Relationship between occlusal contacts and jaw-closing muscle activity during tooth clenching: Part I

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The literature is replete with articles concerned with bruxism, its etiology, and its treatment.[1-3] Bruxing or parafunction, whether it includes clenching or grinding, is considered to involve frequent and often long-lasting tooth contact with the appearance of symptoms in the teeth, muscles, and jaw joints that may progress to overt pathology.[2-6]

While there is an apparent association among clenching or grinding, signs of dysfunction, and excessive stress in the teeth and joints, no formal work seems to have been conducted to describe the muscle groups involved and their electromyographic responses when clenching or grinding is carried out in specified directions on specified occlusal contacts. Aside from its value in diagnosis and treatment, such information would be useful when simulating biomechanical stresses at the teeth and articular surfaces, because modeling techniques are sensitive to the tensions assigned to individual muscles.[7-10]

This article examines and describes the relationships between electromyographic activity in the jaw-closing muscles and the location, area, and direction of effort applied to specific bite (contact) points, some of which were selected to simulate clinical conditions.

METHODS

The experiments were divided into two parts. The first part involved vertically directed clenching tasks carried out at specific contact points, while the second included only eccentrically directed efforts.

Vertical effort study

Ten men were chosen at random with respect to occlusion and craniofacial type, the only criterion being that each subject have a reasonably intact dentition with good occlusal support around the arch. Ages ranged from 25 to 44 years with a mean of 35.4 years.

Occlusal stops. Dental casts were mounted on a Denar Mk II semiadjustable articulator (Denar Corp., Anaheim, Calif.), and six acrylic resin occlusion stops were made for each subject (Fig. 1). The stops were approximately 1 mm thick at the incisors with the articulator opened vertically from the subject's intercuspal position. They incorporated upper and lower teeth in the second molar and canine regions bilaterally and offered two alternative anterior schemes: an anterior incisal stop or an anterior incisal block that involved all teeth from canine to canine. The stop design included both upper and lower teeth to increase the stability of the stops, to eliminate the effect of cuspal inclines, and to prevent lateral movement while directing forces to the teeth as axially as possible. Zinc oxide-eugenol paste relines were performed prior to each recording session to enhance the stability and fit of the stops.

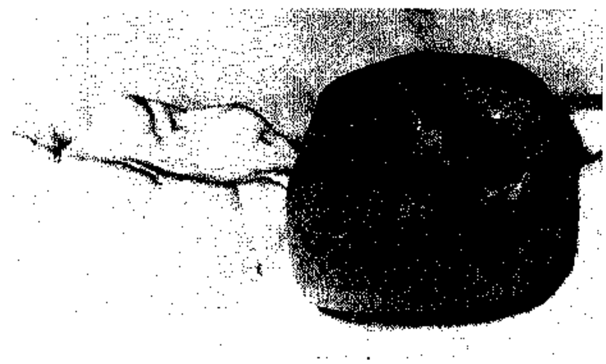

Fig. 1. Occlusal stop design illustrating size of typical molar stop and indentations of opposing cusps that prevented displacement during desired clenching task and provided stable interocclusal support.

Electromyography. Six muscle channels were available for electromyographic recordings. In all 10 subjects, bipolar surface electrodes recorded muscle activity from the anterior temporal muscle and the superficial masseter muscle bilaterally. In three subjects the posterior temporal muscles were recorded bilaterally. Electrode placement was chosen by palpation of the muscles prior to the session. Skin impedance was reduced with an alcohol scrub, and the electrodes were placed parallel with the muscle fiber orientation, secured with colloidin,

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Table I. Occlusal stop combinations used in vertical effort study

Task No.	Stop combination
1	Natural intercuspation
2	Simulated intercuspation (bilateral molars, canines, and incisor stops)
3	Incisor stop
4	Anterior incisal block
5	Left canine
6	Right canine
7	Left molar
8	Right molar
9	Left group contact (left canine and molar)
10	Right group contact (right canine and molar)
11	Left canine with right cross-arch molar
12	Right canine with left cross-arch molar
13	Left group contact with right cross-arch molar
14	Right group contact with left cross-arch molar

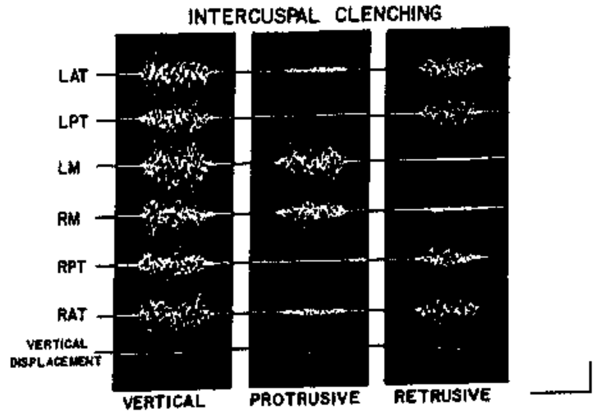

Fig. 2. Typical raw electromyographic signals for a sequence of intercuspal clenches viewed on storage oscilloscope. *LAT* = Left anterior temporal muscle; *LPT* = left posterior temporal muscle; *LM* = left superficial masseter muscle; *RM* = right superficial masseter muscle; *RPT* = right posterior temporal muscle; *RAT* = right anterior temporal muscle. Calibration bars are illustrated on lower right with *vertical bar* representing 300 μV and *horizontal bar* representing 1 second. Vertical displacement channel was used only to identify gross displacements and was not calibrated.

and filled with Redux-Creme (Hewlett-Packard, Waltham, Mass.) electrode conducting paste. A ground electrode was secured to the right wrist. In seven subjects, electromyographic activity was measured in the left medial pterygoid muscle by means of paired, insulated, fine wire electrodes, 0.002 inch in diameter. These were introduced intraorally through a 27-gauge hypodermic needle placed in the middle anterior portion of the muscle. The wires were attached to the buccal mucosa of the left maxilla with adhesive wax before being led out of the corner of the mouth. Care was taken not to disturb the wire positioning during the subsequent placement of the occlusal stops.

All recorded signals were amplified, filtered, and sampled each millisecond by the analog to digital converter of a disc-based computer system (Hewlett-Packard, 1000 series E and peripherals).[11]

Tasks. Each subject was instructed to perform 10 vertical clenches per task, alternating between a subjective maximum comfortable clench and a subjective half maximal clench. The half maximal clench was introduced to allow the subject a rest and to gather submaximal clenching data that might have had some behavioral significance. Because the occlusal stops were easy to remove and replace, a different combination was used after each set of 10 clenches. The stop combinations are described in Table I and were introduced in a random sequence.

Data handling. Typical responses for an intercuspal clench, protrusive clench, and retrusive clench are seen in Fig. 2. The raw data could be examined and errant clenches edited or removed if judged to be spurious either as a result of the subject not performing the clench or, rarely, if a stop broke during the clench. Raw data in digitized form were stored for each muscle and task, and means and standard deviations were calculated over a 400 msec period about the center of the response for each clench. For each muscle, a mean and standard deviation for the task as a whole could then be derived by use of the mean values of each of the five responses that comprised the task.

Table II. Occlusal stop combinations used in eccentric effort study

Task No.	Stop combination	Direction of effort
1	Natural intercuspation	Vertical
2	Left molar	Vertical
3	Left molar	Ipsilateral (left)
4	Left molar	Contralateral (right)
5	Left molar	Protrusive
6	Left molar	Retrusive
7	Left canine	Vertical
8	Left canine	Ipsilateral (left)
9	Left group contact	Vertical
10	Left group contact	Ipsilateral (left)
11	Left canine, right molar	Vertical
12	Left canine, right molar	Ipsilateral (left)
13	Left group contact, right molar	Vertical
14	Left group contact, right molar	Ipsilateral (left)
15	Bilateral molars	Vertical
16	Bilateral molars	Left
17	Bilateral molars	Right
18	Bilateral molars	Protrusive
19	Bilateral molars	Retrusive

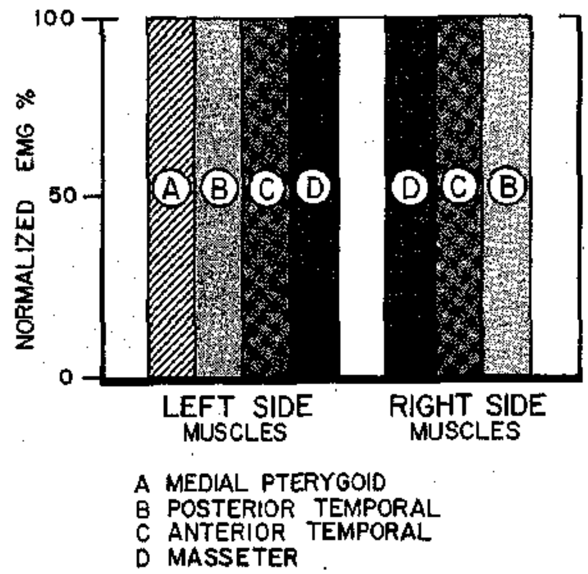

Fig. 3. All figures to follow are histograms that conform to format of this figure. Mean normalized EMG for grouped data are shown coded for each muscle according to key. In figures to follow, bars that represent one standard deviation are included in each histogram. Statistical comparisons of data for each figure are presented and referred to in the text. Descriptions of tasks and interpretations of figures are also found in the text. *A* = Medial pterygoid muscle; *B* = posterior temporal muscle; *C* = anterior temporal muscle; *D* = masseter muscle.

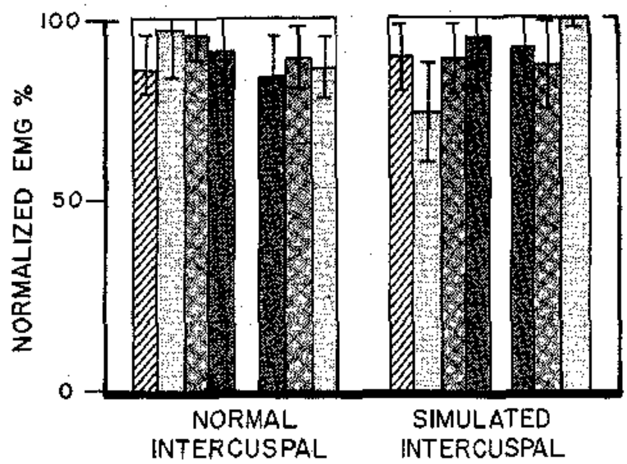

Fig. 4. Comparison of normalized muscle activity between vertical clenching in normal intercuspal and simulated intercuspal position. (See Fig. 3 legend for key.)

The mean data for each subject were normalized to their greatest individual response for the series of tasks; that is, each individual's greatest mean response for any task would be counted as 100% activity, and all other tasks performed by that subject would be expressed as a percent of the peak value. The normalized data were grouped to allow comparisons made by paired *t* test to describe the particular trends in muscle activity between specific tasks. Histograms were also compiled for the series with the means and standard deviations of the group normalized data.

Eccentric effort study

Ten subjects selected according to the same criteria as those described previously participated in the second study. Their ages ranged from 25 to 42 years, with a mean of 33.5 years.

The occlusal stop combinations used in this part of the study involved only the molar teeth of both sides and the left canine teeth. Six muscle channels were again available for electromyographic recordings. The left and right anterior temporal muscles, the left posterior temporal muscle, and the superficial masseter muscles of both sides were sampled in all subjects. The remaining channel was used for the left medial pterygoid muscle (five subjects) or the right posterior temporal muscle (five subjects).

Each subject was instructed to perform five subjective maximum comfortable clenches per task. Subjects were also instructed to clench vertically, left, right, protrusively, or retrusively, depending on the contact combination used. In combinations that involved the canine contact, only vertical and lateral efforts to the side of the canine were considered relevant; while on molar contacts vertical, left, right, protrusive, and retrusive efforts were all considered relevant to clinical situations. The stop design stabilized the jaw and essentially prevented lateral movement during the eccentric efforts from the opened intercuspal position. The tasks are summarized for stop combination and direction of effort in Table II.

In all other respects, the procedures used to obtain quantitative data were the same as those described for the first part of the study.

RESULTS

Vertical effort study

Intercuspal and simulated intercuspal position. With one exception, all muscle data recorded during clenches in the natural intercuspal position were not significantly different from those in the simulated intercuspal position (Figs. 3 and 4). Posterior temporal muscle activity, however, decreased significantly in the simulated case (Table III).

Anterior incisal block. Use of the anterior incisal block with coverage from canine to canine compared with the use of the incisal stop alone was associated with significantly greater normalized muscle activity in all muscles except the medial pterygoid, which maintained high activity in both tasks (Fig. 5). The activity produced

Table III. Comparison of normalized muscle activity between clenches in natural intercuspal position and simulated intercuspal position

Task comparison	Muscle						
	LMPT	LSM	RSM	LAT	RAT	LPT	RPT
ICP Sim. ICP (n)	NS 7	NS 10	NS 9	NS 10	NS 9	** 10	NS 3

Probability (p) of difference by chance determined by Student paired t test: N.S. = not significant, $p > .05$; $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$.
Normalized mean data statistically analyzed for comparison depicted and numbered at the left. ICP = Natural intercuspal position; sim. ICP = simulated intercuspal position with occlusal stops on second molars, canines, and incisors; n = number of comparisons analyzed for that muscle; LMPT = left medial pterygoid; LSM = left superficial masseter; RSM = right superficial masseter; LAT = left anterior temporal; RAT = right anterior temporal; LPT = left posterior temporal; RPT = right posterior temporal muscle.

Table IV. Comparison of normalized muscle activity produced on bite block clench with various other positions

Task comparison	Muscle						
	LMPT	LSM	RSM	LAT	RAT	LPT	RPT
Ant. incisor (n)	NS 5	*** 9	** 8	* 9	* 8	* 9	*** 5
Ant. l. canine (n)	NS 5	*** 10	** 9	NS 10	** 9	NS 10	** 5
Ant. l. molar (n)	NS 5	NS 10	NS 9	NS 10	NS 9	** 10	NS 5
Ant. l. group (n)	NS 5	NS 10	NS 9	NS 10	NS 9	NS 10	NS 5
Ant. l. canine(x) (n)	NS 4	NS 9	NS 8	** 9	NS 8	* 9	NS 5
Ant. l. group(x) (n)	NS 5	NS 9	* 8	* 9	*** 8	** 9	NS 5
Ant. bilateral molar (n)	NS 5	NS 10	NS 9	** 10	*** 9	** 10	NS 5

Ant. = Anterior bite block; l. canine(x) = left canine with cross-arch molar contact; l. group(x) = left group contact with cross-arch molar contact. (See Table III for additional definitions and notes.)

by the incisal block task was seen to approach and even surpass the activity of some of the molar combinations (Table IV).

Anteroposterior relationships. The least muscle activity was observed during the incisal clench, followed by the canine clench, with the greatest activity along the arch exhibited by the molar clench (Table V). However, the difference in normalized activity between incisor and canine clenches was significant for the ipsilateral temporal muscles only. In contrast, all the muscles recorded, both ipsilateral and contralateral, showed significant increases during a molar clench compared with an incisor or canine clench (Fig 6).

Cross-arch contact relationships. The task with canine plus cross-arch molar contact produced significantly greater activity than a canine clench alone in all the muscles recorded. Group contact with cross-arch molar contact caused a significant increase in the activity of both masseter muscles and in the temporal muscles ipsilateral to the cross-arch contact when compared with unilateral group contact alone (Fig. 7 and Table VI).

Ipsilateral and contralateral relationships. Comparisons were also made between ipsilateral and contralateral muscle responses in specific muscle pairs with unilateral stop combinations (Table VII). The ipsilateral temporal muscles increased significantly in activity when contact was on a canine or on group contact combinations, while the medial pterygoid and masseter muscles did not. The ipsilateral medial pterygoid and masseter muscles increased significantly in activity when molar contact alone was used, while the other muscles did not (Fig. 8).

Eccentric effort study

Regardless of the stop combinations used, vertical clenching efforts were generally found to cause significantly greater muscle activity than lateral efforts when these were directed toward the ipsilateral buccal side (Fig. 9 and Table VIII). In the latter case, most comparisons yielded a significant decrease in the activity of all muscles, except for the ipsilateral posterior temporal muscle.

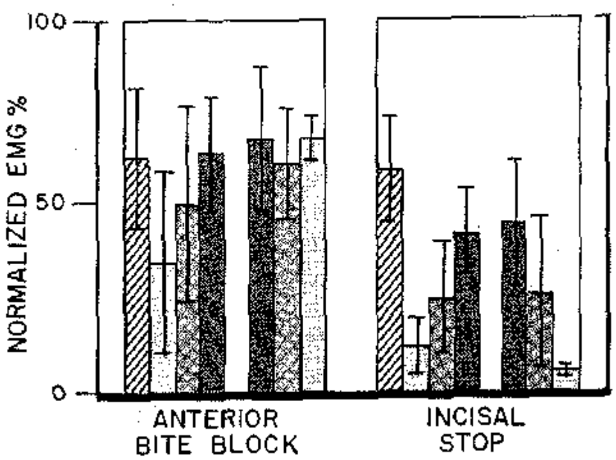

Fig. 5. Comparison of normalized muscle activity between vertical clenches on anterior incisal block and incisal stop. (See Fig. 3 legend for key.)

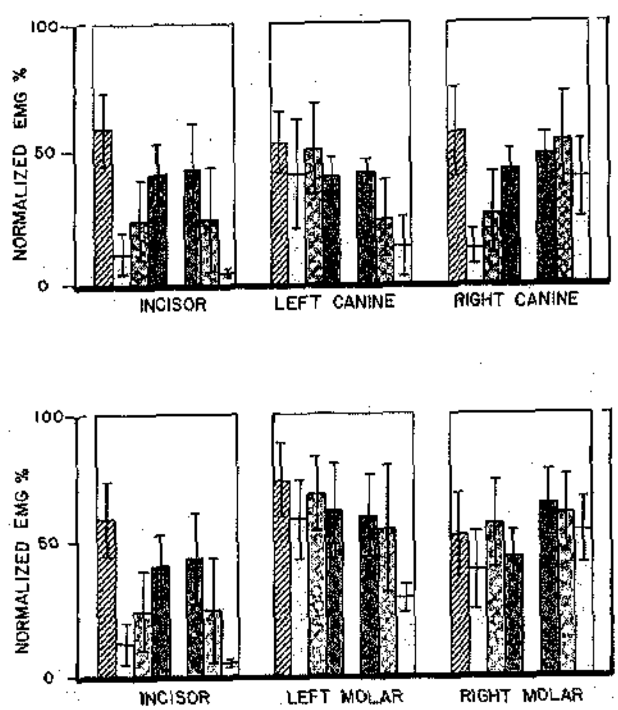

Fig. 6. Comparison of normalized activity between vertical clenches on anterior and posterior contact positions. (See Fig. 3 legend for key.)

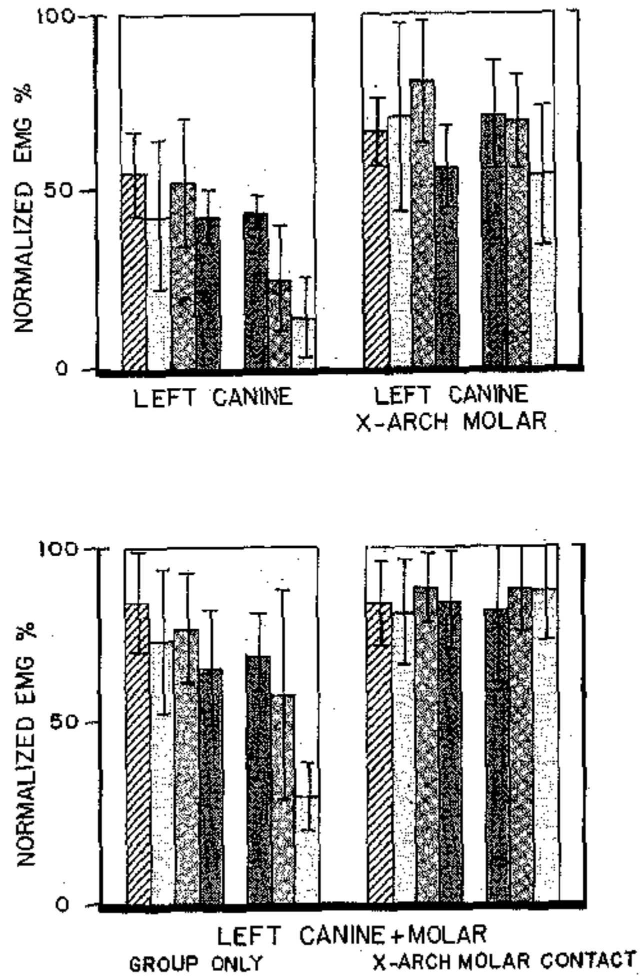

Fig. 7. Comparison of normalized muscle activity between vertical clenches on unilateral contacts and corresponding cross-arch contact combination. (See Fig. 3 legend for key.)

Eccentric efforts with molar contact only

Vertical-lateral relationships. Vertical efforts on unilateral and bilateral molar contacts evoked significantly more muscle activity than lateral efforts directed to either side. Lowered activity during lateral effort was observed bilaterally in the masseter muscles, in the temporal muscles contralateral to the direction of effort, and in the medial pterygoid muscle ipsilateral to the direction of effort (Figs. 10 and 11). Activity in the contralateral medial pterygoid muscle and the temporal muscle ipsilateral to the direction of effort was not significantly different from that during vertical clenching efforts on the same contacts (Table IX).

Lateral relationships. When lateral efforts to right and left sides were compared for the same molar contacts (Table X), activity in the medial pterygoid muscle contralateral to the direction of the effort and the temporal muscles ipsilateral to that direction was seen to increase significantly. The contralateral masseter muscle did not change significantly. The ipsilateral masseter muscle and the contralateral temporal muscles showed significant decreases in activity (Figs. 10 and 11).

Vertical-protrusive relationships. When protrusive effort was applied to the same molar contacts, almost all muscles exhibited a significant decrease in activity compared with that observed in vertical effort (Figs. 10 and 11). Activity was also seen to decrease slightly but insignificantly in the medial pterygoid muscle when bilateral molar contacts were used (Table IX).

Table V. Comparison of normalized muscle activity between vertical clenches on anterior and posterior contact positions

	Muscle						
Task comparison	LMPT	LSM	RSM	LAT	RAT	LPT	RPT
Incisor l. canine (n)	NS	NS	NS	**	NS	***	NS
	7	9	8	9	8	9	2
Incisor r. canine (n)	NS	NS	NS	NS	**	NS	NS
	7	9	8	9	8	9	2
Incisor l. molar (n)	*	**	*	***	**	***	NS
	7	9	8	9	8	9	2
Incisor r. molar (n)	NS	NS	NS	**	**	**	NS
	7	9	8	9	8	9	2
l. canine l. molar (n)	*	**	*	**	**	*	NS
	7	10	9	10	9	10	3
r. canine r. molar (n)	NS	NS	**	**	NS	**	*
	7	10	9	10	9	10	3

r = Right; l = left. (See Table III for additional definitions.)

Table VI. Comparison of normalized muscle activity between vertical clenches on unilateral contacts and corresponding cross-arch contact combination

	Muscle						
Task comparison	LMPT	LSM	RSM	LAT	RAT	LPT	RPT
l. canine l. canine(x) (n)	**	**	***	**	**	*	*
	6	9	9	9	9	9	3
r. canine r. canine(x) (n)	**	***	**	***	***	***	NS
	6	9	9	9	9	9	3
l. group l. group(x) (n)	NS	*	*	NS	*	NS	*
	7	10	9	10	9	10	3
r. group r. group(x) (n)	*	**	NS	**	*	**	NS
	7	10	9	10	9	10	3

See Tables III & IV for definitions.

Table VII. Comparison of normalized muscle activity between vertical clenches on ipsilateral and contralateral contacts

	Muscle						
Task comparison	LMPT	LSM	RSM	LAT	RAT	LPT	RPT
l. canine r. canine (n)	NS	NS	NS	**	***	***	NS
	7	10	9	10	9	10	3
l. molar r. molar (n)	*	*	NS	NS	NS	NS	NS
	7	10	9	10	9	10	3
l. group r. group (n)	NS	NS	NS	**	NS	*	*
	7	10	9	10	9	10	3

See Tables III & IV for definitions.

Vertical-retrusive relationships. A retrusive effort on the unilateral or bilateral molar contacts, when compared with a vertical clench resulted in significant decreases in activity for the pterygoid, masseter, and anterior temporal muscles (Table IX). The posterior temporal muscle responses did not alter significantly (Figs. 10 and 11).

Protrusive-retrusive relationships. A retrusive effort on the molar contacts when compared with protrusive effort (Table XI) resulted in a significant increase in activity in the temporal muscles bilaterally; a significant decrease in activity was observed in the medial pterygoid and masseter muscles (Figs. 10 and 11).

DISCUSSION

Intercuspal and simulated intercuspal positions

The results have shown that for minimal vertical opening from the intercuspal position, the activity in most elevator muscles generally remains comparable to that during natural intercuspal clenching. The findings

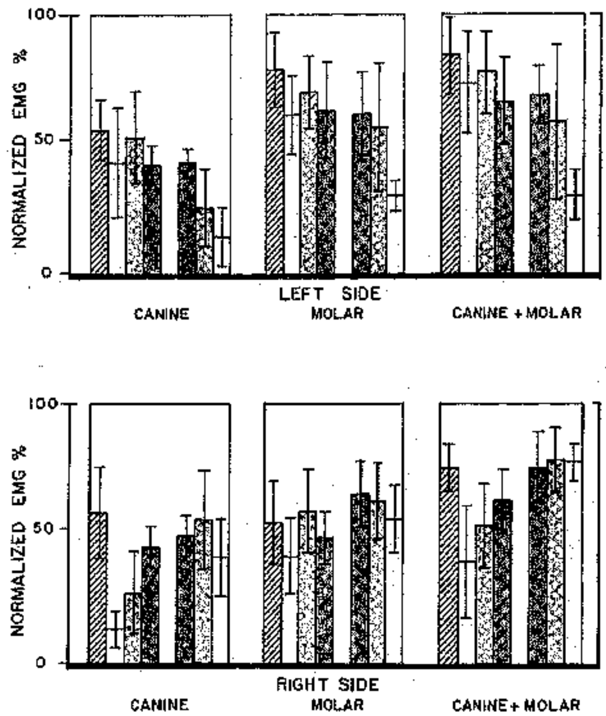

Fig. 8. Comparison of normalized muscle activity between vertical clenches on ipsilateral and contralateral contacts. (See Fig. 3 legend for key.)

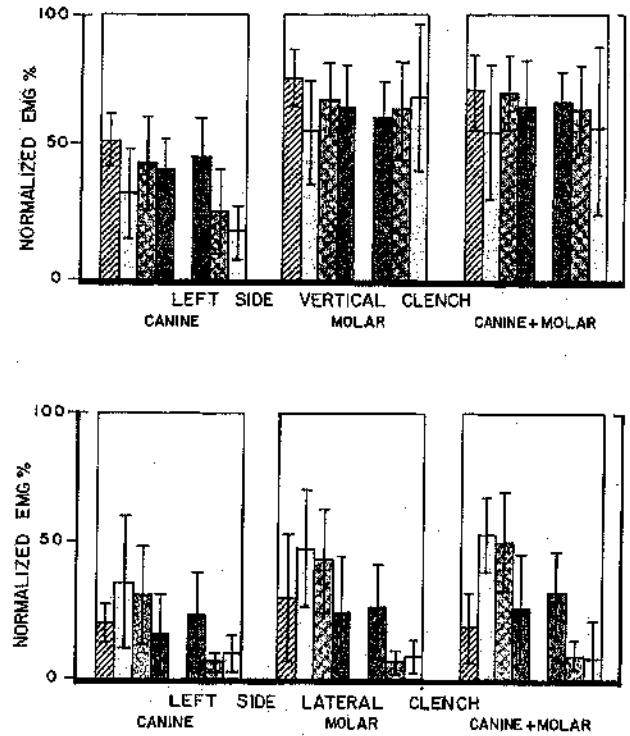

Fig. 9. Comparison of normalized muscle activity between vertical and lateral clenching efforts. (See Fig. 3 legend for key.)

agree with previous research, which has reported similar muscle activities during clenching on occlusal splints on natural teeth.[12-15]

An explanation for the decreased posterior temporal activity observed in the simulated task might be that the enveloping nature of the occlusal stop design provided an excellent platform for a more anteriorly directed force that was otherwise denied by the natural dentition. Anteriorly directed vectors of tooth force usually do not involve posterior temporal activity for muscle fiber orientation in that muscle favors jaw retraction. The reduced response in this muscle, however, was not considered a reason to reject the stops as an experimental model of intercuspation in the natural dentition.

Anteroposterior location of the contact point

The anteroposterior position of tooth contact was seen to have a marked effect on the muscles involved in clenching tasks. Greater activity was observed when posterior contacts were used, and the finding agrees with previous measurements of occlusal force made under similar conditions.[16] Assuming that electromyographic activity and bite force are linearly related at small vertical openings under isometric conditions, this result can be expected.[17-19] It has been suggested that the biomechanics are best suited to create greater muscle activity and occlusal force posteriorly in the arch.[19,20] Periodontal mechanoreceptors feedback may also be involved, because a greater density of mechanoreceptors with low stimulus thresholds are located anteriorly.[21,22] Because mechanoreceptors have been implicated in inhibitory feedback mechanisms to the jaw elevator muscles,[23,24] greater inhibition and subsequent lower muscle activity would be expected during function on anterior contact points given the production of sizeable occlusal forces.

A more involved explanation is needed to account for changes that accompany the use of eccentrically directed forces, because only the ipsilteral temporal muscles were observed to increase consistently in activity as the contact point was moved posteriorly along the arch; the other muscles either decreased in activity or did not change significantly. The periodontal innervation is sensitive to lateral tooth movement and is also dense in the buccal periodontal ligament, at least in some species.[25] These receptors would be stimulated during lateral clenching efforts, and could provide inhibitory feedback to the elevator muscles. However, such feedback would have to be selective to explain the increased response of the ipsilateral temporal muscles. A similar postulate would be used if the receptor input from other sites, for example the temporomandibular articulation, was contributory. Hellsing's[26] comments regarding trained and prepatterned motor control may be more relevant. Previ-

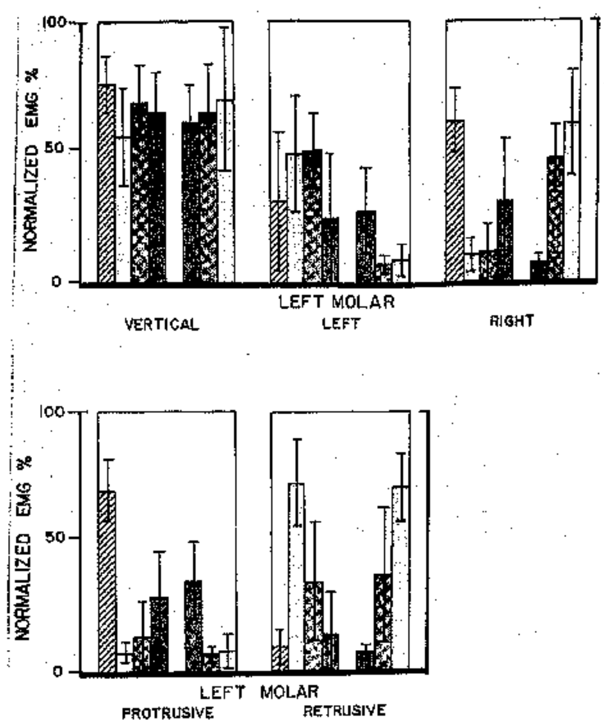

Fig. 10. Comparison of normalized muscle activity between vertical and eccentric efforts on unilateral molar contacts. (See Fig. 3 legend for key.)

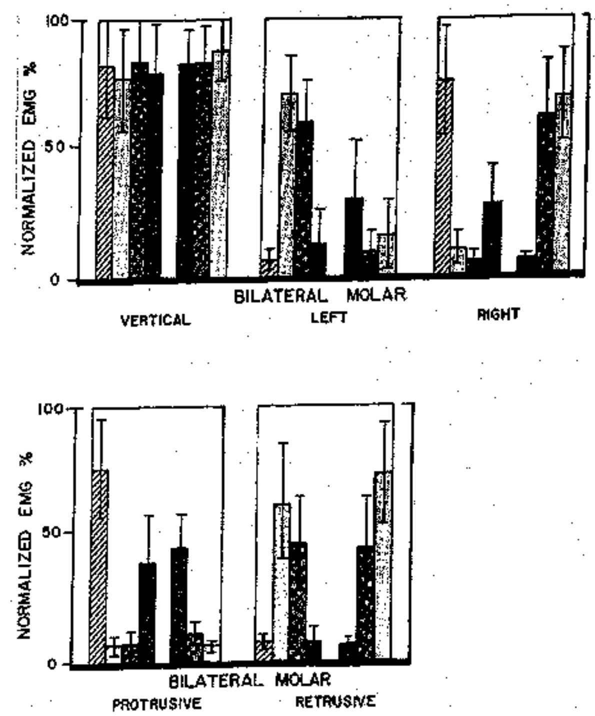

Fig. 11. Comparison of normalized muscle activity between vertical and eccentric efforts on bilateral molar contacts. (See Fig. 3 legend for key.)

ous experience, based on a combination of peripheral feedback and voluntary effort, is likely to have been used to grade the activity in specific muscles that were selected because they were optimally arranged for the production of the desired forces.

Cross-arch contacts

The results of the vertical effort study involving cross-arch contacts indicated that these combinations were associated with a generalized increase in muscle activity. In fact, the activity produced in the simulated tasks was similar to that produced in the intercuspal position. These observations are consistent with the findings of Wood and Tobias,[27] who described a small but insignificant decrease in total muscle activity when they compared maximum vertical clenching on an equilibrated occlusal splint with clenching on a splint with tooth contacts on one side removed, except for a second molar.

It seems that during vertical effort on occlusal stops, cross-arch contacts in the molar region act in a supporting fashion and possibly permit the development of increased interocclusal force during clenching. When eccentrically directed efforts are applied in the same situation, however, the amount of activity generated by the muscles is severely limited and is confined primarily to the ipsilateral temporal and contralateral medial pterygoid muscles.

Eccentric contacts and direction of effort

The direction of effort applied to a particular contact is clearly an important factor in determining the muscle groups involved and their strength of contraction.

In the lateral clenching efforts of the second study, the most active muscles were the ipsilateral temporal and contralateral medial pterygoid muscles. The contralateral lateral pterygoid muscles were probably active also during these tasks.[28] * Only minor contributions were observed from the masseter and contralateral temporal muscles. These findings are in general agreement with previous works that included some eccentric clenching acts.[28-32] The sidedness effect presumably was masked in the vertical unilateral clenching of the first study because of the increased activity observed in all muscles.

The temporal muscles, especially posterior, were most sensitive to retrusive clenching, which is consistent with their fiber orientation. This confirms previous findings.[29, 33] The deep masseter muscle has been reported to act in a similar fashion to the posterior temporal muscle during retrusive acts.[30, 34]

The medial pterygoid and masseter muscles were found to be quite responsive in protrusive and incisal clenching. This is also consistent with their fiber orientations and with previous literature concerned with similar clenching acts.[29, 31] The masseter muscle appears

*Wilkenson, T.: Personal communication, 1983.

Table VIII. Comparison of normalized muscle activity between vertical and lateral clenching efforts

	Muscle						
Task comparison	**LMPT**	**LSM**	**RSM**	**LAT**	**RAT**	**LPT**	**RPT**
l. canine(v) (l. lat) (n)	**	***	**	*	*	NS	*
	5	10	10	10	10	10	5
l. molar(v) (l. lat) (n)	*	***	***	*	**	NS	*
	5	9	9	9	9	9	4
l. group(v) (l. lat) (n)	***	**	***	NS	***	NS	NS
	5	9	9	9	9	9	4
l. group(x) (l. lat) (n)	**	***	***	*	***	NS	*
	4	9	9	9	9	9	5
l. canine(x) (l. lat) (n)	*	***	***	*	***	NS	*
	4	9	9	9	9	9	5
bilateral molar(v) (n) (l. lat)	*	***	***	*	***	NS	***
	4	9	9	9	9	9	5

v = Vertical clench; l. lat = left lateral clench on same contacts. (See Table III for additional definitions.)

Table IX. Comparison of normalized muscle activity between vertical and eccentric efforts on molar contacts

	Muscle						
Task comparison	**LMPT**	**LSM**	**RSM**	**LAT**	**RAT**	**LPT**	**RPT**
l. molar(v) (r. lat) (n)	NS	***	***	***	NS	***	NS
	5	10	10	10	10	10	5
bi. molar(v) (r. lat) (n)	NS	***	***	***	NS	***	NS
	5	10	10	10	10	10	5
l. molar(v) (pro.) (n)	*	***	***	***	***	***	*
	5	10	10	10	10	10	5
bi. molar(v) (pro.) (n)	NS	***	***	***	***	***	***
	5	10	10	10	10	10	5
l. molar(v) (ret.) (n)	***	***	***	**	*	NS	NS
	5	10	10	10	10	10	5
bi. molar(v) (ret.) (n)	**	***	***	**	**	NS	NS
	5	10	10	10	10	10	5

bi. molar = Bilateral molar; r. lat = right lateral effort; pro. = protrusive effort; ret. = retrusive effort. (See Table III for additional definitions.)

to function optimally only during protrusive and incisal clenches and may be affected by periodontal feedback from the anterior region. The medial pterygoid muscle activity remains consistently high in both cases, and in this regard the medial pterygoid muscle seems less susceptible to inhibition than the masseter muscle.

Number and site of tooth contacts

Moller[35] suggested that jaw muscle activity is dependent on the number of occlusal contacts, while Tallgren et al.[31] concluded that the anteroposterior jaw relationship may be important. In the present study, care was taken to ensure that the jaw relationship was fixed and constant under all conditions. However, compared with the incisor and canine stops, clenching on the large anterior incisal block resulted in a generalized increase in muscle activity. From this it could be deduced that the number of occlusal contacts and the surface area of contact were important. The results were far from consistent when increases in the numbers of contacts posteriorly were compared. When muscle activity was compared between a clench on the anterior incisal block, which involved 12 anterior teeth, and a clench on a unilateral molar stop, which included two posterior teeth, no significant differences were observed. However, as the number of contacts increased in the posterior combinations, the anterior incisal block clenches generally were seen to be less in comparison. It appears that an increase in the number of contacts, and probably therefore the contact surface area, is important anteriorly. Posteriorly, however, the muscles reach nearly optimal levels earlier with fewer contacts, and the muscles do not seem to be as significantly affected by the number and area of contacts.

Joint loading

Clenching of the incisors has been assumed to create proportionately more reactive force at the temporoman-

Table X. Comparison of normalized muscle activity between lateral efforts to opposite sides on molar contacts

Task comparison	Muscle						
	LMPT	LSM	RSM	LAT	RAT	LPT	RPT
l. molar(l.) l. molar(r.) (n)	* 5	NS 9	** 9	*** 9	* 9	*** 9	* 4
bi. molar(l.) bi. molar(r.) (n)	NS 4	NS 9	* 9	*** 9	*** 9	*** 9	** 5

See Tables III and IX for definitions.

Table XI. Comparison of normalized muscle activity between protrusive and retrusive efforts on molar contacts

Task comparison	Muscle						
	LMPT	LSM	RSM	LAT	RAT	LPT	RPT
l. molar(pro.) (ret.) (n)	** 5	* 10	*** 10	** 10	** 10	*** 10	*** 5
bi. molar(pro.) (ret.) (n)	** 5	*** 10	*** 10	*** 10	*** 10	*** 10	* 5

See Tables III and IX for definitions.

dibular joints than clenching of the molars, at least if comparable loads are developed at the teeth.[8] The present experiments have shown that the greater support afforded by an anterior incisal block, as opposed to that offered by an incisal stop, is associated with a considerable amount of muscle activity during clenching. Patients with posterior occlusion collapse, who frequently function on several anterior teeth only, are likely to develop greater reactive forces than patients who function on small areas of anterior contact alone or who have molar support. Thus patients with a posterior occlusion collapse may be susceptible to increased joint loading during clenching and consequently predisposed to tissue change or damage in the joint area.

Parafunctional considerations

Clenching is considered parafunctional if it involves long-lasting tooth contacts when the subject is neither chewing nor swallowing. The most common symptoms of parafunctional behavior are thought to be related to muscle hyperactivity, and it can be assumed that muscles that exhibit the greatest activities during particular clenching tasks would be the most likely to become tender.

From the present study, it appears that when a subject clenches maximally on his natural teeth in the intercuspal position and in a nearly vertical direction, all the muscles will respond at or near their optimum levels. However, if the subject changes the direction of effort of the clench, the active muscle combinations will be dependent on the specific direction of the effort. If the clench is performed in a protrusive direction from the intercuspal position, the masseter and pterygoid muscles, will be most active. If the clench is directed retrusively, the temporal muscles, especially the posterior fibers, will be most active. If a lateral clench is attempted from the intercuspal position or on any combination of cuspal inclines, the ipsilateral temporal and contralateral pterygoid muscles should exhibit the highest levels of activity. Therefore, during eccentric excursions in a parafunctional environment, even though the muscle activity may be somewhat low, the temporal and pterygoid muscles appear to be the most likely to develop tenderness because of excessive activity.

SUMMARY

1. Electromyographic recordings from the anterior temporal muscle fibers bilaterally, the posterior temporal muscle fibers bilaterally, the superficial masseter muscle bilaterally, and the left medial pterygoid muscle were used to study the effects of changing the location, size, and direction of effort on specific contact points during maximal clenching tasks in human subjects.

2. Vertical clenching efforts in the natural or simulated intercuspal position generally showed the highest muscle activities for all the muscles recorded.

3. When the contact point moved posteriorly along the arch from incisors to molars, the activity in the ipsilateral temporal muscles was seen to increase, while the activity in the ipsilateral medial pterygoid and the masseter muscles bilaterally was seen to decrease during vertical clenching tasks.

4. Eccentric efforts on specific contact points generally resulted in lower activity than the corresponding

vertical effort. This was usually seen in all muscles, but not all values were significant.

5. The ipsilateral temporal and contralateral pterygoid muscles showed the most activity during maximal clenches in lateral direction with little contribution from the other muscles.

6. The temporal muscles showed the most activity in retrusive clenching, with activity in the other muscles nearly nonexistent.

7. The medial pterygoid and masseter muscles were found to be the most active muscles during protrusive and incisal clenching, while the temporal muscle activity was low.

8. When the size and number of contacts were increased anteriorly, a generalized increase in muscle activity was seen. The same trend occurred posteriorly but was not as consistent or significant.

9. Cross-arch contacts were associated with a slight but significant bilateral increase in masseter muscle activity and an increase in temporal muscle activity ipsilateral to the cross-arch contact when maximum vertical clenches were performed. However, no significant increases were observed when the effort was directed laterally.

10. The findings of this electromyographic study on changes of the contact point, size of contact point, and the direction of effort applied on a contact point confirm their specific associations with the activity of muscle groups. Significant data have also been made available for a biomechanic approach to the investigation of degenerative joint changes.

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Silent period in jaw elevator muscle activity during mastication

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Several investigations have been directed toward determining control of the jaw-closing musculature. Although considerable significance has been attached to the silent period, its neurophysiologic mechanisms and functional significance are still in question, including its relationship to jaw closing.

Many sites are capable of inducing an inhibitory effect on jaw-closing motoneurones by mechanical, electrical, and auditory stimulation.[1-3] Stimulus magnitude, level of background muscle activity, and the form of the stimulus are documented factors that account for its variability. Most data, however, have been obtained under rather artificial circumstances, as stressed by Dubner et al.,[4] for example, by tapping the chin under sustained voluntary clenching.

The functional significance of the silent period during mastication is not clearly understood. Some researchers, such as Hannam,[5] tend to believe that it is a biologic artifact because of its insignificant duration relative to the time course of the chewing cycle and the forces developed within the cycle. It is an observable motor behavioral response that occurs near the end of the closing phase and lasts for 15 to 20 msec. After the silent period, the jaw-closing muscle activity returns for approximately 50 msec.[6-10]

This article describes the nature of inhibitions in jaw elevator muscle activities under the condition of naturally occurring stimuli.

MATERIAL AND METHODS

Material. Four healthy subjects, 2 men and 2 women, and 1 patient were included in the study. Subjects reported no history of functional disturbances of the masticatory system. The mean age of the subjects was 25 years, with a range of 19 to 31 years. The patient, who was a 36-year-old man, had an occlusal trauma evidenced clinically and radiologically by increased tooth mobility and by discomfort when pressure was applied to his lower left second premolar. None of the individuals was on medication at the time of the experiment, and no medication was given.

Chewing assignment. Beefstick (Frito-Lay, Inc., Dallas, Tex.) 10 mm long was given to each participant to chew. Each participant recorded 10 complete masticatory sequences. No instructions were given on how to chew the food. Beefstick is of medium/soft-consistency. Unlike peanuts, carrots, or apple, the bolus is kept together during chewing.

Clinical procedure. A bipolar surface electromyographic technique was applied with Ag/AgCl disk electrodes (E4 flat, 9 mm disk, Grass Inc., Quincy, Mass.) and a ground electrode (E34S nylon spring ear clip electrode, Grass Inc.) attached to the right earlobe. Recording electrodes were placed 20 mm apart, center-to-center, in the direction of main muscle fibers, over the left and right masseter and anterior temporal muscles. Jaw movement was monitored with the mandibular Kinesiograph (MKG-5 Research, Myotronics Research, Inc., Seattle, Wash.).

Discomfort. The patient used a thumb switch to mark

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