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

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The site and number of occlusal contacts, as well as the direction of applied effort, influence activity in the jaw-closing muscles during tooth clenching.[1] Their effects in some instances are profound. Understanding the relationship among occlusal contact, clenching behavior, and the response of specific muscles might be useful in the interpretation of muscle symptomology, in parafunctional acts such as bruxing and clenching, and in the prediction of reactive forces in the temporomandibular joint.

In previous experiments, combinations of small acrylic resin occlusal stops were used to separate the teeth and to provide stable platforms at particular locations around the dental arch. The present study was conducted without occlusal stops and with the use of contacts of natural teeth only. The study was designed to test whether the average subject clenching in a specified way at particular sites would behave as his counterpart did when artificial occlusal stops were used under more controlled conditions.

METHODS

Twenty subjects with reasonably intact dentitions and good molar support took part in the experiments. They were chosen randomly with respect to occlusal classification and craniofacial type. The only criteria for selection was the ability to comprehend and execute instructions concerning jaw position and clenching effort. The sample included 18 men and 2 women, who ranged from 23 to 42 years of age with a mean of 30.8 years.

Tasks

Each subject was asked to perform 5 maximum comfortable clenches for each task. The tasks included clenching the teeth vertically with left, right, protrusively, and retrusively directed efforts in the intercuspal position with as little movement of the jaw as possible.

Tasks that involved eccentrically directed effort were undertaken also. For these tasks the subjects were instructed to position their lower teeth as comfortably as possible on the lingual inclines of upper buccal cusps and clench with a vertical and presumed lateral component of effort, without slipping on the incline. Clenching was attempted unilaterally on canine and group function contacts. Group function was considered as any number of posterior contacts in addition to the canine contact on the working (clenching) side. Subjects were also asked to attempt canine and group function contacts with cross-arch molar contact. The teeth in contact were checked visually and with articulating paper to confirm particular contact combinations.

The tasks are summarized in terms of contact combinations and directions of effort in Table I. Because of individual occlusal constraints, not all subjects were able to perform all tasks.

Electromyography

Details of the methods used to record and quantitate electromyographic activity with a combination of surface and fine-wire electrodes and a computer-based system were reported previously.[1]

Six muscle channels were available for electromyography. Recordings were made from all 20 subjects from the anterior fibers of the left and right temporal muscles, the fibers of the left posterior temporal muscle, and the superficial fibers of the masseter muscles on both sides. Needle electrodes were used to record from the medial pterygoid muscles in 9 subjects, and the right posterior temporal muscle was recorded in 11.

Computer sampling and data analysis involved the editing of spurious clenches as well as the calculation of average values for each clench and for each task. Normalization to each subject's peak response for the series of tasks was carried out for each muscle, followed by calculation of group means for each task and an analysis for differences by paired t tests.

RESULTS

Intercuspal position

Vertical-eccentric relationships. Activity in the intercuspal position with vertical effort was compared with that in the intercuspal position when effort was

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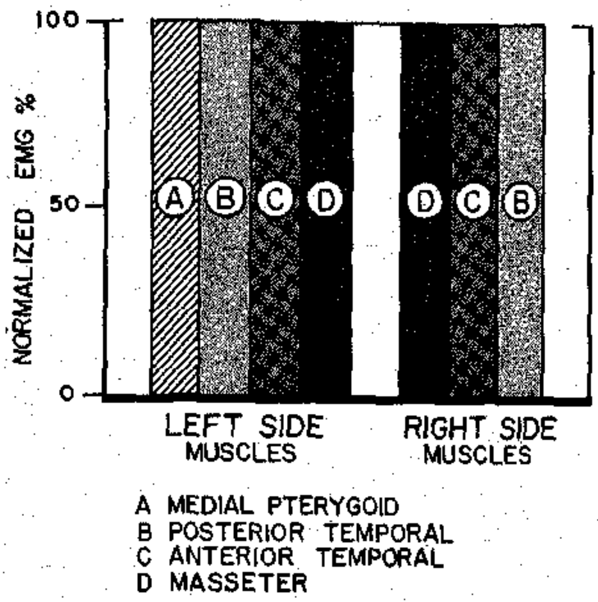

Fig. 1. All figures are histograms that conform to this format. Mean normalized EMG for grouped data are shown coded for each muscle according to key. Bars that represent one standard deviation are included in each histogram. Statistical comparisons of data for each figure are presented in tables and referred to in text. Descriptions of tasks and interpretations of figures are also found in text. *A* = Medial pterygoid muscles, *B* = *posterior temporal muscles; C* = *anterior* temporal muscles, *D* = masseter muscles.

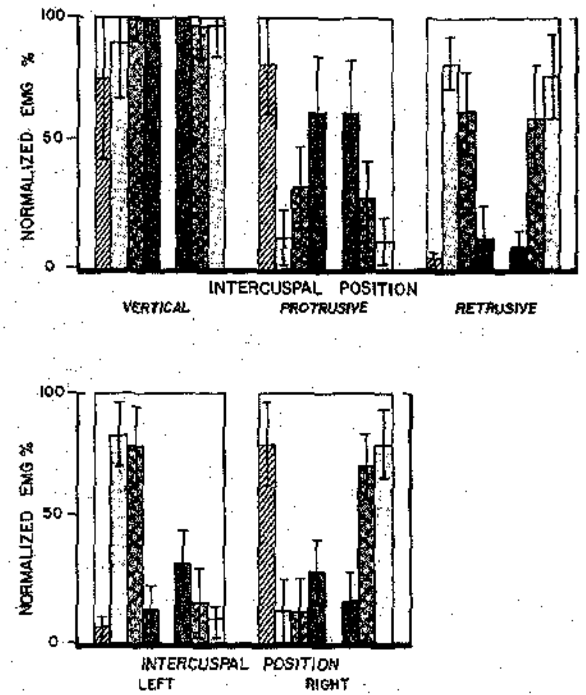

Fig. 2. Comparison of *normalized muscle activity* between intercuspal clenching efforts on natural teeth. *Histogram key is found* in Fig. 1.

exerted protrusively, retrusively, left, and right (Table II). In almost every instance responses were significantly greater than those during eccentric effort in intercuspation (Figs. 1 and 2). The only exceptions were the medial *pterygoid muscle in protrusive* and contralateral efforts where activity did not change significantly, and the left posterior temporal muscle, *where responses on retrusive* and ipsilateral efforts were also insignificantly different.

The vertical intercuspal clenches were also compared with all other tasks in the study. Except for the medial pterygoid muscle, muscle activity was always significantly greater for all the muscles recorded in the intercuspal position than for any other combination. The activity of the medial pterygoid muscle was not reduced significantly during incisal, protrusive, or contralateral efforts.

Lateral relatonships. Muscle activity during lateral efforts to the right and left sides from the intercuspal position are compared in Table II. Medial pterygoid and *masseter muscle responses* contralateral to the direction of effort were significantly greater, as was temporal muscle activity *ipsilateral to the direction* of effort. Correspondingly, pterygoid and masseter muscle responses ipsilateral, and temporal *muscle responses* contralateral to the direction of effort, were significantly less (Fig. 2).

Table I. Occlusal contact combinations

Task No.	Contact combination	Direction of effort
1	Natural intercuspation	*Vertical*
2	Natural intercuspation	Protrusive
3	*Natural intercuspation*	Retrusive
4	Natural intercuspation	Left
5	Natural intercuspation	Right
6	Incisors	
7	Left canine	
8	Right canine	
9	Left group function	
10	*Right group function*	
11	Left group function with right cross-arch molar	
12	Right group function with left cross-arch molar	

Protrusive-retrusive relationships. Intercuspal protrusive and retrusive tasks are compared in Table II. When the retrusive effort was compared to the protrusive effort, a significant increase in muscle activity was observed in the temporal muscles bilaterally. A significant decrease was noted in the medial pterygoid and masseter muscles bilaterally during retrusive effort (Fig. 2).

Table II. Comparison of normalized muscle activity between intercuspal and other clenching efforts on natural teeth

Task comparison	Muscle						
	LMPT	LSM	RSM	LAT	RAT	LPT	RPT
ICP	NS	***	***	***	***	***	***
ICP (pro (n)	9	20	20	20	20	20	11
ICP	***	***	***	***	***	NS	*
ICP (ret) (n)	9	20	20	20	20	20	11
ICP	**	***	***	**	***	NS	***
ICP (l) (n)	7	13	13	13	13	13	6
ICP	NS	***	***	***	***	***	*
ICP (r) (n)	7	13	13	13	13	13	6
ICP (pro)	***	***	***	***	***	***	***
ICP (ret) (n)	9	20	20	20	20	20	11
ICP (l)	***	**	*	***	***	***	***
ICP (r) (n)	7	13	13	13	13	13	6
ICP	NS	***	***	***	***	***	***
incisor (n)	9	20	20	20	20	20	11
ICP	**	***	***	***	***	***	***
l. canine (n)	9	19	19	19	19	19	10
ICP	NS	***	***	***	***	***	***
r. canine (n)	9	20	20	20	20	20	11
ICP	**	***	***	***	***	*	***
l. group (n)	8	16	16	16	16	16	8
ICP	NS	***	***	***	***	***	*
r. group (n)	9	17	17	17	17	17	8
ICP	***	***	***	***	***	***	***
l. group(x) (n)	8	16	16	16	16	16	8
ICP	*	***	***	***	***	***	***
r. group(x) (n)	6	15	15	15	15	15	9

Probability (p) of difference by chance determined by Student paired t test: NS = not significant, $p > .05$; * = $p < .05$; ** = $p < .01$; *** = $p < .001$; 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; ICP = intercuspal position; Pro = protrusive; RET = retrusive; group = group function, x = cross-arch contact; l. = left; r. = right.

Eccentric positions

Anteroposterior relationships. A clench on a canine contact compared with an incisal clench resulted in a significant increase in muscle activity in the ipsilateral temporal muscles (Table III). A significant decrease in activity occurred in the ipsilateral medial pterygoid and the masseter muscles bilaterally. No significant change was noted in the contralateral medial pterygoid and temporal muscles (Fig. 3).

Single molar contact used for anteroposterior comparisons in the earlier study[1] was unobtainable in the natural dentitions of the subjects, and unilateral group function was therefore selected for comparative purposes. When compared with an incisal clench, the unilateral group function clench resulted in a significant increase in muscle activity in the ipsilateral temporal muscles. Significant decreases were observed in the ipsilateral medial pterygoid and masseter muscles. No other changes were found (Table III).

The results were not as uniform when a canine clench was compared with a group function clench (Table III). The ipsilateral temporal muscles were again seen to increase significantly with group-function clenching. The contralateral masseter muscle was also seen to increase but with effort on one side only; that is, the phenomenon did not react symmetrically with effort on the other side. The same activity occurred with the posterior temporal muscle. No other significant changes were seen.

Cross-arch relationships. The group on the whole could not produce a canine with cross-arch molar contact, so the only cross-arch comparison performed was that of group function with cross-arch molar contact. This was compared with group function alone (Table IV). The only significant change was an increase in the masseter muscle ipsilateral to the cross-arch contact with effort on one side only. Effort on the other side also caused an increase, but it was not significantly different (Fig. 4).

Ipsilateral-contralateral relationships. When an ipsilateral canine clench and a contralateral canine clench was compared (Table V), the ipsilateral clench resulted in a significant increase in muscle activity in the contralateral medial pterygoid and masseter muscles,

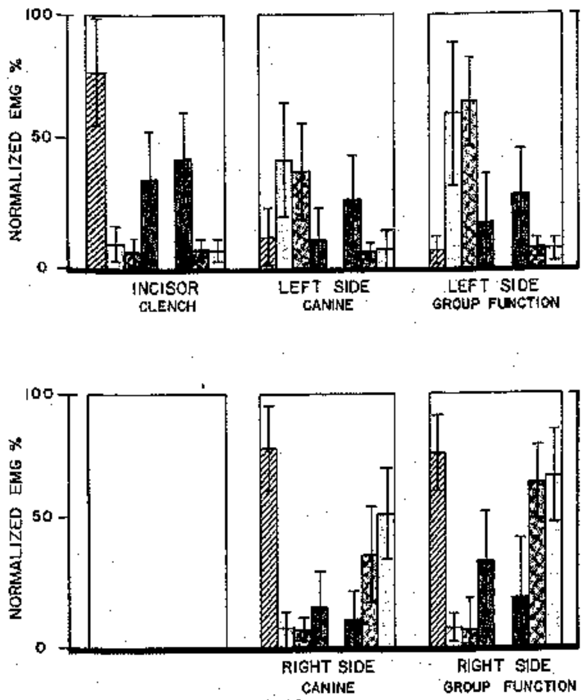

Fig. 3. Comparison of normalized muscle activity between clenches on anterior and posterior contacts on natural teeth. (See Fig 1 for key.)

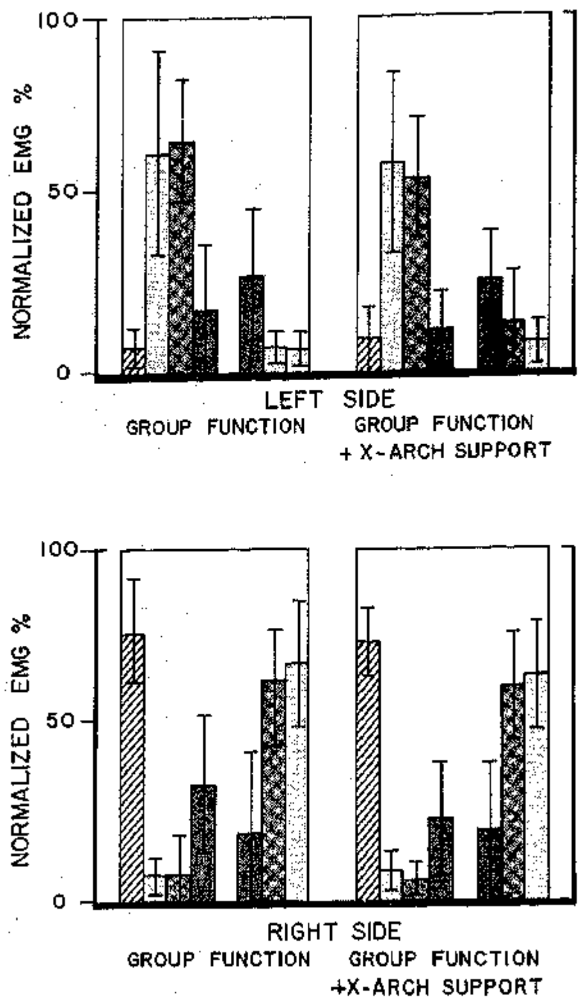

Fig. 4. Comparison of normalized muscle activity between clenches on unilateral contact and corresponding cross-arch contact combination on natural teeth.

and in the ipsilateral temporal muscles (Fig. 3). The ipsilateral medial pterygoid and masseter muscles and the contralateral temporal muscles significantly decreased in activity.

Similar results were obtained when activity recorded during group function and group function with cross-arch molar contact was compared for effort on left and right sides. Only the masseter muscles did not always show significant changes (Table V).

DISCUSSION

Despite the random selection of subjects, their different occlusions, and differences in ability to perform certain tasks, the results were surprisingly similar for the group as a whole. The changes in activity of different muscles with the various tasks closely resembled those observed previously when similar tasks were performed with artificial occlusal contacts under more controlled conditions.[1] In the present study, minor displacement of the jaws were required to achieve some of the contacts, and the positioning of the teeth on opposing cuspal inclines presumably varied between subjects and conceivably in the same subject between tasks. Such discrepancies in distance from the intercuspal position were small, and certainly even smaller at the muscle insertions, and were unlikely to have had a significant effect. The similarities between the two studies, one of which involved no displacement of the mandible, also imply that the small changes in jaw position that occurred in the experiments were not a major variable.

It seems reasonably certain in natural dentitions that the distribution of activity in the jaw closing muscles during clenching varies in a predictable manner according to the site or sites of contact between the teeth and on the direction in which effort is applied to the sites. Behavior of this kind might be expected, given the anatomic arrangement of the muscles concerned. The study demonstrates that the distribution of responses can be predicted with reasonable certainty given some insight into the location and nature of habitual tooth contact and the probable direction of force applied to it.

Special significance can be attached to the medial pterygoid and temporal muscles. Both are active during normal intercuspal clenching. The medial pterygoid muscle retains the same order of activity during incisal clenching, as well as in protrusively and contralaterally directed efforts. Both parts of the temporal muscle are

Table III. Comparison of normalized muscle activity between clenches on anterior and posterior contacts on natural teeth.*

Task comparison	Muscle						
	LMPT	LSM	RSM	LAT	RAT	LPT	RPT
Incisor	*	***	*	***	NS	***	NS
l. canine (n)	9	19	19	19	19	19	10
Incisor	NS	**	***	NS	***	NS	***
r. canine (n)	9	20	20	20	20	20	11
Incisor	**	*	NS	***	NS	***	NS
l. group (n)	8	16	16	16	16	16	8
Incisor	NS	NS	**	NS	***	NS	*
r. group (n)	9	17	17	17	17	17	8
l. canine	NS	NS	NS	**	NS	*	NS
l. group (n)	8	16	16	16	16	16	8
r. canine	NS	*	NS	NS	***	NS	NS
r. group (n)	9	17	17	17	17	17	8

*Numbers vary more due to difficulty some subjects had in producing desired contact. (See Table II for definitions.)

Table IV. Comparison of normalized muscle activity between clenches on unilateral contact and corresponding cross-arch contact combination on natural teeth

Task comparison	Muscle						
	LMPT	LSM	RSM	LAT	RAT	LPT	RPT
l. group	NS	NS	*	NS	NS	NS	NS
l group(x) (n)	8	16	16	16	16	16	8
r. group	NS	NS	NS	NS	NS	NS	NS
r. group(x) (n)	6	15	15	15	15	15	8

See Table II for definitions.

Table V. Comparison of normalized muscle activity between clenches on ipsilateral and contralateral contact combinations on natural teeth

Task comparison	Muscle						
	LMPT	LSM	RSM	LAT	RAT	LPT	RPT
l. canine	***	**	**	***	***	***	***
r. canine (n)	9	19	19	19	19	19	10
l. group	***	**	NS	***	***	***	***
r. group (n)	8	16	16	16	16	16	8
l. group(x)	***	NS	NS	***	**	***	***
r. group(x) (n)	6	15	15	15	15	15	8

See Table II for definitions.

equally active during retrusively and ipsilaterally directed efforts and these muscles are the most likely to be most active during eccentric bruxing or clenching when it is associated with lateral or protrusive effort in or near the intercuspal position.

The side on which clenching takes place has a marked effect on the balance of activity between the muscles of a pair. This is especially evident in the medial pterygoid, temporal, and masseter muscles when posterior teeth are involved in eccentrically directed effort. All three groups show marked asymmetry in behavior under these conditions. It is also clear that activity in the temporal muscles increases as the contact point moves posteriorly in the dental arch and that the anterior temporal muscle is especially sensitive in this regard.

Taking all these trends into account, it might be expected that a patient who clenches vigorously on a left incisal edge or who applies a labially directed force to the upper anterior teeth on the left side will show strong activity in the right medial pterygoid, moderate activity in both masseters, and little in the temporal and left medial pterygoid muscles. Bruxing or clenching in the molar region with most of the effort directed to the left side would be predicted to increase activity in the left temporal muscles as well.

The main consequence of incorporating a cross-arch molar contact during clenching seems to be a greater response than would otherwise be the case in the masseter muscle on the side of the cross-arch (balancing) contact. It is premature to comment on the significance of this finding other than to infer that an altered biomechanical system must exist when it occurs. How the additional occlusal load-bearing zone and increased muscle tension in the masseter on the same side alter stress distribution, particularly at the temporomandibular joints, remains to be seen. Useful approaches to this question include theoretic modeling techniques that use the principles of static equilirium theory to solve for joint and tooth forces.[2,3]

The results of this study highlight the need to assign a feasible proportional balance of muscle tensions when modeling the force vectors in such systems; whenever a contact point or direction of effort is specified, so must the values assigned to the muscles be included in the model. Unfortunately this has not been common practice in theoretic analyses. It is relevant also that the lateral pterygoid muscle was not included in the study. It might reasonably be expected that this muscle will be active during many clenching tasks.

The combined results of the present and the previous studies[1] suggest that it might be possible to correlate symtomatology with the assumed action of specific muscle groups in patients who engage in excessive bruxing or clenching. Based on the site and severity of frequently used wear facets, predictions of the muscles likely to be symptomatic could be made according to the facets involved and the probable nature of their use. The predictions could be tested against muscles that show actual signs or symptoms of pathology.

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CANADA

Functional adaptation to changes in vertical dimension

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Vertical dimension of the face is defined as the distance between two arbitrarily selected points: one in the maxilla and one in the mandible. The difference between vertical dimension of the face in intercuspal position (IP) and postural position (PP) is referred to as the freeway space (interocclusal distance). The establishment of an optimal vertical dimension of the face in prosthodontics is critical for the function of the stomatognathic complex. Thompson[1] believed that throughout life there is no change of the mandibular rest position (synonymous with PP); thus tooth wear results in an increase of interocclusal distance if not compensated by growth of the alveolar process. Encroaching on or exceeding the interocclusal distance in restorative dentistry can lead to irreversible functional disturbances. Laskin[2] stated that "overextension" of the jaw elevator muscles leads to muscle spasm and sponsors the development of the myofascial pain-dysfunction syndrome.

Conversely, Goldspink[3,4] demonstrated that striated muscles in the rat and cat readily adapt to changes in

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