusal contacts, increasing interferences between dental elements with reduction of mandibular excursion.<sup>17-21</sup>

Many studies analyzed the modifications consequent to a surgical reposition of bone basis.

Finn, Throckmorton, Bell and Legan did not show an increase of the maximum muscular force post surgical of muscular advancement and maxillary retroposition.<sup>22</sup>

Also Van den Braber et al affirmed that oral function is not influenced by mandibular advancement surgery.<sup>23</sup> On the contrary round Athanasiou had discovered that surgical correction of maxillary prognathism increased the intensity of occlusal contacts and hypothesized that such harmonization of the dentofacial skeleton would influence the neuromuscular system.<sup>24</sup> Kobayashi et al affirmed that the steadiness of the masticatory rhythm is improved by orthognathic surgery in subjects with mandibular prognathism.<sup>25</sup>

A Tatsumi et al study has proved that, after the surgical orthodontic treatment, an aesthetic improvement, a reduction of the duration of the masticatory cycle and an improvement of the activity of masticatory muscles are obtained.<sup>26</sup> These advantages suggest that patients who undergo this operation gain a functional readjustment in post-surgical phase Proffit reported a maximum bite force increase in some patients in post-surgical phase. Unfortunately, this increase was not an improvement compared to the beginning of the therapy, but a return to initial conditions before starting orthodontic therapy.

These changes underwent a huge variability, due to the different sensibility of patients on dental, muscular and articulation level. Besides, to explain the obtained results, the patient's will and emotional stress were probably more important than muscular advantages and biomechanics.

The majority of studies have analyzed only a single phase of the treatment.

The aim of this work consists in the evaluation of the neuromuscular functionality and mandibular kinesiology in 100 patients undergoing orthodontic surgical treatment.

Values obtained analyzing masticatory muscles in patients with important skeletal discrepancies using three different kind of electromyographic instruments were compared.

## 2. Material and methods

### *Study group*

All patients during the orthognathic surgery treatment at the Orthodontic Section of the department of Surgical, Reconstructive and Diagnostic Sciences have been submitted to classical instrumental exams, clinical and radiographic, and also periodically to an electromyographic and electrokinesiographic evaluation.

The analyzed sample is composed of 100 patients [44 men and 56 women] at the end of growth.

Criteria followed in selecting patients were:

- adult age
- the presence of a dento-skeletal discrepancy
- the necessity of a combined orthodontic-surgical treatment

The three criteria had to coexist at the same time.

The electromiographic and the kinesiographic examination have been performed on orthodontic-surgical patients:

- during the first visit
- before the start of the orthodontic therapy
- during the presurgical phase of orthodontic bimonthly
- every month from three months before the surgical operation to three months after
- the day before the surgical operation
- during the intermaxillary fixation
- at the removal of the fixation
- during post-surgical orthodontic phase with the same terms (times) of pre-surgical orthodontic phase.
- at the removal of surgical bite
- at the end of the treatment
- during follow up

In every phase, patients executed two electromyographic examinations through two different electromyograms.

Before every tests clinicians asked patients if they had dental or muscular pain in order to avoid errors.

The electromyographic instruments used in the work were the electromiography Freely [De Gotzen - Legnano - Italia], the electromiography and electrognatography K6-I EMG [Myotronics - Tukwila WA - USA] and the electromiography and electrognatography Biopak [Bioresearch Associate -USA].

The muscles considered have been the anterior temporal muscle and the masseter muscle.

In order to compare the data versus the healthy population, a control group has been settled. This group consists of patients in adult age, skeletal class I, with absence of temporal-mandibular problems and absence of a previous orthodontic or a combined orthodontic-surgical treatment.

Finally a statistic test evaluation has been performed with t test and ANOVA test.

### *Methods*

The muscles considered in the electromyographic evaluation have been:

- the anterior temporal muscle
- the masseter muscle in its superficial component

- The patient was in a special totally undisturbed and noiseless room. He sat on a rigid stool with an adjustable height, so to have the angle between thigh and leg of 90° (degrees).

The legs were parallel to the floor, the back upright and the gaze beyond the horizon.

Head was in natural head position.

After skin cleaning with a wad soaked in Neoxinal (clorexidina 0,5% in hydroalcoholic solution with no less than 70% of alcohol) to reduce forehead impedance and facilitate adhesiveness, electrodes were positioned.

The electrodes position was the same for both the equipments and unmodified with the use of either equipment.

The electrodes were disposable and bipolar, Duo Trade Silver/ Silver Chloride previously gelled. The interpolar distance was of  $21 \pm 1$  mm, each pole was circular, 10 mm in diameter.

The bipolar electrodes were positioned according to the following procedure:

- for the masseter muscle: the operator, behind a seated subject, palpates the belly of the muscle while the patient clenches his teeth. To position the bipolar electrode parallel to the muscle fibres, the line connecting the commissura labiorum oris with the tragus is ideally drawn as well as the line connecting the the lateral part of eye and gonion.

The position of the electrode makes the superior pole in the intersection point between the two lines and its major axis is along the esocanto-goniac line.

- for the temporal muscle: the muscle is palpated while clenching thus localizing the major axis of the zygomatic process of the frontal bone.

The bipolar electrode is positioned along the line parallel to this process passing about a transverse finger posteriorly and superiorly to it; this way the electrode will be parallel to the muscle fibres and positioned more or less superficially in comparison with the frontoparietal suture.

A grounding electrode (monopolar) is positioned on a silent muscular area of the forehead. Such electrode may be positioned on the volar surface of the forearm, considered a possible silent area. The electromyographic instrument utilises such electrode as a reference eliminating part of all background noises. So, it can be considered a first filter to abolish interferences.

The tests with the two instruments are executed consecutively without taking off electrodes. An average of data collected by each patient was then done at every therapeutic phase.

### 3. Results

At the beginning of the treatment the patients present a compensatory equilibrium to malocclusion. During presurgical orthodontic phase electromyographic and electrognatographic values become worse and they continue worsening after surgical intervention. They improve in post surgical orthodontic phase.

After the removal of the orthodontic appliance, electromyographic values improve until they reach optimal values. Mandibular movement rehabilitation is satisfactory and constant also if it needs more time than muscular rehabilitation. At the end of the treatment maximum mandibular opening is still less than the preoperatory one. (fig. 1-14)

The three instruments have been planned through different principles, they are based on different ideas and they have different aims.

The different types does not avoid the possibility to obtain complementary data, not even in numeric values, but in their meaning. (fig. 15-21)

Data obtained from all instruments gives to the clinicians the same information, also if they are expressed in different ways.

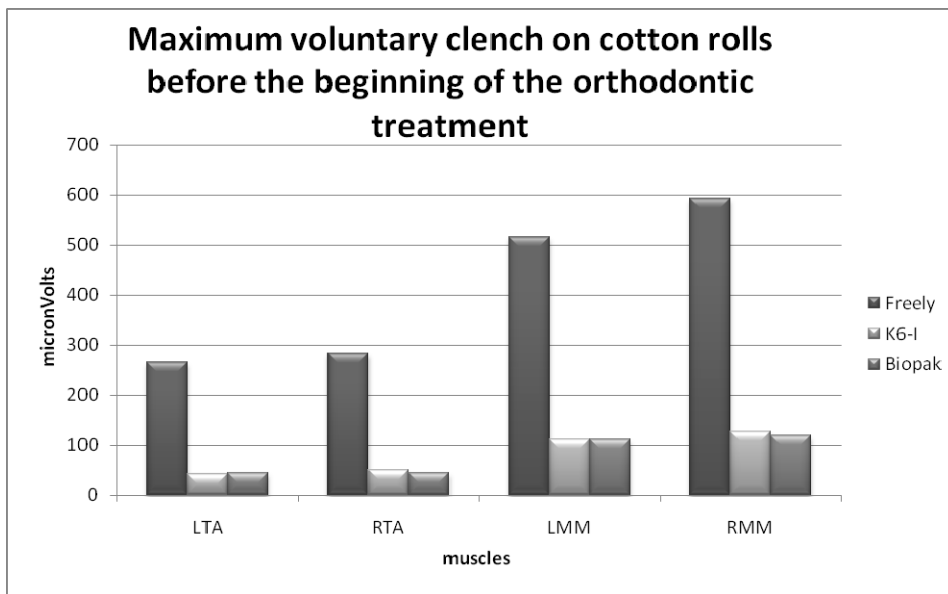


Fig. 1.

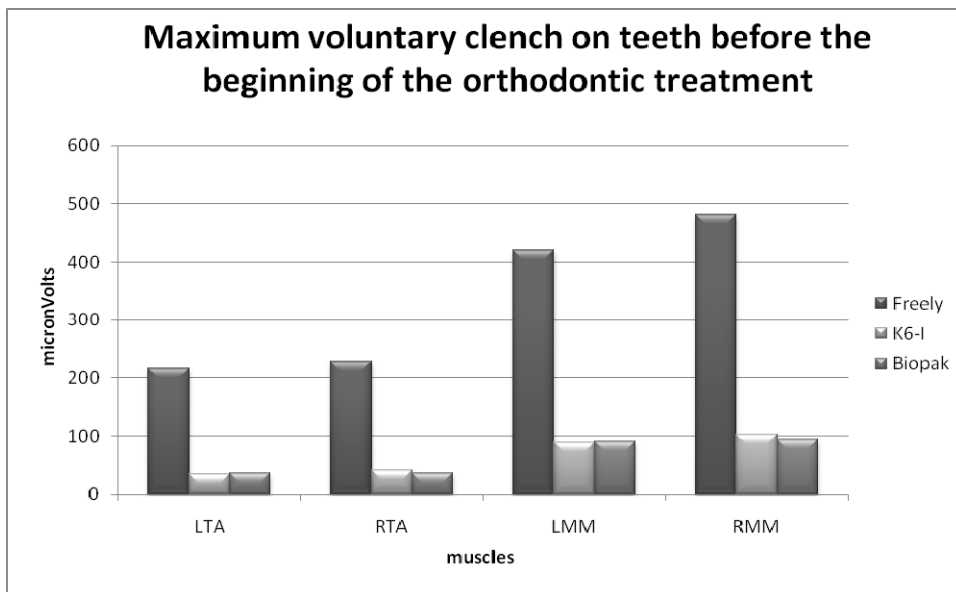


Fig. 2.

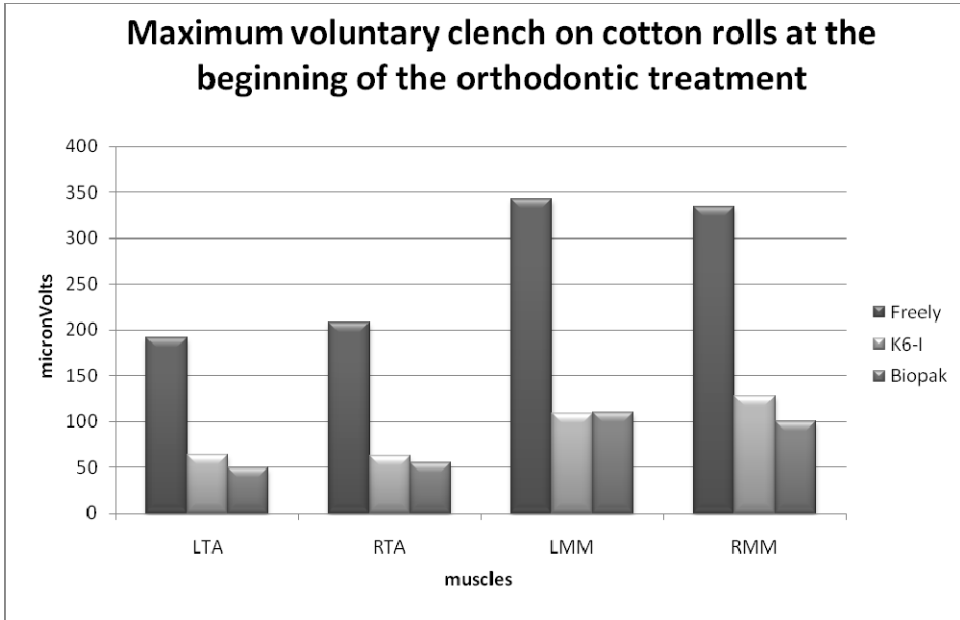


Fig. 3.

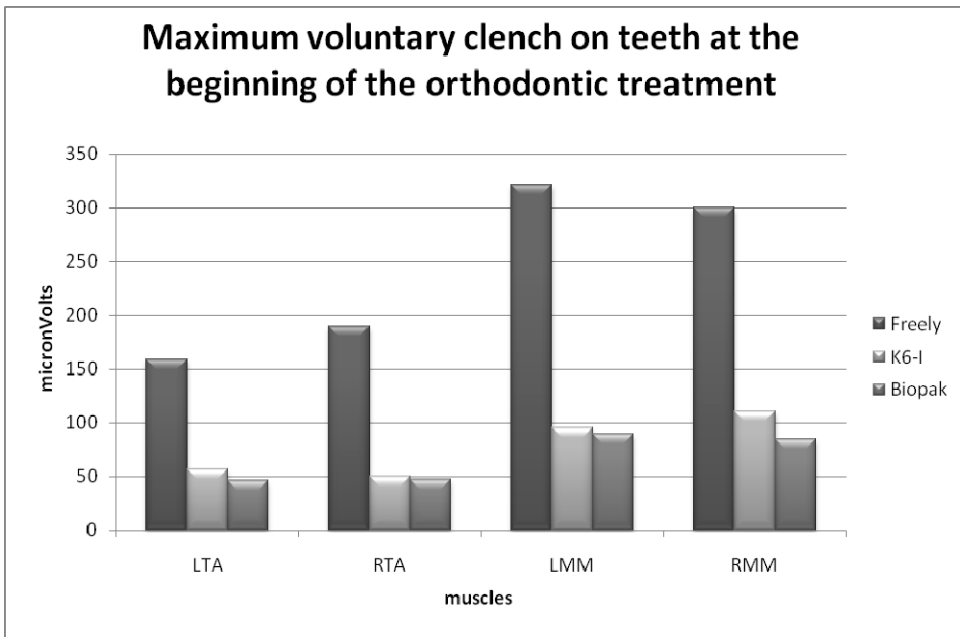


Fig. 4.

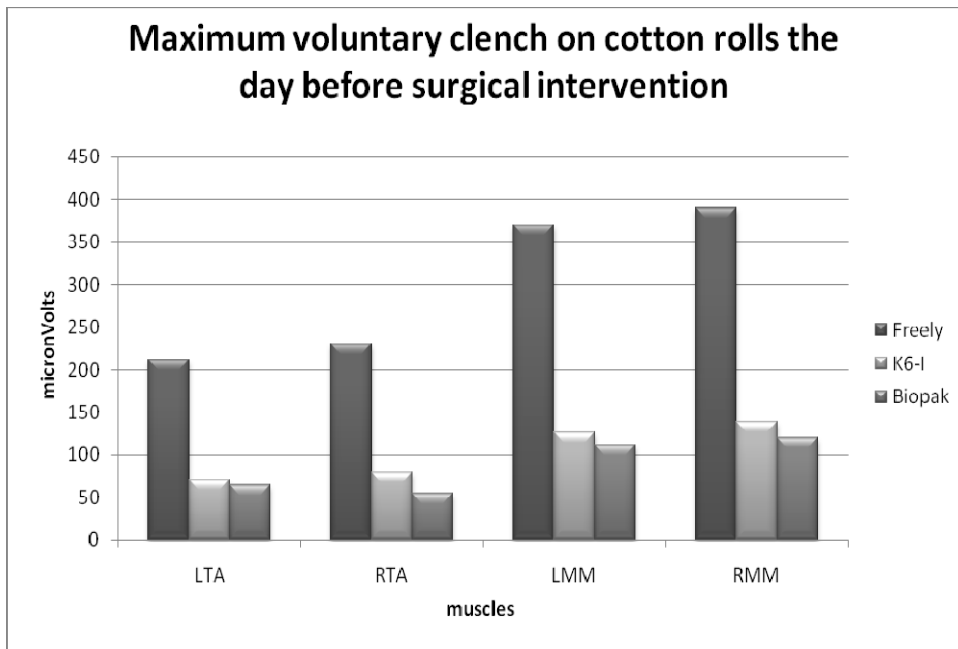


Fig. 5.

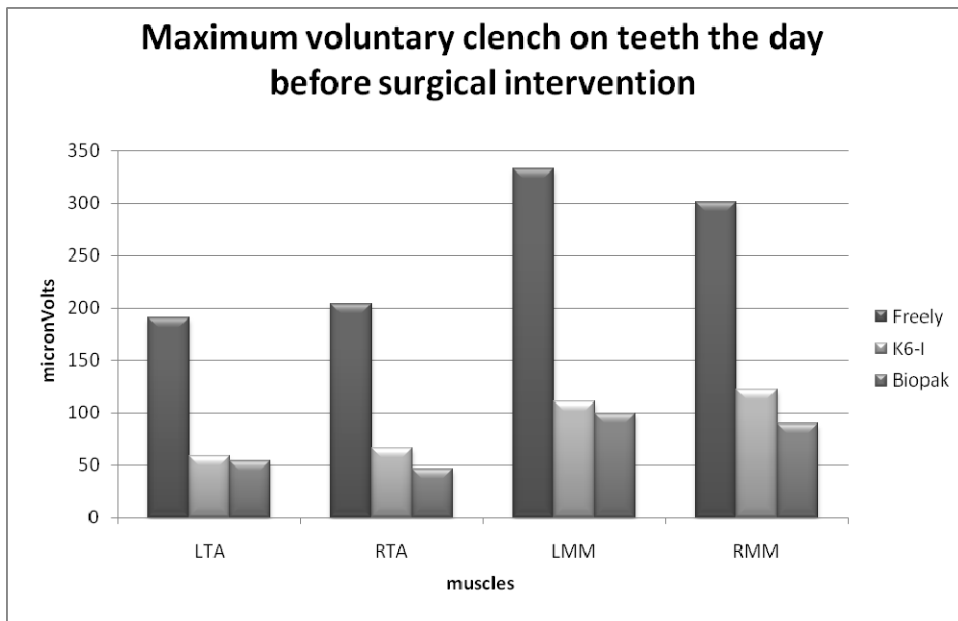


Fig. 6.

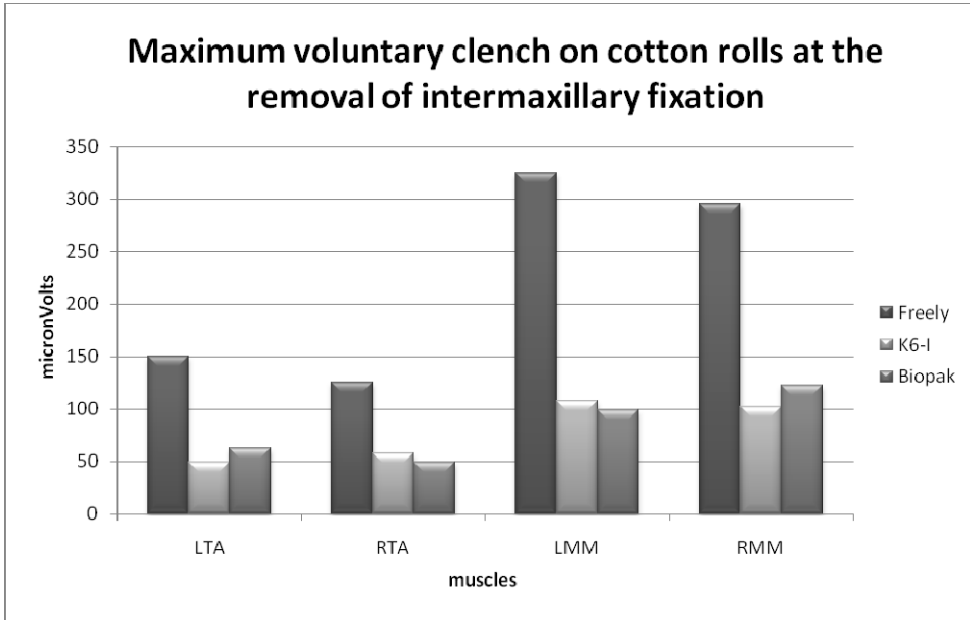


Fig. 7.

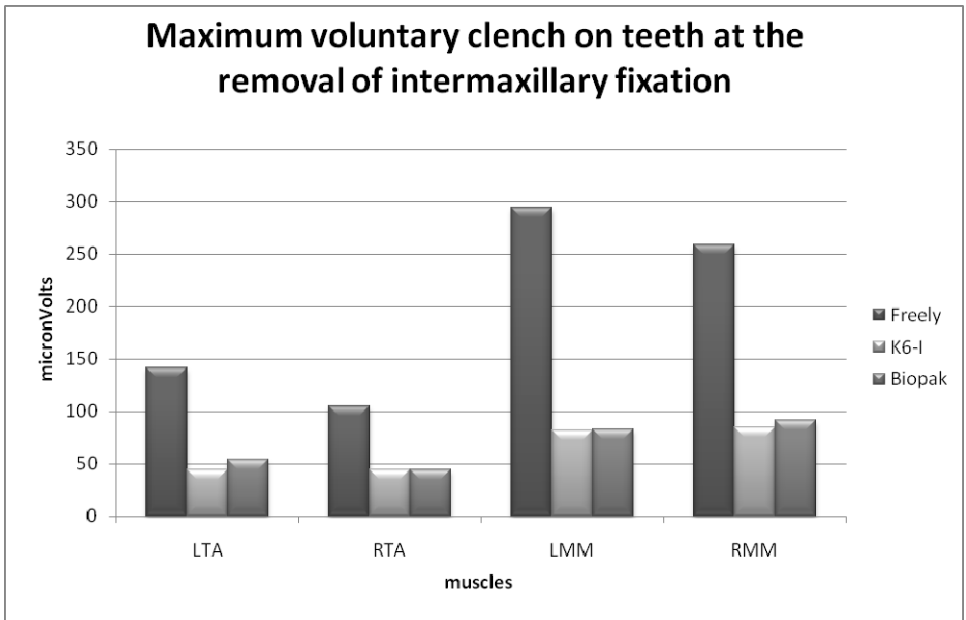


Fig. 8.



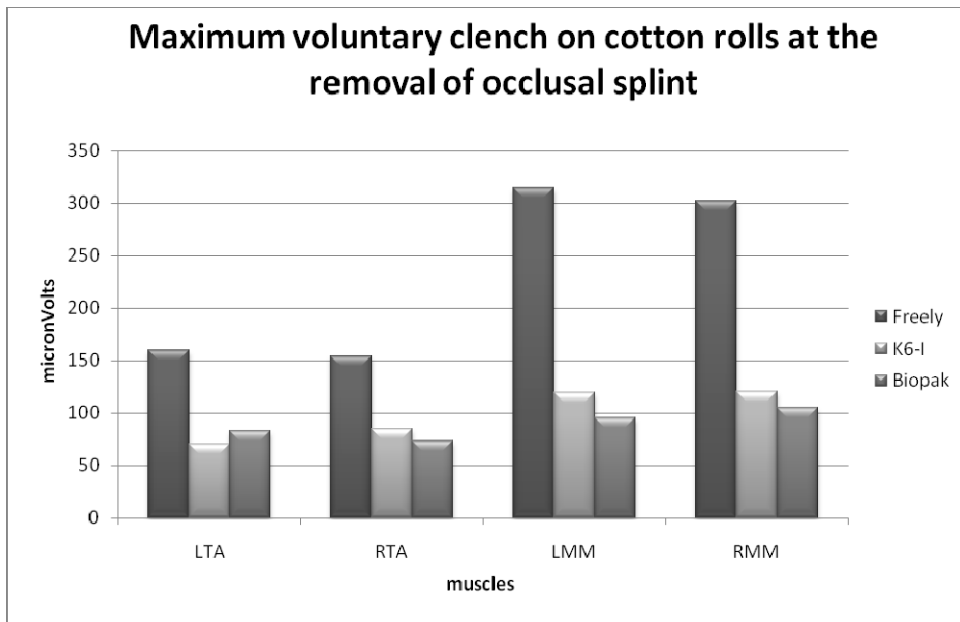


Fig. 9.

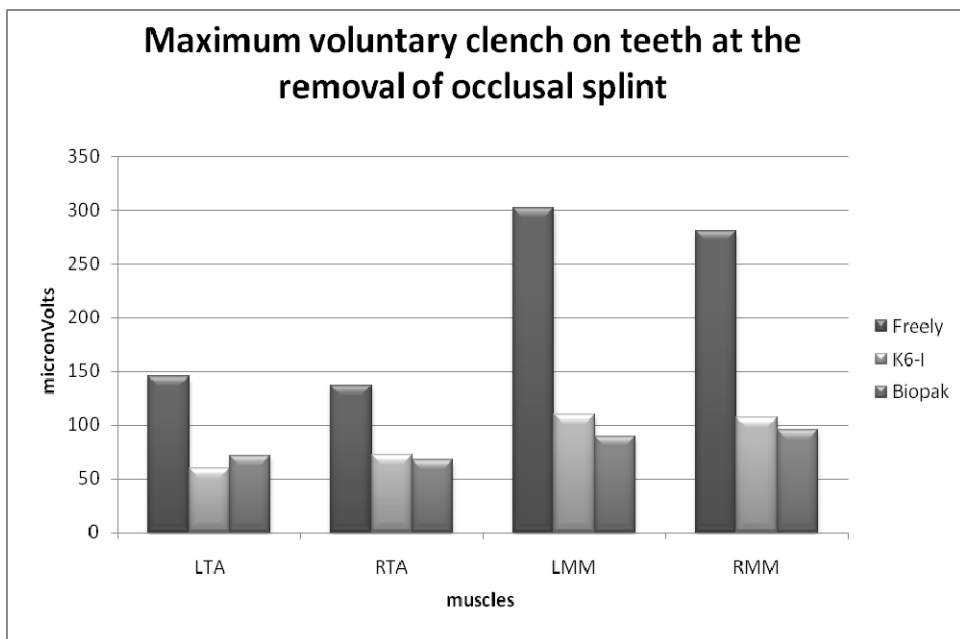


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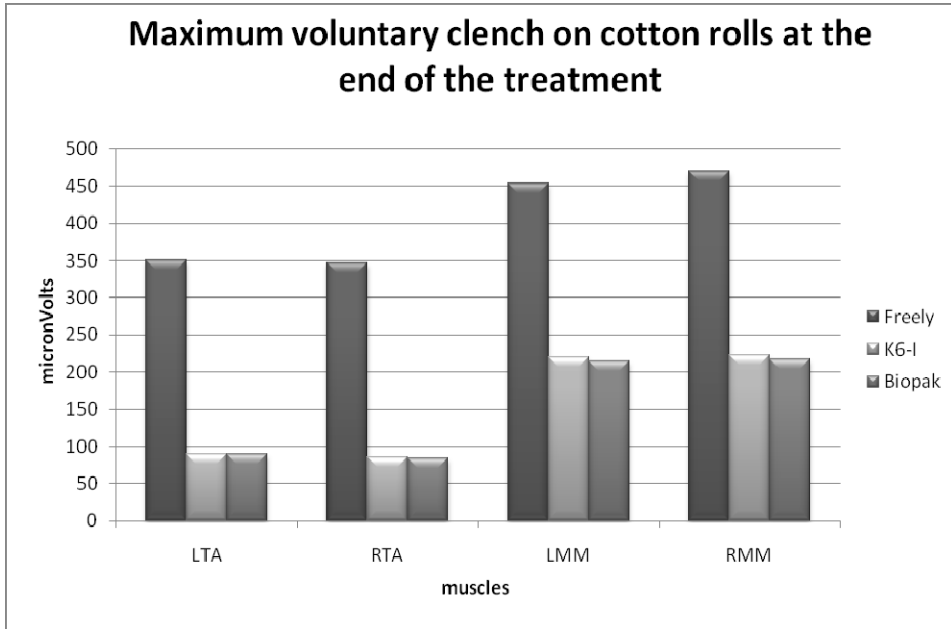


Fig. 11.

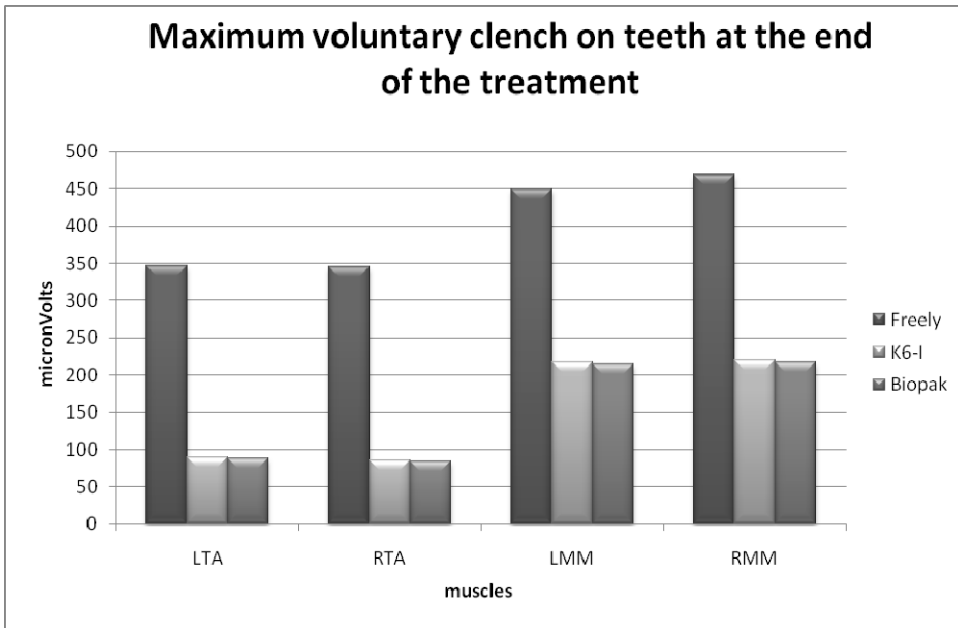


Fig. 12.

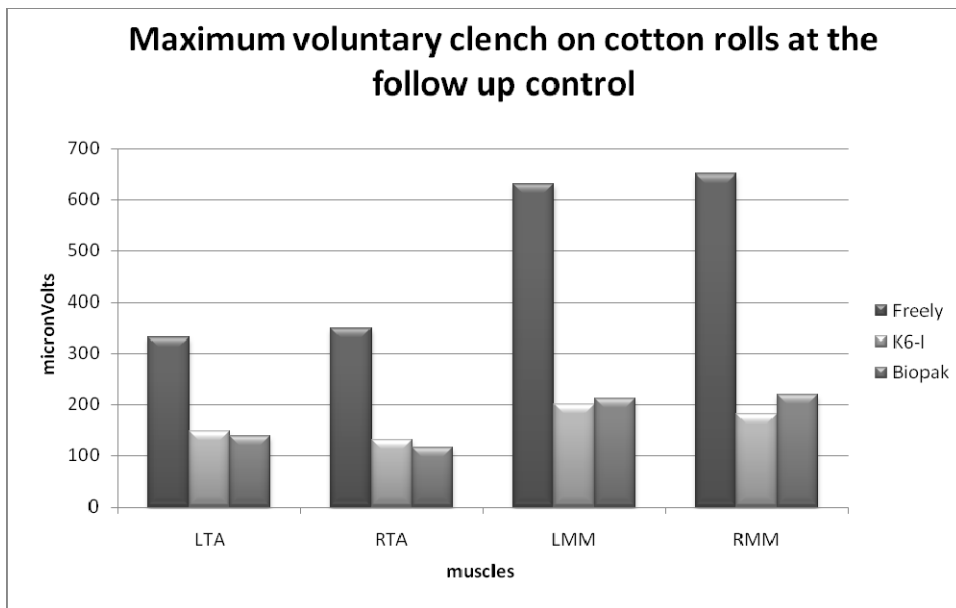


Fig. 13.

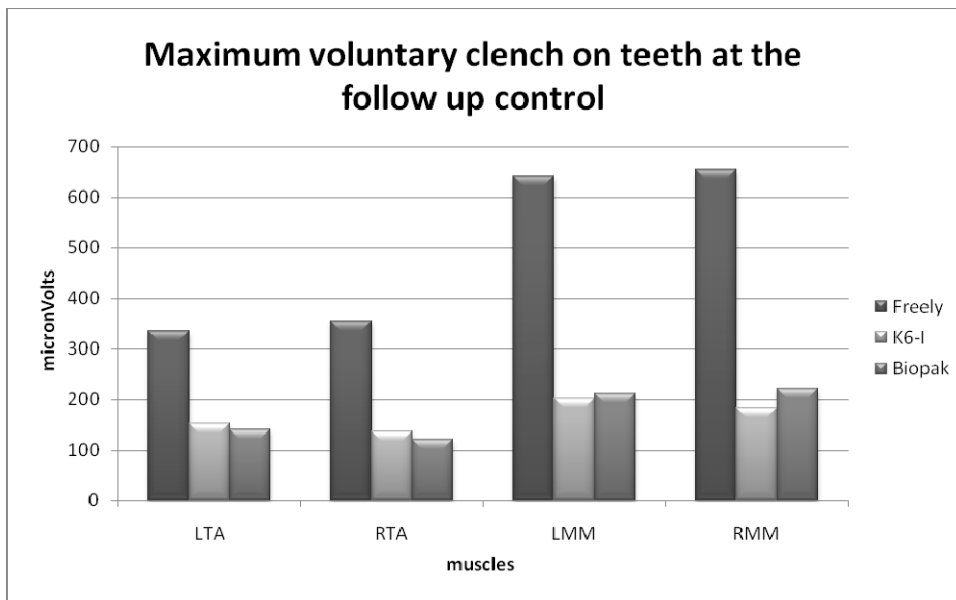


Fig. 14.

Fig. 1-14. Maximum voluntary clench on cotton rolls and on teeth during the different phases of the treatment.

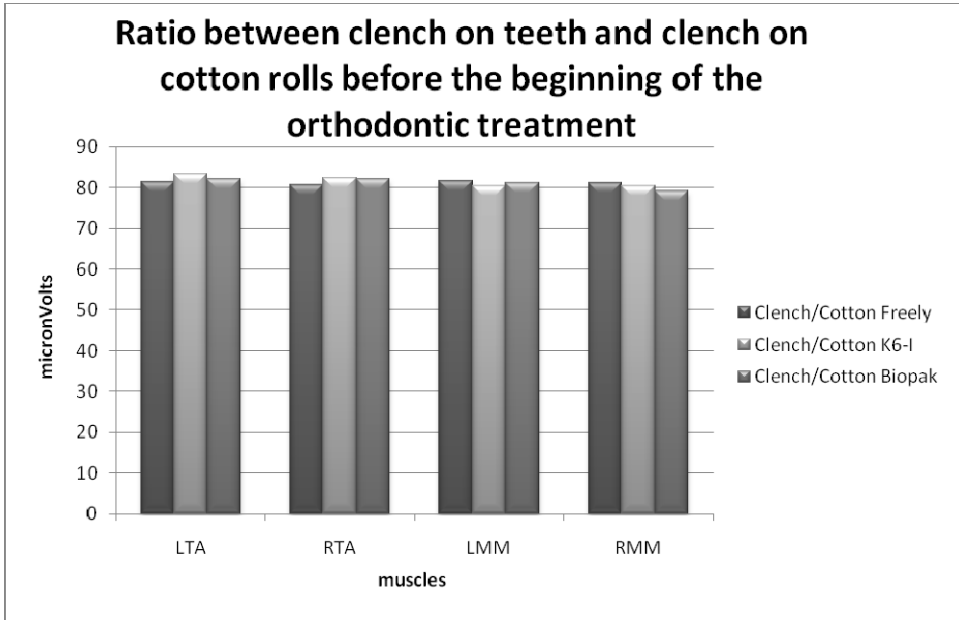


Fig. 15.

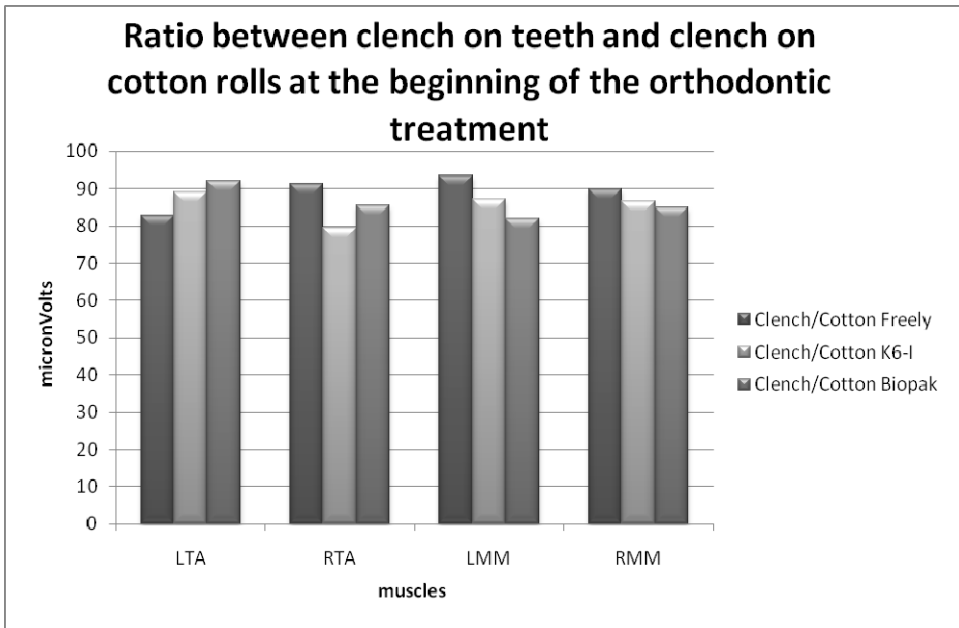


Fig. 16.

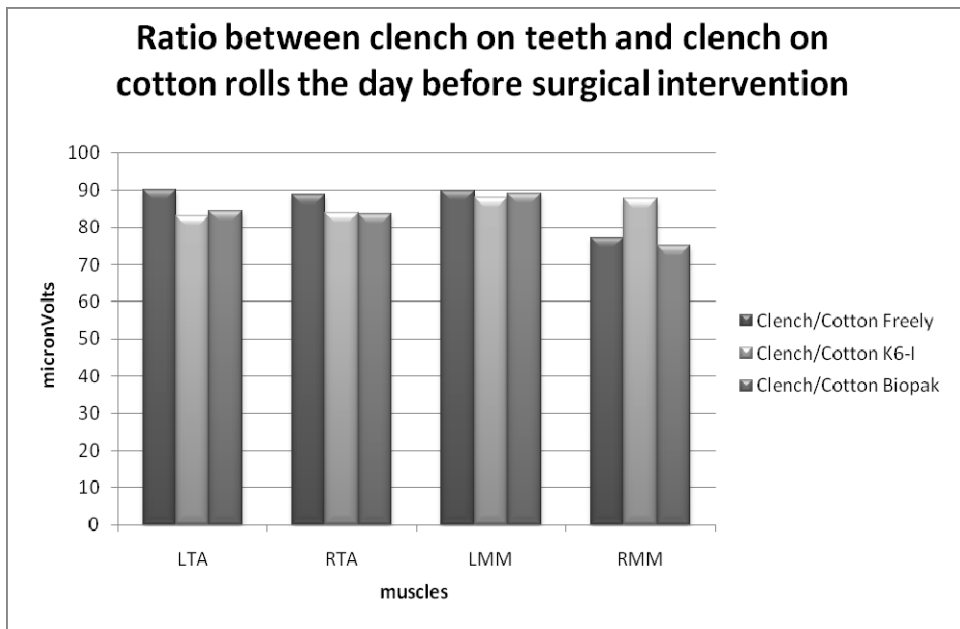


Fig. 17.

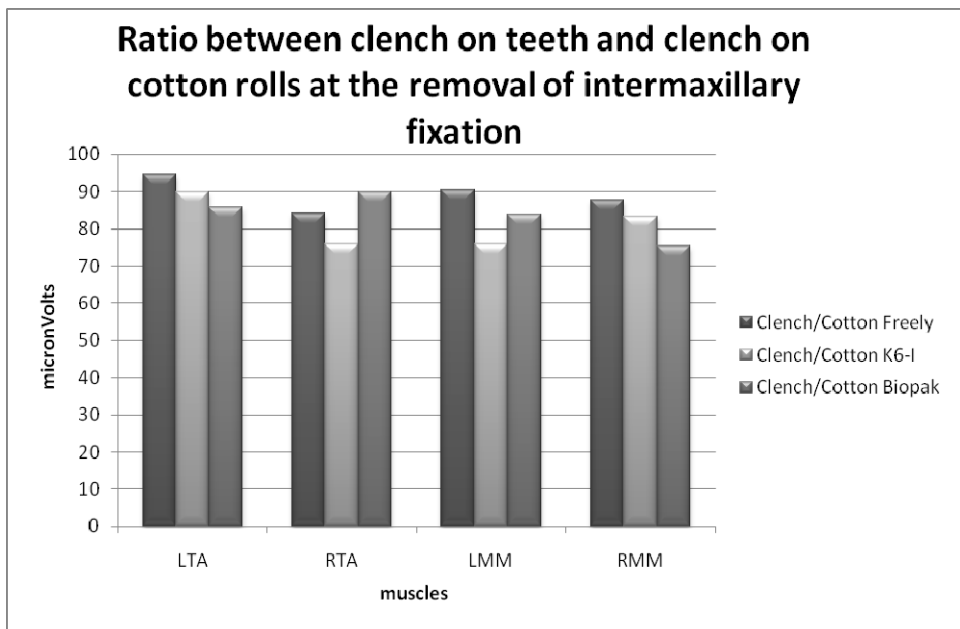


Fig. 18.

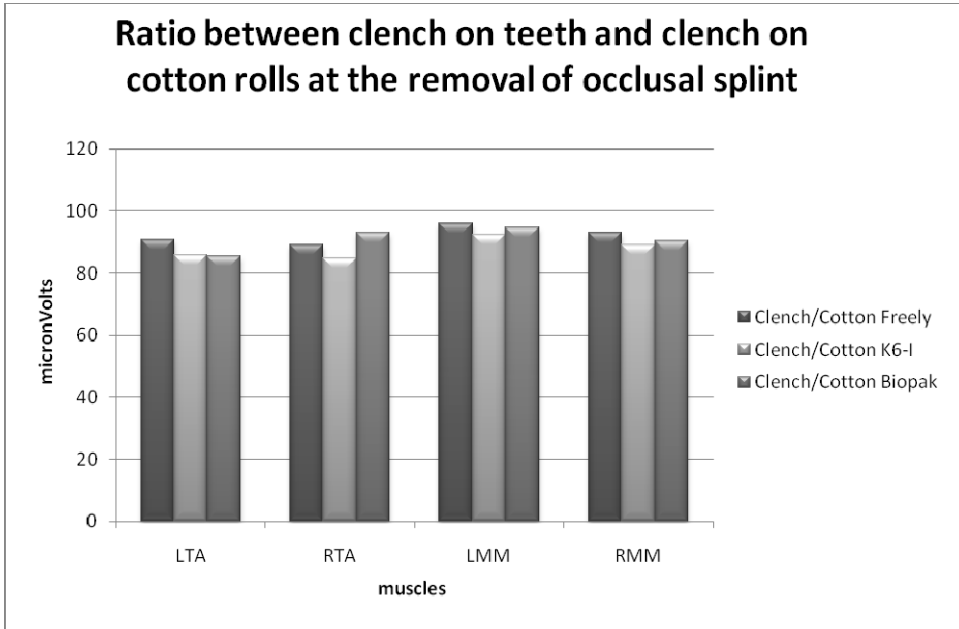


Fig. 19.

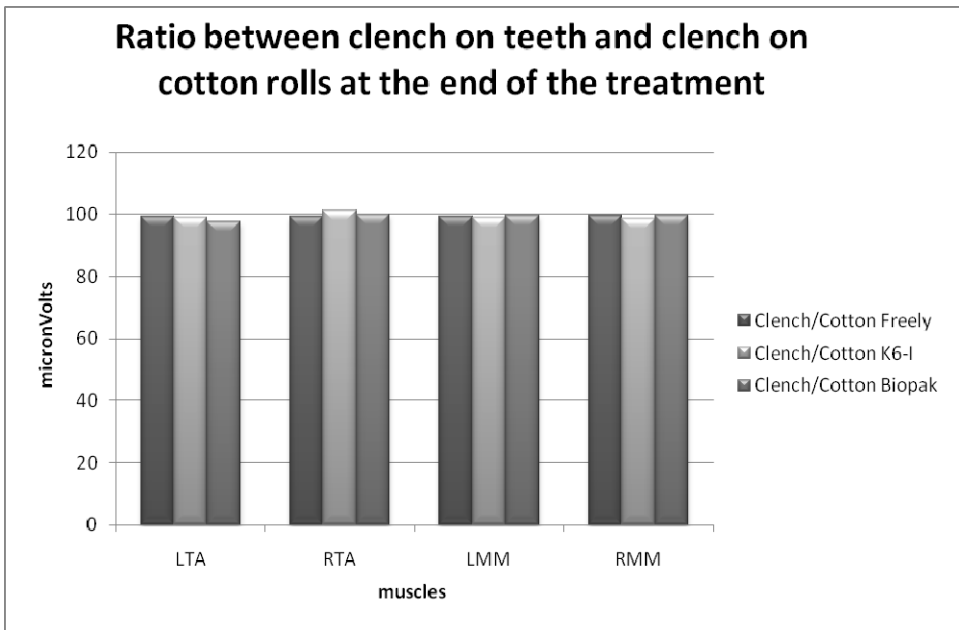


Fig. 20.

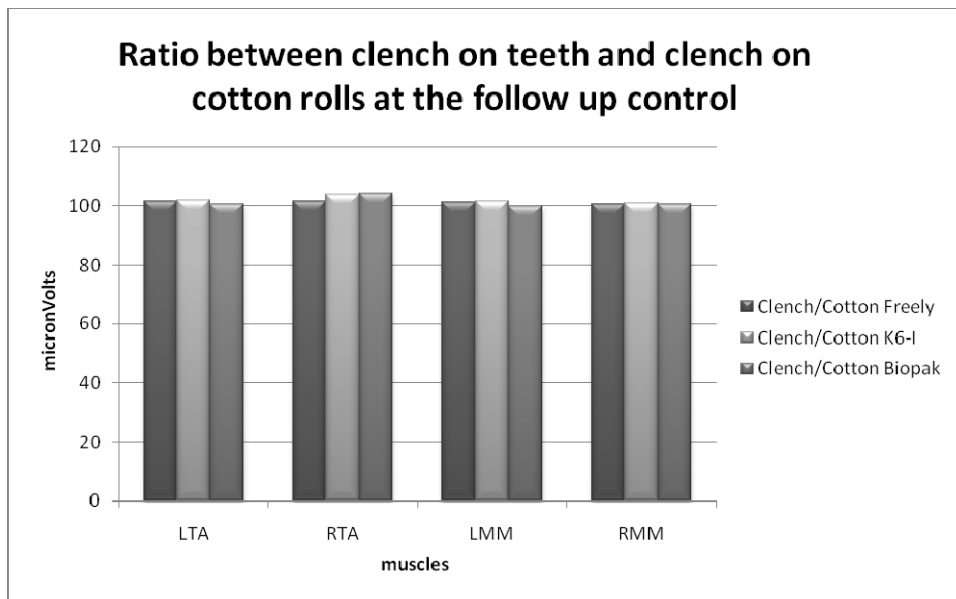


Fig. 21.

Fig. 15-21. Ratio between maximum voluntary clench on cotton rolls and on teeth during the different phases of the treatment.

#### 4. Discussion

The instruments have been planned through different principles, they are based on different ideas and they have different aims.

The protocol studied for Freely by Ferrario et al has been organized in order to obtain the maximum of reproducibility because it is based on a standardized methods which allows to evaluate real percent data.<sup>6</sup>

Following this protocol, micronVolt in maximum voluntary clench on teeth and on cotton rolls were not considered in order to avoid false evaluations.<sup>6</sup>

Besides, this protocol consists in evaluating tests executed in clench on teeth and in comparing them with the ones executed on cotton rolls, in order to obtain percent data with a higher degree of reliability because of the override of every kind of interference due to a non correct position in electrodes or to other external variables.

K6-I electromyograph was projected based on different principles and it does not do this calculation. Besides, ratio between maximum voluntary clenac on teeth and on cotton rolls have been calculated manually in order to obtain data comparable with Freely.

Moreover, the instruments are calibrated in different way and they use different amplifiers and signal filters.

Besides, comparing micronVolt values registered on both instruments in the same time, huge differences can be underlined, but comparing their percent values obtained from clench/cotton ratio similar data can be obtained.

This indicate that the micronVolt muscle activity is different from the two instruments but their percent values are similar and both electromyographs can be overlapped.

Especially, in this study in patients in orthodontic-surgical therapy, values obtained by the instruments are more similar in the phases which precede the orthodontic surgical therapy and at the end of the treatment.

In the immediate postsurgical phase, patients have an instable occlusion and there is a lower reproducibility of the measurements.

Lots of differences between skeletal class II and skeletal class III patients have been evidenced by the analysis of the data obtained.

The IMPACT index, which underlines the muscular force expression in time, is definitely major in skeletal class II patients than in skeletal class III patients almost in all treatment phases.

Such difference is statistically significant. Only at the end of the treatment does not a statistically significant difference between the different groups persist.

The activity of the four muscular fasciae, expressed in micronVolt, is definitely major in skeletal class II than in skeletal class III subjects at the beginning of the treatment.

This difference, statistically significant, tends to disappear in the successive phases.

These results have been obtained both on the exercises with cotton rolls between the arches and in clench, with both the electromyographic systems.

As regards mandibular kinesiology, the maximum mandibular opening movement is wider in skeletal class III patients in all the treatment phases, except for the end of the therapy.

The protrusive movement is always major in skeletal class II patients. This gap is reduced at the end of the therapy, but it does persist.

Statistically significant differences about right and left lateral movements have not been evidenced.

By a comparison of the temporal muscle PERCENT OVERLAPPING COEFFICIENT [POC] index it has been underlined that in the initial phases the muscular activity presents a reduced neuromuscular equilibrium. Skeletal class II patients are particularly uncompensated at the beginning of the treatment. After the start of the orthodontic therapy the POC index improves but the value, which isn't included in the physiological range, is constant up to the surgical operation. In the last part of the surgical orthodontic treatment the POC index improves and at the end of the treatment it is included in the physiological range. Skeletal class III patients present in the pre-surgical phases values close to the physiologic limit and improve only at the end of the treatment. Values are physiologic at the end of the treatment.

Skeletal class II patients present a major harmony in the temporal muscle activity compared with skeletal class III patients. The masseter muscle POC index presents a light reduction of the overriding range of the muscular activity after the appliance cementing. This value improves up to the end of the treatment, when the POC index is similar in all skeletal class.

As regards POC medium progressive improvement of the value between the first acquisition made at the beginning of the treatment until the end of the fix orthodontic therapy can be noticed.

Class II patients are more overriding than class III patients at the beginning of treatment. At the end of treatment POC values underline a sufficient neuro-muscular equilibrium, yet there is a difference of about two points of percentage between the classes (the index is slightly better for class II patients).

The progressive improvement of POC indexes in all classes shows that orthodontic treatment tends to develop a major equilibrium among different muscular activities.

As regards POC index a similar progress to skeletal class II and III patients has been noticed even in small samples, hence the insertion of the value of skeletal class I patients in the relative figures.



TORS index shows similar values in skeletal class II and III patients, without the attainment performed at the beginning of the treatment; data remain higher than the normal value [considered equal to 10%] during the period of the orthodontic treatment, at the end of the treatment the TORS value is nearly normal.

The ASIMMETRY index which shows the side of prevalence has an opposite course between the two classes, that is, while for class III patients it diminishes up to the attainment performed in the final part of the orthodontic post-surgical treatment where it starts to increase again, class II patients have an opposite response, nevertheless values are still quite normal.

About the index of TORQUE, class II patients tend to have an occlusal prior centre of mass [negative value], in order to become positive in post-surgical attainments and to arrange themselves close to zero at the end of the treatment. In class III patients the index always remains positive [posterior contact] and it always remains in the range of normality; at the end of the treatment the value is close to zero.

TORQUE index has an alternating course in both classes, its values are quite normal.

The ability in developing force in time in the test on cotton rolls shows a course in part superposable between the two skeletal classes, the decrease of the force up to the level of the attainments performed after the beginning of the orthodontic therapy and after the surgical operation it remains constant, in order get back to the previous values at the end of the treatment. Also the course of the IMPACT in the test of the greatest clench shows a similar response, but not completely superposable between two skeletal classes; nevertheless the decreases of the value of IMPACT up to the level of the surgical operation are still confirmed.

The IMPACT values %\*sec highlighted by the two classes show a partial superposable course, with the exclusion of the attainment performed after the beginning of the orthodontic therapy in class II patients where the value tends to diminish, while it increases in class III patients. Finally all the values are quite normal [ $100 \pm 15\%$ \*sec] but for the attainment performed after the period of intermaxillary block. At the end of the treatment values are slightly inferior than  $100\%$ \*sec.

Observing more data of class II and III patients, it has to be noticed that the first group develops a minor muscular activity in comparison to the second group, nevertheless in the other levels class II patients develop a major electric energy, during all the orthodontic fixed treatment, the same observations can be noticed for IMPACT indexes  $\mu V$ \*sec. This factual information could be connected to the reduced number of subjects who have an attainment in the initial phase, and it could be the same for attainments performed at the end of the treatment. Considering the afore said things and observing the index of medium POC, there's to notice that even if on the one hand skeletal class III develop a major clench force, it is always true that these result balance than class II patients [medium POC class II patients =80%; class III patients=78%] and the program connected to the electromyography Freely results more important and bases itself on data got from formulas instead from relative values.

Lots of differences between open and deep skeletal bite patients have been underlined by the analysis of the electromyographic data obtained at the beginning of the treatment.

The impact value and muscular activity in micronVolt analysis shows a major muscle activity in deep bite patients than in deep bite ones.

These results have been obtained with both the electromiographic systems.

The following authors too proved that high angle cases were associated with weaker musculature than low angle patients: Möller (1966), Sassouni (1969), Ingerval et al (1974), Bakke (1991), Kayukawa (1992), Farronato (1992) and Bong Kuen Cha (2007).<sup>27-33</sup>

Ahlgren et al. (1973, 1985) proved a positively correlation between the mandibular plane angle (SNGoMe) and the temporal muscle activity (TMA).<sup>34,35</sup> Moller and Ingervall obtained opposite results.<sup>36,37</sup>

Ueda et al (1998) proved that vertical craniofacial morphology is positively correlated with temporal muscle activity (TMA) and negative correlated with masseter muscle activity (MMA).<sup>11</sup>

Fogle et al. (1995) obtained opposite results. They proved that a correlation between craniofacial morphology and masticatory function doesn't exist. The only correlation is between muscle function and patients age.<sup>38</sup> The differences existing between the two groups at the beginning of the treatment, statistically significant, tend to disappear at the removal of the fix orthodontic appliance confirming the orthodontic surgical treatment's corrective role in according to Santoro's study.<sup>39</sup>

Furthermore, before the starting of the fix orthodontic therapy, patients present a compensatory equilibrium to disgnatia. During successive phases electromyographic and electrognatographic continue worsening according to Oliver et al (1985), Proffith et al (1989), Brown et al (1991) and Thomas et al (1995). They improve in post surgical orthodontic phase only.<sup>40-43</sup>

At the end of the orthodontic surgical treatment electromyographic values improve and reach optimal values.

Mandibular movement rehabilitation needs more time than the muscular one even if it is satisfactory and constant too.

At the end of the treatment maximum mandibular opening is still less than the preoperative one.

No statistically significant differences between the two groups have been highlighted about mandibular kinesiology.

## 5. Conclusion

This study confirms that the functional rehabilitation in patients in orthodontic-surgical treatment occurs in a good way and in a good time.

The functional evaluation in patients during orthodontic-surgical therapy is an important element to reduce as much as possible a incorrect neuromuscular activity that can cause a relapse; it also helps clinicians to follow treatment phases and to control the results obtained.

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