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Influence of variation in anteroposterior occlusal contacts on electromyographic activity

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A full upper stabilization splint divided into three pairs of occlusal bilateral blocks was made for eight healthy young adult subjects. The three pairs of blocks allowed the location of the centric occlusal contacts to vary and to be distributed over equivalent periodontal surfaces. The electromyographic activity of the masseter and temporal muscles was recorded with surface electrodes during maximum voluntary clenching over the centric occlusal blocks. The electromyographic activity from the elevator muscles with the anterior blocks was significantly less than with the intermediate and posterior occlusal blocks. With use of the intermediate blocks, the activity from the elevator muscles was significantly less than with the posterior blocks. The elevator activity with the posterior blocks was similar to that with the full coverage splint. (J PROSTHET DENT 1989;61:617-23.)

The influence of the number and location of tooth contacts on elevator muscular activity has been reported by several authors. Möller[1] suggested that jaw muscle activity is dependent on the number of occlusal contacts. Furthermore, Van Steenberghe and De Vries[2] showed that an increase in the number of teeth that come into contact on both sides of the arch results in an increase of the force that can be developed between the jaws.

Wood and Tobias[3] described a small and insignificant decrease in total muscle activity when maximum vertical clenching on a balanced occlusal splint was compared with clenching on a splint where tooth contacts were removed on one side. MacDonald and Hannam[4] reported that when muscle activity during a clench on the anterior incisal block that involves 12 anterior teeth is compared with muscle activity during a clench on a unilateral molar stop that includes two posterior teeth, no significant differences were observed. However, as the number of contacts increased in the posterior combinations, the muscle activity of the anterior incisal block clenches generally were observed to be less. This finding suggests that for the anterior teeth an increase in the number of contacts and probably, therefore, of the contact surface area is important. However, for posterior teeth the muscles reach nearly optimal levels earlier with fewer contacts, and the muscles do not seem to be affected as significantly by the number and surface of contacts.

As far as we know, no formal work has been conducted to study the influence of the location of tooth contacts on elevator muscular activity when maintaining the periodontal surface areas constant. Therefore, the aim of this work was to determine the effect of variations in the localization of tooth contacts in centric occlusion on both sides of the dental arch on the integrated EMG activity of masseter and anterior temporal muscles during maximal voluntary clench-

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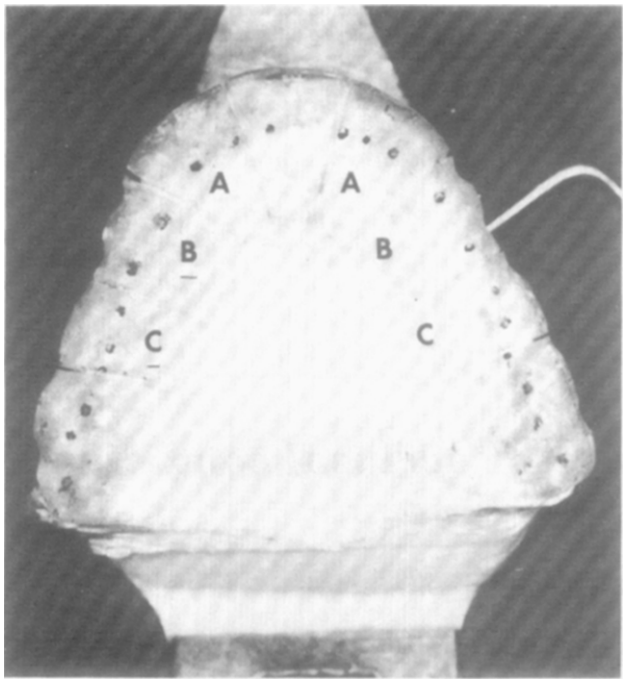

Fig. 1. Maxillary occlusal splint divided in different pairs of occlusal blocks. *A* - *A*, Anterior blocks; *B* - *B*, intermediate blocks; *C* - *C*, posterior blocks.

ing, maintaining the surface of periodontal areas constant. In addition, the biomechanic and neurophysiologic considerations involved in the EMG behavior are explained.

MATERIAL AND METHODS

This study was performed on eight subjects, four women and four men, in the age range of 19 to 24 years with a mean of 23.1 years, with healthy functional occlusion, bilateral molar support, and absence of signs and symptoms of craniomandibular dysfunction. Each subject underwent a clinical and functional examination in accordance with an occlusal diagnostic record that had been specially prepared for this investigation.

For each subject a full maxillary stabilization occlusal splint was made of transparent thermopolymerizing acrylic resin, with flat occlusal surfaces and uniform, simultaneous, and multiple occlusal contacts at centric relation–centric occlusion. The increase in the vertical dimension of occlusion produced by the splints ranged from 1 to 2.1 mm in the first premolar region.

After 4 days of use to allow for adaptation before EMG recordings, the splints were divided on both sides into three pairs of occlusal blocks (Fig. 1): two anterior blocks with contact of the lower canines and lateral incisors (Fig. 2, *A*); two intermediate blocks with contact of both mandibular premolars (Fig. 2, *B*); and two posterior blocks with contact of the first mandibular molars (Fig. 2, *C*). The occlusal blocks were lined with Temp Bond liner (Kerr/Sybron, Romulus, Mich.) for better retention. This procedure accomplished the following results:

1. It varied the anteroposterior centric localization of occlusal contacts.

2. It ensured that the localization of occlusal contacts covered nearly equivalent periodontal surface areas[5] as follows:

—Right and left anterior blocks: sum of the periodontal surface areas of the right and left lateral incisors and maxillary canines = 904 mm^2
—Right and left intermediate blocks: sum of the periodontal surface areas of the two right and two left maxillary premolars = 908 mm^2
—Right and left posterior blocks: sum of the periodontal surface areas of the right and left first premolar = 866 mm^2

EMG recordings of the left masseter and anterior temporal muscles were performed by placing bipolar surface electrodes (Grass 5e 5s, Grass Instrument Co., Quincy, Mass.), applying the technique described in previous articles.[6,7] EMG activity was filtered (80 Hz to 100 kHz), amplified 1000 times, and then amplified again 10 times, integrated (time constant 1800 msec), and finally registered in a polygraph (Nihon Kohden RJG-4022, Nihon Kogyo Co. Ltd., Tokyo, Japan).

The subjects, sitting in upright position in a dental chair with the head supported inside a Faraday cage, were submitted to the following recording series of EMG activity during maximal voluntary clenching in centric occlusion, within a time period of 4 seconds, with a 20-second rest period between clenchings to avoid muscular fatigue:

Series 1: Three recordings without splint (Fig. 3, *A*)
Series 2: Three recordings with the complete splint inserted (Fig. 3, *B*)
Series 3: Three recordings with both anterior occlusal blocks inserted (Fig. 2, *A*)
Series 4: Three recordings with both intermediate occlusal blocks inserted (Fig. 2, *B*).
Series 5: Three recordings with both posterior occlusal blocks inserted (Fig. 2, *C*)

ANALYSIS OF DATA

In each series the peak of the integrated EMG activity of the three curves registered at the left anterior temporal and masseter muscles was manually measured.

Subsequently, a mean value was used for each subject, based on the three curves in each series and for each muscle, because the standard deviation was similar and negligible.

The mean value of the EMG activity obtained for each muscle during maximal voluntary clenching in centric occlusion with the complete splint inserted (series 2) was assigned the value of 100%. The mean values of the remaining four series were expressed in percent of the thus defined 100%.

The nonparametric Friedman test was used to compare the series for each muscle. Comparisons of the different series were done through the Wilcoxon rank test.

RESULTS

Tables I and II show the mean values expressed as percent of integrated EMG activity for the masseter and the anterior

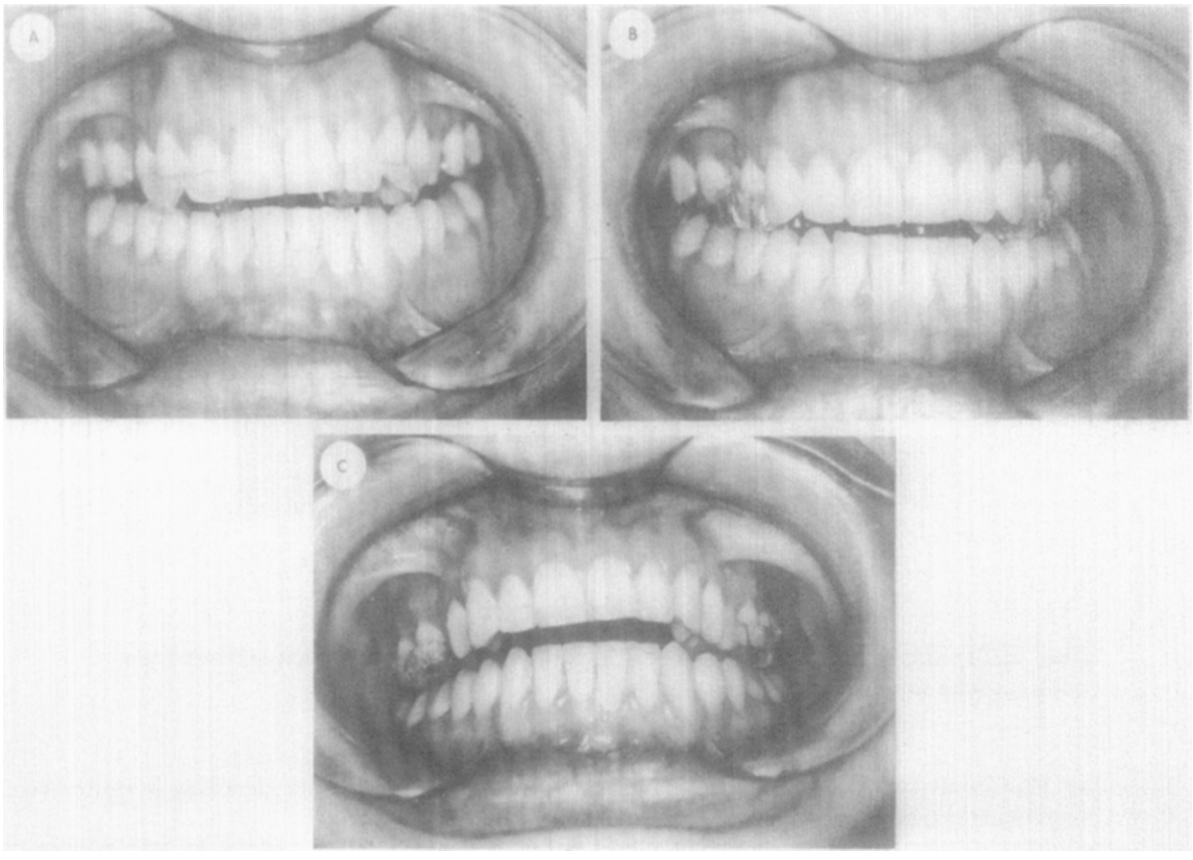

Fig. 2. Subject in centric occlusion with both anterior occlusal blocks inserted **(A)**, with both intermediate occlusal blocks inserted **(B)**, and with both posterior occlusal blocks inserted **(C)**.

temporal muscles of each subject for each recording series. Also shown are the group means and standard deviation for the eight subjects for each one of the five recorded series.

The tables show that the EMG activity of the masseter muscle during maximal voluntary clenching while the fully covering splint was placed in the mouth (series 2) was greater than without the splint (series 1), whereas the EMG activity of the anterior temporal muscle with the splint, compared with the series without the splint, was nearly the same.

Furthermore, for both muscles a manifest reduction of the EMG activity occurred for series 3 (anterior occlusal blocks) in relation to the other series. Although the masseter and temporal activity was greater in series 4 (intermediate occlusal blocks) than in series 3, it was smaller compared with the other series studied. In addition, it can be noted that the activity of both elevator muscles in series 5 (posterior occlusal blocks) was similar to that of series 2 (with the complete splint inserted).

Although it is true that the description of the integrated EMG activity of the masseter muscle and the anterior temporal muscle among the different series studied reflected the general tendency shown in the group mean of the eight subjects, Tables I and II indicate that the EMG activity of some subjects showed deviations from the described general activity.

Fig. 4 shows the group mean of the eight subjects for each

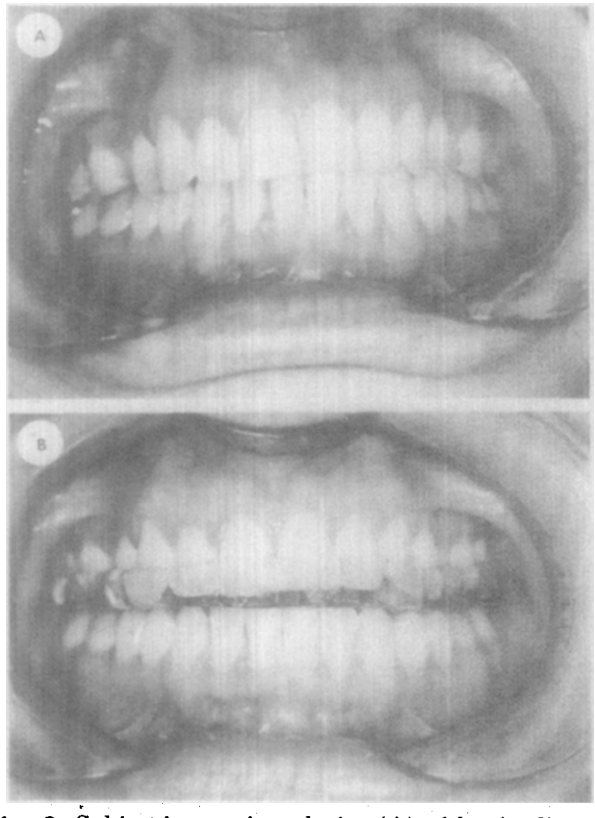

Fig. 3. Subject in centric occlusion **(A)** without splint and **(B)** with complete splint inserted.

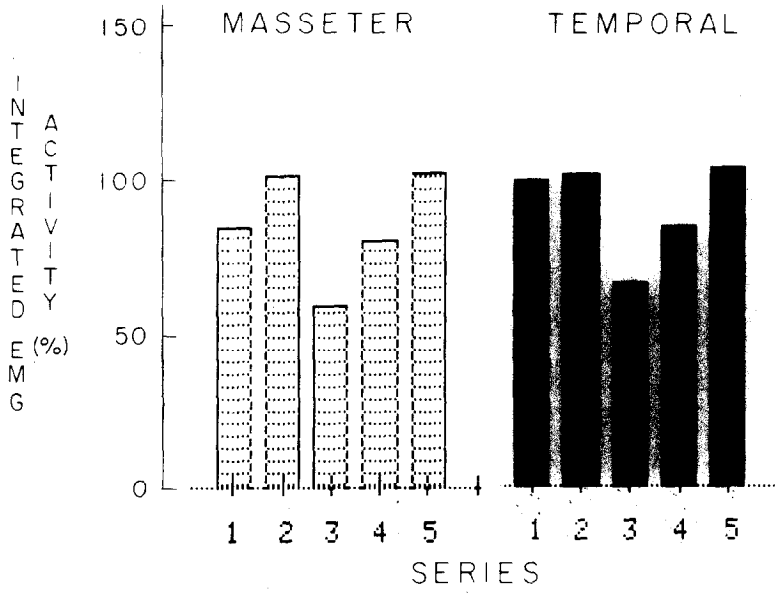

Fig. 4. Bar graph showing group mean of integrated EMG activity of masseter and temporal muscles for each experimental series.

Table I. Integrated EMG activity (%) of the masseter muscle during maximal voluntary clenching in centric occlusion for the different experimental series

Subjects	Series 1 (Without splint) $\bar{X}$	Series 1 (Without splint) SD	Series 2 (With splint)	Series 3 (Anterior occlusal blocks) $\bar{X}$	Series 3 (Anterior occlusal blocks) SD	Series 4 (Intermediate occlusal blocks) $\bar{X}$	Series 4 (Intermediate occlusal blocks) SD	Series 5 (Posterior occlusal blocks) $\bar{X}$	Series 5 (Posterior occlusal blocks) SD
1	62.88	2.2	100	39.93	0.8	64.69	1.3	97.54	6.2
2	83.91	4.5	100	71.36	3.1	78.02	5.6	104.23	12.4
3	95.44	0.6	100	52.89	2.4	71.18	3.3	98.95	5.5
4	81.23	5.0	100	66.72	4.2	85.20	5.9	94.95	3.2
5	90.39	5.3	100	59.66	5.5	85.72	2.9	99.55	3.7
6	94.60	2.5	100	67.88	2.9	92.95	2.8	101.32	7.5
7	73.37	3.0	100	52.63	1.8	77.65	2.0	110.59	8.2
8	80.00	5.8	100	52.85	3.2	74.29	4.9	97.14	3.8
Total	82.73	11.0	100	57.99	10.4	78.72	9.0	100.53	4.9

recording series of the integrated EMG activity of the masseter and anterior temporal muscles. These values were obtained from Tables I and II. In this figure one can visualize the already described behavior of both muscles in the sense that the activity of the masseter muscle in series 2 was similar to that of series 5 and larger than that of series 1, 3, and 4. On the other hand, the activity of the temporal muscle of series 2 was similar to that of series 1 and 5, but greater than that of series 3 and 4. For both elevator muscles the smallest activity was seen in series 3.

Table III compares all of the series studied. Significant differences of EMG activity were found for both muscles (nonparametric Friedman test).

Table IV compares paired series in both muscles. In the masseter muscle the activity without a splint (series 1) was significantly less than that recorded with the splint in place (series 2). On the other hand, for the temporal muscle no significant differences were observed.

In addition, the activity recorded with the splint in place (series 2) was significantly greater for both elevator muscles than the one that results with the anterior occlusal blocks in place (series 3) and with the intermediate occlusal blocks in place (series 4). On the other hand, the EMG activity in series 2 did not differ from that recorded with the posterior occlusal blocks in place (series 5).

The EMG activity of the masseter and temporal muscles with the anterior occlusal blocks in place (series 3) was significantly smaller than that recorded with the intermediate occlusal blocks in place (series 4) and with the posterior occlusal blocks in place (series 5). On the other hand, the EMG

Table II. Integrated EMG activity (%) of the anterior temporal muscle during maximal voluntary clenching in centric occlusion for the different experimental series

Subjects	Series 1 (Without splint) $\bar{X}$	Series 1 (Without splint) SD	Series 2 (With splint)	Series 3 (Anterior occlusal blocks) $\bar{X}$	Series 3 (Anterior occlusal blocks) SD	Series 4 (Intermediate occlusal blocks) $\bar{X}$	Series 4 (Intermediate occlusal blocks) SD	Series 5 (Posterior occlusal blocks) $\bar{X}$	Series 5 (Posterior occlusal blocks) SD
1	57.28	2.5	100	34.08	0.5	48.43	0.5	76.71	6.6
2	109.89	0.0	100	64.12	3.2	81.04	10.4	112.80	7.1
3	103.73	3.3	100	79.96	1.1	86.88	2.1	102.64	3.1
4	112.11	7.5	100	79.22	3.5	88.34	2.3	104.48	3.0
5	98.70	3.7	100	46.17	11.1	86.04	5.4	104.76	6.9
6	113.70	5.2	100	92.73	4.5	110.29	1.9	112.86	7.3
7	91.66	3.5	100	64.17	8.0	84.27	4.3	101.59	0.3
8	92.86	5.2	100	60.00	5.0	78.57	5.1	98.57	3.4
Total	94.49	18.3	100	65.06	19.0	82.96	16.9	101.80	11.3

Table III. Analysis of integrated EMG activity of masseter and anterior temporal muscles between all series studied (nonparametric Friedman test)

Condition	Masseter muscle Xr^2	Temporal muscle Xr^2
Between all series	29**	69.5**

**$p < 0.001$.

Table IV. Analysis of integrated EMG activity of masseter and anterior temporal muscles between paired series (Wilcoxon rank test)

Comparison between condition	Masseter muscle	Temporal muscle
Series 1 vs series 2	*	NS
Series 2 vs series 4	*	*
Series 2 vs series 4	*	*
Series 2 vs series 5	NS	NS
Series 3 vs series 4	*	*
Series 3 vs series 5	*	*
Series 4 vs series 4	*	*

*$p < 0.01$.

activity of both muscles with the intermediate occlusal blocks in place was significantly less compared with that recorded with the posterior occlusal blocks in place (series 5).

DISCUSSION

This study shows a different behavior in the EMG activity of the masseter and anterior temporal muscles during maximal voluntary clenching in centric occlusion with the splint in comparison to the behavior obtained without the splint. Although the activity of the masseter muscle significantly increases with the splint, the activity of the anterior temporal muscle is similar under both conditions.

The greater activity of the masseter muscle with the splint agrees with the observations of Wood and Tobias,[3] Freesmeyer and Manns,[8] Miralles et al.,[9] and Manns et al.[10]

A possible explanation for this increased activity of the masseter muscle is that it is mainly a generator of interocclusal force.[11, 12] The application of a full upper stabilization splint creates an effective occlusal stability of the mandible in centric occlusion through bilateral, simultaneous, and symmetrically distributed occlusal contacts of equal intensity of the lower teeth over the functional surface of the splint. Under this condition, the masseter muscle is able to develop its greatest power.

Another explanation for the increased masseteric activity is that this muscle responds efficiently under the effect of an occlusal splint, which provides full coverage of the occlusal surfaces of the teeth and absorbs pressures from the periodontal structures of all teeth, thereby allowing greater muscular activity to develop.

The similar behavior of the EMG activity of the anterior temporal muscle with and without a splint is in accordance with the findings of Freesmeyer and Manns,[8] Miralles et al.,[9] and Manns et al.,[10] but it is in disagreement with those of Wood and Tobias[3] who observe an increase of the EMG activity with the splint in place. This similar behavior of the temporal activity muscle under both conditions is probably because this muscle functions more as a postural muscle of the mandible than as a force generator.[11, 12]

The anteroposterior location of tooth contacts was seen to have a marked effect on the muscles involved in clenching tasks. A highly significant decrease of the EMG activity of the masseter muscle and the anterior temporal muscles was observed during maximal voluntary clenching with the anterior blocks in place, compared with that obtained with the intermediate blocks. On the other hand, the greatest EMG elevator muscle activity was observed when posterior contacts were used (posterior occlusal blocks). Since the EMG activity and the closing force have a linear relationship un-

der isometric contractions at the same muscle length or vertical dimension, the listed findings agree with previous studies that used tension transducers to measure the occlusal force between pairs of teeth.[13-15]

The effect of the reduction of the EMG elevator muscle activity with occlusal contacts located in the anterior part of the arch compared with that obtained with occlusal contacts located closer to the posterior part of the arch, may be explained in the context of the following biomechanical and neurophysiologic considerations.

Since the stomatognathic system functions like a third-degree lever,[15, 16] the muscles that elevate the mandible will generate a greater muscle activity and occlusal force from the posterior teeth than from the anterior teeth.

Neurophysiologically, the posterior teeth present a lesser density of periodontal mechanoreceptors with a higher mechanosensitive threshold. The anterior teeth have a greater density of periodontal mechanoreceptors with a lower mechanosensitive threshold.[17-19] The periodontal mechanoreceptors are sensitive to pressure, and their afferent information is carried to the motor nucleus through the sensitive nuclei of the trigeminal nerve. They are used in inhibitory feedback mechanisms to the jaw elevator muscles that protect the teeth from excessive and unphysiologic loads.[20-22]

In this investigation, the periodontal stimulation is caused by maximal clenching on the occlusal blocks of the splint. The pressure transferred to the periodontium is directly proportional to the occlusal force and indirectly proportional to the surface area of the periodontium over which the pressure is distributed. Since occlusal blocks with nearly equivalent periodontal surface areas were used, the periodontal pressure was only proportional to the occlusal force.

Because the activity of the elevator muscles and the resulting occlusal force are minor at the anterior teeth, according to the biomechanical considerations already mentioned, it therefore can be expected that a lower periodontal pressure activates the periodontium on the level of the anterior occlusal blocks. In this way, the lesser EMG activity registered with these blocks is due to a greater mechanosensitive elevator inhibitory mechanism arising from a greater density of periodontal mechanoreceptors with a lower threshold.

The decrease of the muscular activity during maximal voluntary clenching on the anterior occlusal blocks indicates that pressure areas are created on the level of both temporomandibular joints because posterior occlusal support is lacking.[3, 23] For this reason the inhibitory reflex effect also originates partially from the articular proprioceptors.[10]

In this investigation, the EMG activity of masseter and anterior temporal muscles during maximal clenching with both posterior blocks in place did not differ from that with a complete splint in place. MacDonald and Hannam[4] found similar EMG activity of the elevator muscles during maximal clenching in centric position over acrylic resin occlusal stops when these stops were positioned on the level of both second molars, as well as with bilateral and symmetrically distributed occlusal stops, designed by them to simulate the intercuspal position. This finding indicates that the elevator muscles reach optimal levels of EMG activity, even with fewer occlusal contacts located closer to the posterior part of the dental arch. On the other hand, these findings seem to show that to allow for the development of greatest occlusal forces during maximal voluntary clenching in centric position it is important to establish bilateral and symmetrical occlusal contacts on the posterior teeth. The number of these contacts is less important than their location.

To summarize, the results of this study suggest that the use of blocks with nearly equivalent periodontal surface areas allows more accurate differentiation between the biomechanic and neurophysiologic factors that are involved in the varying localization of the tooth contacts.

SUMMARY

A full maxillary stabilization splint divided into three pairs of occlusal bilateral blocks was made for eight young adult subjects (mean age 23.1 years), with functional occlusions and no craniomandibular dysfunction. The blocks were divided as follows: two anterior blocks wherein the mandibular lateral incisor and canine were in contact; two intermediate blocks with contacts of both mandibular premolars; and two posterior blocks with contacts of the first mandibular molar. This made it possible to vary the location of the occlusal contacts in centric occlusion and to distribute them over equivalent periodontal surface areas.

The EMG activity of the masseter and temporal muscles was recorded with surface electrodes during maximum voluntary clenching in centric occlusion.

CONCLUSIONS

This investigation produced the following conclusions:

1. The elevator muscle EMG activity with anterior blocks was significantly less than with intermediate occlusal blocks or posterior blocks.
2. The elevator muscle activity using intermediate blocks was significantly less than that with posterior blocks.
3. The elevator muscle activity using posterior blocks was similar to that recorded with the full coverage splint.
4. The variations of the EMG elevator muscle activity were interpreted on the basis of biomechanical and neurophysiologic considerations.
5. To allow the development of greatest occlusal forces in centric occlusion, it is important to establish bilateral and symmetrical occlusal contacts of the posterior teeth. The number of these contacts is less important than their location.

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