Anterior Temporalis Muscle:  
Relation Between Muscular Activity and Variation of Vertical Dimension

INTRODUCTION

It is generally accepted that muscular elongation or more precisely the sarcomere length of the fibers of a skeletal muscle, determines its ability to produce active tension. Therefore the amount of tension that the mandibular muscles can develop will vary with the degree of jaw opening. Experiments designed to find the length tension relationships of human mandibular muscles have been attempted by several investigators. In this sense in a previous work it has been determined, for the masseter muscle, the physiologically optimal muscular elongation (18.25 mm of interocclusal distance), where this muscle develops the maximum force with minimum EMG activity.

Since the elevators muscles have not only a more complex macrostructure, but also a more complex muscle fibre composition, our aim was to determine if the physiologically optimal muscular elongation of the anterior temporal muscle, in comparison to the masseter, is nearer or further to the occlusal vertical dimension.

METHODS

Seven adults, four men and three women with ages ranging from 21 to 39 years with a mean of 25.3, who had normal functional occlusion and no dysfunction of the stomatognatic system, were studied.
Superficial electrodes (Grass 5e 5s)* were applied on the anterior temporalis muscle as described by Manns and Spreng\(^7\) in a previous work. Bite force was registered extraorally through a gnathodynamometer at different jaw opening, from 7 mm intermaxillary separation to almost maximal opening. The gnathodynamometer consisted of a strain gauge transducer composed of three sections as described by Manns et al.\(^8\) in a previous work.

Mouth opening was measured from the distal borders of the canines. The bite plates, lined with rubber and leather, were placed at the canine-premolar level on the same side where the EMG was registered (Fig. 1).

The strain gauge was activated by force on the two bite plates. Bite force was recorded through the electrical resistance changes of the strain gauge, measured by a Wheatstone bridge and amplified 1,000 times by an SGS operational Amplifier uA 741 and visualized by a voltmeter. The Wheatstone bridge was reset to zero before each measurement.

The strain gauge transducer was calibrated by a counterweight set and a system of levers before each experiment. They proved to be linear in a range of 2 to 30 Kg (1 Kg is equivalent to 9.81

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Newtons). Each experimental subject was comfortably seated in a Faraday cage and submitted to two different series of experiments.

**Series 1:** Recording of EMG activity of the anterior temporal muscle at constant bite force.

The subject maintained bite force value constant at 10 to 20 Kg on a voltmeter placed at eye level, while EMG activity of the temporal muscle was inscribed on an inkwriting recorder (Nihon Kohden RJG-4022)* at different jaw openings.

Eight recordings were performed for each subject. Four were performed changing the jaw opening every 5 mm from 7 up to 35 mm, and four finer ones, changing the jaw opening every 1 mm from 15 to 30 mm.

This series included 64 experimental measurements (32 gross and 32 finer ones).

**Series 2:** Recording of the bite force at constant anterior temporal muscle EMG activity.

The EMG recorded from the temporal muscle was amplified, integrated, and sent to a voltmeter. The subject was asked to maintain the needle of the voltmeter at a certain constant millivoltage level, indicating a constant EMG with different jaw openings, while variations in bite force were measured by the gnathodynamometer and inscribed by the ink-writing recorder.

Constant EMG value was previously calculated for each experimental subject, asking the patient to reach maximum EMG activity at 7 mm jaw opening. This value was assigned 100% and subjects were asked to maintain a constant EMG at 20% or 40% of this value.

Series 2 also included 64 measurements. Recordings were performed as in series 1.

**ANALYSIS OF DATA**

Recordings of EMG activity of series 1 and bite force of series 2 were analyzed as follows. As each recording lasts approximately 15 seconds they were divided into 2 second steps. Then values in the ordinate were obtained by manual measuring and the mean amplitude calculated for each registered curve. To standardize

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Fig. 2. Relation between integrated EMG activity and jaw opening from 7 up to 35 mm, changing every 5 mm) under constant bite force (10 and 20 Kg). The vertical bars in this figure as in Fig. 3 represent standard deviation of the mean values.

Fig. 3. Relation between integrated EMG activity and jaw opening (from 15 to 30 mm, changing every 1 mm) under constant bite force (10 and 20 Kg).

RESULTS

mean amplitude values obtained in series 1, 100% was fixed as the minimum value of EMG activity registered with 20 Kg of constant bite force. The rest of the values were referred to as percentages of the assigned 100%. To standardize the mean value of the curves obtained in series 2, 100% was fixed as the maximum value of bite force registered with 40% of constant EMG activity. The rest of the values were expressed in percentages of this 100%.

The standardized values were tabulated per experiment for the different jaw openings, and then the mean values for the experiments of each series and for each experimental subject were calculated.

Fig. 2 shows the relation between integrated EMG activity of the anterior temporal muscle and jaw opening with constant bite force of 10 to 20 Kg (series 1) and with different jaw openings (7 to 35 mm). The curves in broken lines correspond to the mean values of integrated EMG activity obtained for one experimental subject (AC), whose least EMG activity in regard to the different jaw openings mentioned was at 25 mm. Records in unbroken lines correspond to mean values for six subjects (VO, PC, SF, MC, OG, ML) whose least EMG activity was found at 20 mm jaw opening.

Note the similar tendency of the curves to mark high EMG activity
Table 1. Optimum anterior temporalis muscle length

<table>
<thead>
<tr>
<th>SUBJECTS</th>
<th>mm FROM OCCLUSION</th>
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<tbody>
<tr>
<td>S.F.</td>
<td>18</td>
</tr>
<tr>
<td>V.O.</td>
<td>18</td>
</tr>
<tr>
<td>M.L.</td>
<td>19</td>
</tr>
<tr>
<td>P.C.</td>
<td>19</td>
</tr>
<tr>
<td>M.C.</td>
<td>20</td>
</tr>
<tr>
<td>O.G.</td>
<td>20</td>
</tr>
<tr>
<td>A.C.</td>
<td>25</td>
</tr>
<tr>
<td>( \bar{x} )</td>
<td>19.9</td>
</tr>
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at 7 mm jaw opening and the least at 20 to 25 mm, as already mentioned, and then to rise and reach high values at 35 mm jaw opening.

Fig. 3 shows the relation between bite force and jaw opening (7 to 35 mm) at constant EMG activity corresponding to 20% and 40% of the maximum electrical activity of the temporal muscle (series 2). Curves in broken lines indicate mean values of bite force registered for one experimental subject (AC), indicating highest bite force at the 25 mm bite opening with regard to the different jaw opening already mentioned. Records in unbroken lines represent a group of six subjects of the same series with the highest mean bite force at 20 mm. Note the direct correlation between EMG and muscular force.

The tendency of the curves was again very similar. Lower masticatory force was developed at 7 mm jaw opening, gradually increased up to 20 or 25 mm, and then decreased until close to maximum jaw opening.

With the aim of defining more accurately the muscular elongation of the anterior temporalis muscle that elicited least EMG activity (series 1) or highest force (series 2), finer measurements were performed every 1 mm ranging from 15 to 30 mm jaw opening. In this way, the optimum muscular elongation was determined for each subject (Table 1).

**DISCUSSION**

The force developed by a skeletal muscle depends on its length or muscular elongation. If we plot the relation between maximal
isometric tension developed by a muscle versus variations of its muscular length, we obtain a length-tension curve, where it is possible to establish that tension increases progressively with muscle elongation, reaching its highest values at a certain muscular length (optimal or resting length) and then decreases with further muscle stretching. In this way, skeletal muscle length determines the amount of isometric tension it can develop. Since active tension is developed by the interaction of the cross-bridges of myosine molecules of the thick filaments of the sarcomere with the actine molecules of the thin filaments, maximal tension at optimal muscular length will be achieved when maximal number of cross-bridges exist between both (sarcomere length of 2-2.2 μ), and since these are the real mechanical agents responsible of contraction, active tension is a linear function of the number of cross-bridges between the sarcomeric myofilaments.

Nordstrom et al. demonstrated a linear relation between the sarcomere length and jaw opening in the temporal and masseter muscles of the rat. Furthermore, Nordstrom and Yemm observed in the rat masseter muscle, that the optimum elongation that produced the strongest tension was found at 8 mm jaw opening which is very close to its optimal sarcomere length.

In series 2 each subject was asked to maintain constant a certain level of submaximal EMG activity (20% or 40% of total EMG) of the anterior temporal muscle, which is ultimately equivalent to maintaining voluntarily activated a stable or fixed discharge of motor units.

The recordings of masticatory force showed that at a certain intermaxillary separation of 19.9 mm (x of seven subjects) the highest values of masticatory force were reached, which possibly means that the temporal muscle is contracting isometrically at a length corresponding to its optimal sarcomeric length in which the highest amount of available cross-bridges exist between the thick and thin filaments.

This increase in masticatory force up to a 20 mm intermaxillary separation agrees widely with the report of Manns and Spreng for the temporal muscle by means of the intraoral recordings of the masticatory force varying the intermaxillar separation between 0.5 and 20 mm.

In the same way, decrease of bite force registered in smaller or larger jaw openings would be possibly due to less number of cross-bridges available. In muscle elongation close maximum jaw opening, this decrease is easily accounted for by the separation in the Z lines of the sarcomeres, which consequently produces less overlapping of the thin and thick filaments. The decrease in cross-bridges when the temporal muscle shortens from optimal
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muscular elongation to 7 mm jaw opening could be due to one of the mechanisms proposed by Mountcastle: 1, thin filament from opposite Z line overlap, which consequently produces interference with cross-bridges attachment to thin filament and 2, the rigidity of the thick filaments mechanically limits the development of tension and possible because of failure of the activation mechanism.

These results of the temporal muscle agree with those previously reported by Manns et al. for the masseter muscle, in which it was observed that the highest values of masticatory force were registered at an intermaxillary separation of \(\bar{x}: 18.25\) mm. This later results were confirmed in a recent publication in which the maximum incisive force was registered at an interocclusal distance of \(17 \pm 3\) mm.

In series 1, in order to maintain voluntarily a constant bite force of 10 or 20 Kgs, a certain amount of active muscle fibers is necessary, which finally mean a certain number of sarcomere cross-bridges. The least EMG activity of the temporal muscle was also found at 19.9 mm of interocclusal distance (\(\bar{x}\) of seven subjects), again near its optimum muscular elongation where the highest number of sarcomere cross-bridges between thin and thick filaments of its muscle fibers are available. This fact means that near this optimum muscular length, less amount of muscle fibers are necessary to provide a certain muscular activity in order to maintain a bite force of 10 or 20 Kgs constant, which finally means less number of motor units and therefore less EMG activity. On the contrary, in the muscular length corresponding to smaller or larger jaw openings, as already mentioned, there is a less number of cross-bridges, which means that to provide the necessary muscular activity for 10 or 20 Kgs more muscle fibers and therefore more motor units must be recruited, determining higher EMG activity values.

This decrement of EMG activity from smaller jaw openings up to 20 mm was described by Manns and Spreng for the temporal and masseter muscles, and by Storey, Garret et al. and Manns et al. for the masseter muscle.

It is well known that periodontal receptors, Golgi organs, temporomandibular joint (TMJ) receptors play an important role in the determination of excitatory state of motoneurons of the temporal muscle. Therefore, the gradual decrease of integrated EMG activity from 7 mm or near maximum opening to optimal muscular length of the temporal muscle is also probably due to a decrease in excitation and an increasing inhibition of its motoneurons, induced by these peripheral feedback neural mechanisms. Furthermore, Hellsing concluded that in maximal voluntary efforts the motor activity may function without significant
involvement of the peripheral mechanisms, which indicates the dominance of voluntary central commands over the pool of motoneurons of the V motor nucleus.

Summaryzing, if we analyze EMG and bite force response in regard to different bite openings and as a function of muscular elongation, we can appreciate that they follow an inverse behavior. While EMG activity decreases as we get further away from dental occlusion, masticatory force increases; as EMG increases as we approach maximum jaw opening, bite forces decreases. Furthermore, there is a physiologically optimum muscular elongation for each experimental subject, where the anterior temporal develops the highest muscular force with least EMG activity.

Individual differences found in the eight experimental subjects studied, with regard to optimum muscular elongation (distance from occlusion) of the temporal muscle are probably related to crano facial skeletal characteristics, as demonstrated in a previous work\textsuperscript{16} for the masseter muscle.

**SUMMARY**

The relation between EMG activity, bite force, and muscular elongation was studied in seven subjects with complete natural dentition during isometric contractions of the anterior temporal muscle, measured from 7 up to 35 mm jaw opening. EMG was registered with superficial electrodes and bite force with gnathodynamometer. In series 1, recordings of EMG activity maintaining bite force constant (10 and 20 Kg) show that EMG is high when the bite opening is 7 mm, decreases from 18 to 25 mm, and then increases again as jaw opening approaches maximum opening. In series 2, recording of bite force maintaining EMG constant show that bite force increases up to a certain range of jaw opening (around 18 to 25 mm) and then decreases as we approach maximum jaw opening. Results show that for each experimental subject there is a physiologically optimum muscular elongation of maximum efficiency where the anterior temporal develops highest muscular force with least EMG activity.

**REFERENCES**


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