The changes in electrical activity of the postural muscles of the mandible upon varying the vertical dimension

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Manns and Spreng[1] and later Manns et al.[2] studied the relationship between electromyographic (EMG) activity of the masseter and anterior temporal muscles and the variations of vertical dimension (VD), maintaining constant submaximal bite force values of 10 to 20 kg. A gradual decrease of muscular electrical activity was observed, from 0.5 mm of interocclusal distance up to a VD range of 13 to 21 mm from occlusion and then increasing toward maximum opening. Bite force, on the other hand, followed an inverse behavior, with VD variations at constant EMG activity of 20% to 40% maximum EMG activity. This fact allowed the determination of the optimum physiologic muscular elongation for each subject where the muscle develops the maximum force with minimum EMG activity. It is accepted that the length developing the greatest muscular tension corresponds closely to the muscular resting length.[3, 4]

Other authors[5-7] have described an EMG silence or minimum EMG activity[8] at the mandibular postural position and during passive movements of the jaws along the habitual path of closure. Nevertheless, Göepfert and Göepfert,[9] Garnick and Ramfjord,[10] and later Rugh et al.[11] found that the least muscular electrical activity does not correspond to the mandibular postural position but to a VD farther from this jaw position. Garnick and Ramfjord[10] concluded that there is no electromyographically defined mandibular postural position. Rather, they defined a resting range with an average of 11.1 mm for the muscles studied.

The aim of the present work was to study the relation of the VD to resting EMG activity (basal tonic EMG activity [BT-EMG]) of the masseter, anterior temporal, and posterior temporal muscles, through gradual variations on depressing the mandible along the habitual path of opening. Based on this relation, we determined EMG behavior of the muscles mentioned at different vertical dimensions and found a specific VD of minimum EMG activity for each of them.

METHODS

The study was performed in eight men, ranging from 21 to 34 years of age (mean age of 27 years), with normal functional occlusion, and normal function of the stomatognathic system.

EMG recordings were performed by placing bipolar surface electrodes on the masseter, anterior temporal, and posterior temporal muscles of the left side according to the technique described in previous works.[1, 2, 12] EMG activity was filtered (80 to 100 kHz), amplified 1 time and then amplified again from 10 to 50 times, integrated (time constant 1.8 msec), and finally registered in a polygraph.*

VD was measured with a device specifically designed for that purpose (Fig. 1). The apparatus consisted of a vertical metal bar *(I)* with a horizontal bar *(II)* perpendicularly soldered to the superior end and another mobile horizontal bar *(III)* to slide along the vertical bar. On each free end of the horizontal bars, adjustable metallic spikes were placed parallel to each other. The distance between

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*Model 5B, Grass Instrument Co., Quincy, MA.

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Fig. 1. Experimental subject in recording position inside the Faraday cage. Three sections of the extraoral *VD* measuring device are shown: section I = vertical bar; section II = fixed horizontal bar; and section III = mobile horizontal bar.

the horizontal bars with their spikes was measured with a millimeter rule fixed to bar II. The measuring device was fixed to a metal support through an idle arm that could move in all three directions.

The subjects, sitting upright in a dental chair with head supported inside a Faraday cage, were asked to keep their eyes closed during the recordings and to relax their jaw muscles as much as possible. Experimental subjects were submitted to two preliminary recording sessions to accustom them to the experimental conditions. Each session consisted of recording the BT-EMG activity of the masseter, anterior temporal, and posterior temporal muscles under two different conditions of VD.

Series A—dynamic variations of VD. The subject was asked to open his mouth slowly and continuously from the mandibular occlusal position to almost maximum opening, following the habitual path.[8]

Series B—static variations of VD. Series B corresponded to discriminative recordings of the BT-EMG activity (varying the vertical dimension every millimeter), using the measuring device already described (Fig. 1). The nose and chin had been marked previously by adhesive tape punched at the center. With the subject in the maximal interocclusal position (centric occlusion), both spikes were centered according to the perforations so that the distance between horizontal bars I and II, measured by the millimeter rule (Fig. 1), determined the occlusal vertical dimension (interocclusal distance = O mm) in each subject. Starting from this vertical dimension, the interocclusal distance was shifted every 1 mm from 1 to 19 mm and every 2 mm from 19 to 41 mm. Simultaneously, the BT-EMG activity of the masseter, anterior temporal, and posterior temporal muscles were recorded at each interocclusal distance, at intervals of approximately 15 seconds.

Each subject was submitted to five recording sessions, five for series A and five for series B. Thus, there was a total of 40 recordings with dynamic variations of the VD (series A) and 40 recordings with static variations (series B).

Analysis of data

As recordings of integrated EMG activity obtained at different interocclusal distances (series B) lasted approximately 20 seconds, they were divided into 3-second steps. Values in the ordinate were obtained by manual measuring, and the mean amplitude was then calculated for each recorded curve.[1,2] To standardize the average amplitude values of the recordings obtained in each experimental session of series *B*, minimum EMG activity was assigned a value of 1; the rest of the values were referred to this value.

The standardized values at the different interocclusal distances were tabulated per experiment for each muscle and subject. The average values were then calculated for the 40 recordings performed in each muscle of the eight experimental subjects. A

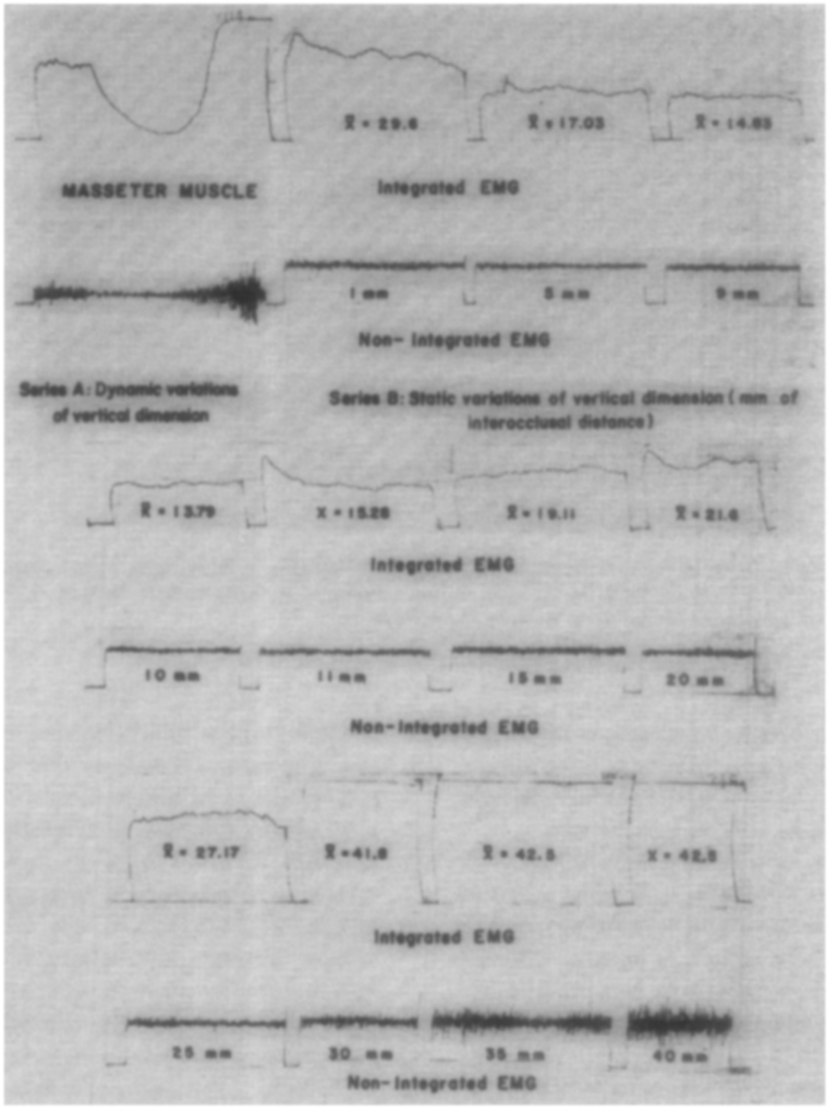

Fig. 2. Recordings of BT-EMG activity of the masseter muscle of subject No. 3, with VD dynamic (series A) and static (series B) variations. *Upper channel,* Integrated EMG. *Lower channel,* Nonintegrated EMG.

graph for each muscle was performed with this single total average (Figs. 4 to 6).

RESULTS

Fig. 2 shows an example of integrated (upper channel) and nonintegrated (lower channel) BT-EMG activity recorded in the masseter muscle of one subject (patient No. 3), with dynamic variations (series A) and static variations (series B) of the VD.

Among the integrated and nonintegrated recordings obtained with dynamic variations of the VD, there was apparently a similar tendency showing a gradual decrease of basal tonic EMG activity starting from mandibular occlusal position, reaching an area of less activity at a certain interocclusal distance, and then gradually increasing to the highest values that appear close to maximum opening.

Integrated EMG recordings (upper channel) obtained with static variations of the VD between 1 and 40 mm of interocclusal distance showed on one hand, the same tendency described for dynamic variations. On the other hand, they denoted the exact site where minimum BT-EMG activity of the

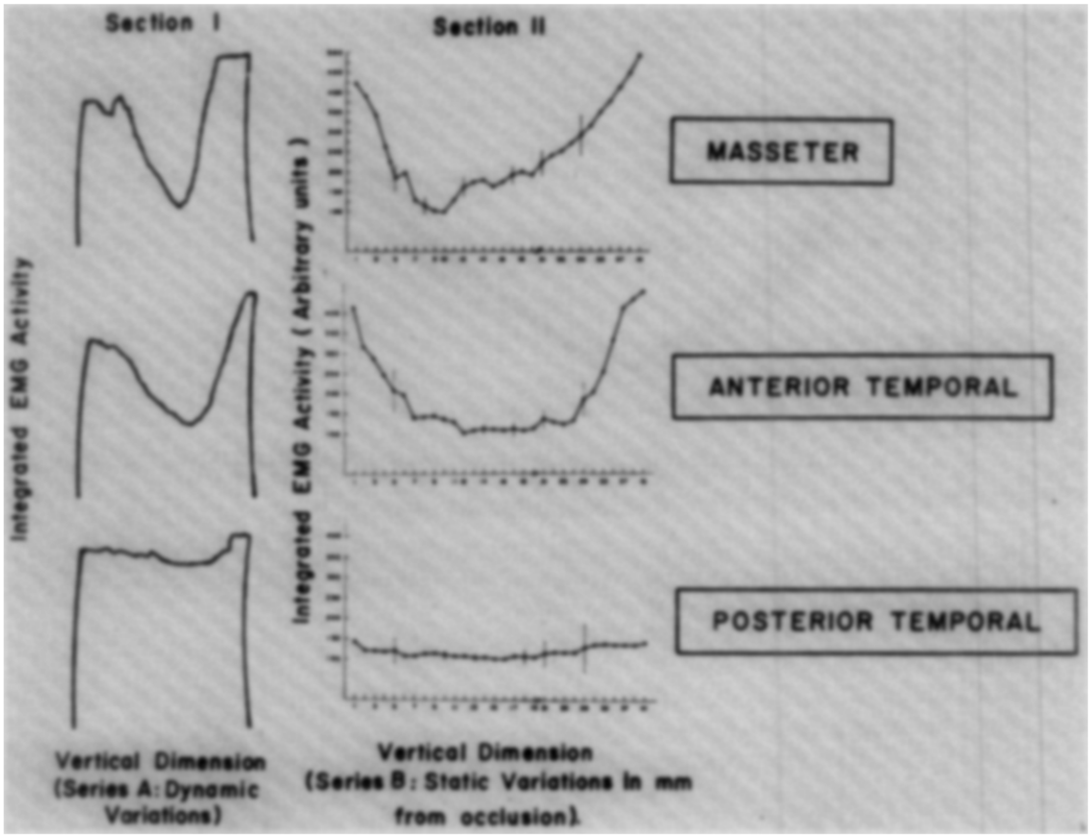

Fig. 3. Vertical dimension versus BT-EMG activity of the three muscles for subject No. 8. Section I, VD dynamic variations (series A, first session). Section II, VD static variations (series B, average of five sessions). *Vertical bars* represent standard deviations of mean values.

masseter muscle occurred, recorded at 10 mm of interocclusal distance. The nonintegrated EMG recordings (lower channel) of the same series B did not allow the area of least muscular electrical activity to be specifically identified, as the recordings around it were very similar.

Fig. 3 shows the relation between EMG activity and VD variations in an experimental subject (patient No. 8). This figure can be divided into two sections:

Section I. showed the curves for BT-EMG activity for masseter, anterior temporal and posterior temporal muscles in session 1, with dynamic variations of the VD (series A).

Section II. corresponded to the relation between BT-EMG activity of the same three muscles (in the ordinate) and static variations of the VD (series B) from 1 to 41 mm of interocclusal distance (in the abscissa). Curves corresponded to average values of the integrated EMG activity of the five sessions for the same subject.

Observations of the recordings of masseter, anterior temporal, and posterior temporal muscles of sections I and II showed a trend similar to that described in Fig. 2.

The recordings of the masseter muscle showed a steeper, more circumscribed EMG activity decrease (at 9 to 10 mm of interocclusal distance in section II) compared to the posterior temporal, which showed a slight, not very evident decrease stretched over a larger VD range (around 6 to 19 mm of interocclusal distance in section II). The anterior temporal curve presented an intermediate tendency throughout (between 12 to 19 mm). If we analyze the VD, which presents minimum EMG activity, a clear dephasing in the recording of the three muscles can be observed. Masseter muscle curves presented minimum electrical activity closer to occlusal VD (between 9 to 10 mm of interocclusal distance, section II). Posterior temporal muscle recordings showed least activity closer to maximal jaw opening (between 15 to 16 mm interocclusal distance, section II).

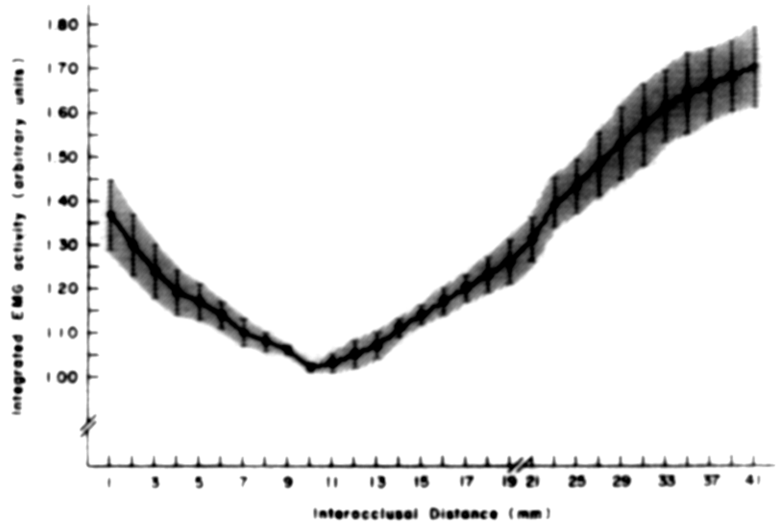

Fig. 4. VD static variations (series B) versus BT-EMG activity of masseter muscle. (Curves for Figs. 4 to 6 correspond to five sessions averaged across eight experimental subjects.) *Vertical bars* represent standard deviations of mean values.

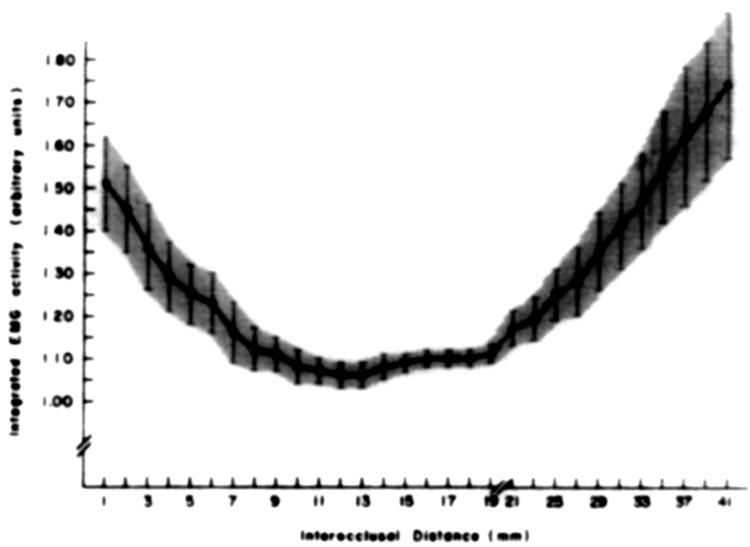

Fig. 5. VD variations (series B) versus BT-EMG activity of anterior temporal muscle.

Again, the anterior temporal curve remains at an intermediate position (12 mm interocclusal distance).

Figs. 4 to 6 show the relation between BT-EMG of masseter, anterior temporal, and posterior temporal muscles, respectively, as well as the static variations of VD (series B) for the five sessions averaged through the eight experimental subjects, from 1 to 41 mm of interocclusal distance. To evaluate errors in the measurements performed in the five recording sessions in each subject, an analysis of variance was performed. F ratios showed no significant difference within or between subjects.

There was an ample correspondence between the tendency of EMG curves of Figs. 4 through 6 and those of Fig. 3 for a single subject, reaching a minimum EMG activity at a certain interocclusal distance specific for each muscle (10 mm for the masseter muscle, approximately 12 to 13 mm for the anterior temporal muscle, and approximately 15 mm for the posterior temporal muscle).

Table I shows the values of interocclusal distance

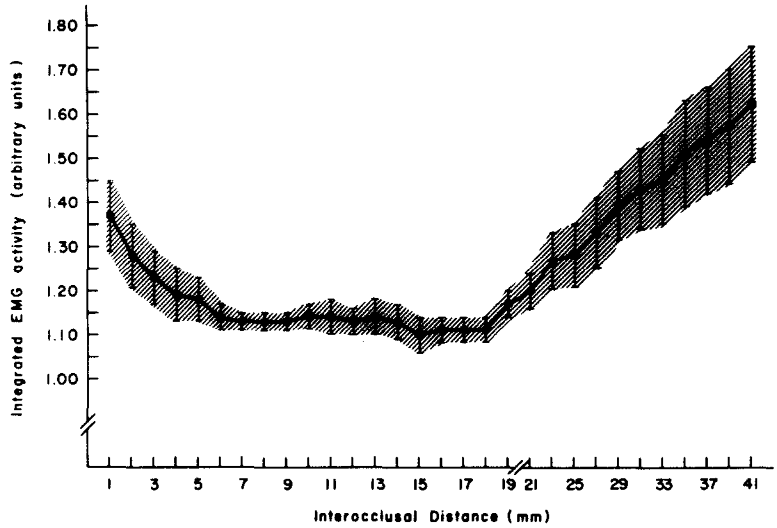

Fig. 6. VD static variations (series B) versus BT-EMG activity of posterior temporal muscle.

Table I. Interocclusal distance corresponding to the minimal EMG activity for each experimental subject

Experimental subject No.	Muscles* Masseter (mm)	Anterior temporal (mm)	Posterior temporal (mm)
1	11	16	16
2	11	11	18
3	10	13	14
4	9	13	13
5	8	8	17
6	10	13	15
7	10	12	15
8	10	12	16

*Mean distances are 10, 12.5, and 15.5 mm for the masseter, anterior temporal, and posterior temporal muscles, respectively.

in millimeters, corresponding to minimum EMG activity for each experimental subject (average of five recorded sessions for series B) and for each muscle studied.

In Table II, the decrease of integrated EMG activities in the three muscles is expressed in percentage, obtained from the values graphed in Figs. 4, 5, and 6, respectively. The value for EMG activity at 1 mm of VD was determined as 100%; other values were referred to this in percentages. From the comparative analysis of the three muscles studied, it can be observed that the anterior temporal muscle presents the largest percentage of EMG decrease at the different interocclusal distance, while in masseter and posterior temporal muscles this decrease is less.

Table II. Quantitative analysis of the decrement of BT-EMG activity (series B)

VD (mm from occlusion) for subject No.	Muscles Masseter (%)	Anterior temporal (%)	Posterior temporal (%)
1	100	100	100
2	95	96	93
3	91	90	90
4	87	85	87
5	85	83	86
6	83	81	83
7	80	77	82
8	79	74	82
9	77	73	82
10	74	72	83
11		71	83
12		70	82
13		70	83
14			82
15			80

DISCUSSION

Carlsöö[13] and Jarabak[5] described an "electromyographic silence" during mandibular opening. Shpuntoff and Shpuntoff[6] and Yemm and Berry[7] found that there was an absence of electric muscular activity in the mandibular postural position. In the present study, electromyographic silence did not occur in any vertical mandibular position. On the contrary, BT-EMG activity was recorded in any mandibular position along the habitual path of opening.

Various studies[8, 14] have reported less muscular activity when the jaw was in its postural position. Experimental results obtained in this study indicate that the BT-EMG activity of the three muscles studied decreases when the jaw is depressed beyond the occlusal position, reaching the minimum as a certain VD range specific for each individual muscle. Further from this point, electric muscular activity increases, presenting maximum values at a vertical dimension close to maximum opening. Consequently, EMG determination of the mandibular postural position seems rather uncertain.

This trend of the tonic activity of the mandibular postural muscles was also observed by Göepfert and Göepfert[9] and by Garnick and Ramfjord.[10] Nevertheless, only the measurements of the last work are homologous to ours, as this study also used a graduated device that allowed a discriminative study (in millimeter per millimeter) of the VD variations. Garnick and Ramfjord[10] determined an area of constant minimal electrical activity for masseter, anterior and posterior temporal, and anterior digastric muscles which they called "resting range." The average for the four muscles studied was 11.1 mm. The VD of minimum EMG activity was not localized for any muscle, as direct, nonintegrated EMG recordings were performed. The advantages of an integrated EMG are evident as the electric muscular phenomenon can be quantified, thus allowing a time recording.[1, 15] This helps to perform a more exact discrimination of EMG potentials during basal tonic activity which is usually very low. Small variations of tonic activity are often impossible to determine using an oscilloscope or polygraph with direct, nonintegrated EMG inscription. (See Fig. 2, series B, among the curves for 5, 9, 10, and 11 mm of interocclusal distance.)

Our experimental results agree with those of Rugh et al.[11] who found a specific VD of minimum EMG activity of each subject ranging from 5 to 14 mm. They determined an EMG rest position of less activity that was inferior to the clinical mandibular rest position.

The relation between EMG, bite force, and elongation of masseter and anterior temporal muscles was analyzed in two previous studies.[1, 2] These studies demonstrated that while EMG activity decreases as the teeth are further from occlusion, masticatory force increases; as EMG increases approaching maximum opening, bite force decreases. Comparing the results of these two studies with our study, it should be noted that the VD of minimum EMG activity (10 mm of interocclusal distance for the masseter muscle and 13 mm for the anterior temporal muscle) was found close to the VD that corresponds to the optimum physiologic muscular elongation (13 to 21 mm interocclusal distance). The major variations of these vertical dimensions are due to the different techniques used for interocclusal measuring and probably to the craniofacial skeletal characteristic, which will be the subject of a future study.

Our results confirm the difference between resting length of the jaw elevator muscles (from 10 to 16 mm interocclusal distance) and the postural length of these muscles (mandibular postural position, from 1 to 3 mm interocclusal distance).

The decrease of electrical activity in the three muscles as VD increases may be explained by "the passive elastic force of the muscles carrying a larger part of the load on the muscle as its length increases."[7, 8, 16] Furthermore, the action of opening the mouth implies a mechanism of reciprocal innervation with nervous impulses that excite the motor neurons of the mandibular depressor muscles and inhibit those of the elevator muscles.[17]

In relation to this muscular mechanism, Carlsöo[4] and Jarabak[5] have shown that as the activity in the elevator muscles disappears, immediately after the contact between the teeth is broken, the activity of the digastric muscle increases, reaching its maximum at the fully open position. Garnick and Ramfjord[10] demonstrated that during slow opening movement the activity in the masseter, temporal, and digastric muscles decreases after the heavy occlusal contact is released. A progressive increment in the activity of the digastric muscle was noted from the half-open mandibular position up to the maximal opening.

The increase of EMG activity further from this VD range of minimum muscular electrical activity could probably be due, in part, to an active stimulation of the masseter and temporal neuromuscular spindles and, in part, to the stimulation of the receptors of the temporomandibular joint.[17] The discharge of both groups of propioceptors would produce a gradual excitation of the elevator motor neurons. This can be appreciated in the VD range close to maximum mouth opening where greater EMG activity of both the masseter and temporal muscles is observed (Figs. 4 to 6).

Several hypotheses have been offered to explain the clinical effectivity of the occlusal splint in the treatment of muscular spasms in bruxism and myofacial pain-dysfunction syndrome. One hypothesis maintains that success in reducing myospasm is due to the muscular relaxation produced by a decrease of EMG activity of the jaw muscles.[18-21] Table II sustains this hypothesis as all three muscles show a noticeable decrease of BT-EMG activity as VD increases.

SUMMARY

The relation between BT-EMG activity and variations of VD (1 to 41 mm of interocclusal distance) was studied in the masseter, anterior temporal, and posterior temporal muscles of eight normal experimental subjects. EMG activity was recorded with surface electrodes, and the VD was measured with a specially designed device. Recordings were performed with dynamic variations (series A) and with static variations (series B) of VD. Series A shows a gradual decrease of EMG activity starting from the occlusal position, passing through a range of maximum reduction at a certain interocclusal distance, and gradually increasing to the highest values close to maximum jaw opening. Series B shows the same progression, although it points out the exact VD at which minimum basal EMG activity is observed in each muscle studied (10 mm for the masseter muscle, 13 mm for the anterior temporal muscle, and 16 mm for the posterior temporal muscle).

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