Effect of bilateral asymmetric tooth clenching on load distribution at the mandibular condyles

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The effects of balancing-side tooth contacts on temporomandibular joint loads are unclear. We used a 3-D computer model to calculate the magnitude and direction of temporomandibular reaction forces during simulated clenching on interocclusal acrylic resin shims and between natural teeth. Muscle tensions were proportioned according to the task modeled. Working-side tooth contacts included the canine alone, as well as group function, and occlusal loads were progressively shifted toward a posterior contralateral simple balancing contact. In the acrylic resin shim experiments, group function with simple balancing contact yielded the highest forces at the load point and at both temporomandibular joints. Movement of the occlusal load toward the balancing side produced greater, anteriorly oriented forces on the working condyle. For natural teeth, changes in the angle of resultant tooth force (simulating facet angulation) greatly influenced condylar forces. As the occlusal load moved toward the balancing side, greater and more laterally oriented forces were produced on the balancing condyle. Unilateral clenching on the canine produced the least condylar and bite forces. The simulation involving natural teeth offers a possible explanation for deviations in form and osteoarthrosis at the temporomandibular joints. (J Prosthet Dent 1990;64:62-73.)

During lateral jaw movements, tooth contact can occur between opposing teeth on the working and balancing sides. Contacts that are made on the balancing side when simultaneous occlusion occurs on the working side are known as simple balancing contacts (SBCs).[1] When a balancing contact disoccludes all working-side contacts, it is defined as a balancing interference (BI).[1] Although both types have long been considered to play a role in muscular and articular dysfunction, evidence for this assumption is at best equivocal, for clinical and epidemiologic measurements have yielded weak or negative correlations between the presence of SBC or BI and dysfunctional signs and symptoms of the masticatory system.[2-10] These poor associations may simply mean that SBCs and BIs are clinically irrelevant. On the other hand, it is possible that although large numbers of subjects with balancing contacts do not normally develop dysfunctional signs or symptoms, a small proportion do so because of their unique functional use of these surfaces, for example, during tooth grinding or clenching. This concept is suggested by the altered muscle activity and symptomatic changes that can follow the insertion of experimental BIs.[11-15]

The site and number of occlusal contacts and the direction of applied effort influence the activity in the jaw-closing muscles during tooth clenching.[16-22] During maximal vertically directed clenches on unilateral occlusal shims, temporal muscle activity increases significantly when the contact is ipsilateral (on a canine alone or on a canine plus ipsilateral second molar), while that in the medial pterygoid and masseter muscles does not. During performance of the same task with an added contralateral (balancing) molar contact, greater activity is found in all muscles.[23] This activity does not seem to be the case when subjects are asked to clench on their natural teeth with an SBC, where a greater response is seen in the masseter muscle ipsilateral to the cross-arch contact.[24] Bilateral masseter muscle activity is sensitive to differences in occlusal support between the left and right sides of the dental arch.[25, 26] In one study, the removal of six contacts on one side of a bite plane (leaving a single contralateral SBC) did not significantly change either the side or the overall activity of the main jaw elevator muscles.[25] When the SBC was removed, however, muscle activity decreased by 21%. The authors suggested that the mandibular condyle on the balancing side may have taken much of the load previously taken by the SBC.

Condylar loads have frequently been simulated by three-

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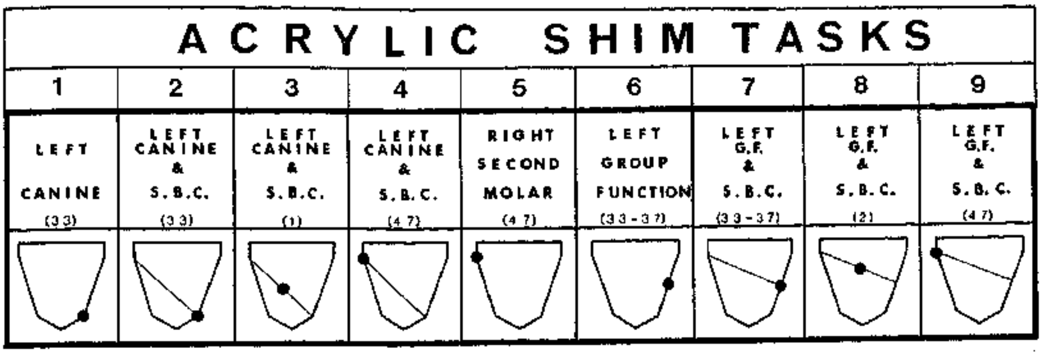


SCALING FACTORS		LEFT CANINE	LEFT CANINE & S.B.C.	RIGHT SECOND MOLAR	LEFT GROUP FUNCTION	LEFT G.F. & S.B.C.
LEFT	Med. Pter.	0.55	0.67	0.54	0.85	0.85
	Post. Temp.	0.43	0.71	0.40	0.73	0.82
	Ant. Temp.	0.52	0.81	0.58	0.78	0.89
	Sup. Mass.	0.42	0.56	0.48	0.66	0.85
RIGHT	Med. Pter.	0.57	0.71	0.79	0.74	0.85
	Post. Temp.	0.15	0.54	0.56	0.30	0.88
	Ant. Temp.	0.25	0.69	0.62	0.59	0.88
	Sup. Mass.	0.43	0.71	0.65	0.69	0.83

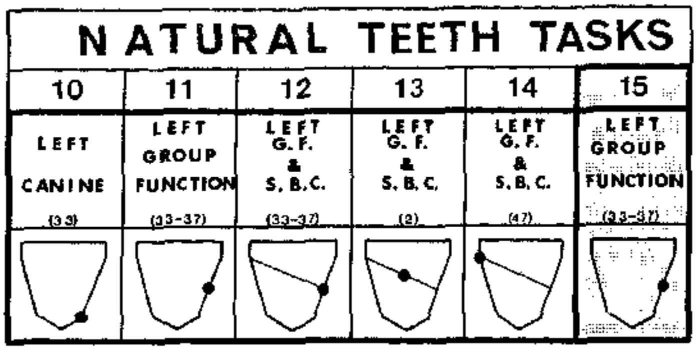
Fig. 1. Acrylic resin shim tasks (1 through 9) and corresponding muscle scaling factors. *S.B.C.*, Simple balancing contact; *G.F.*, group function; numbers in parentheses and filled circles indicate bite point location; *med. pter.*, medial pterygoid muscle; *post. temp.*, posterior temporal muscle; *ant. temp.*, anterior temporal muscle; *sup. mass.*, superficial masseter muscle.

Table I. Weighting factors (derived from Nelson[28]). Values for eight functional muscle groups according to their proportions of whole muscle cross-sections of Weijs and Hillen,[43] assuming a force capability of 40 N/cm^2

Whole muscle*	X-section (cm^2)	Muscle group†	Proportion	Muscle group X-section (cm^2)	Muscle group weight (N)
Masseter	6.80 ± 1.69	Sup. mass.	0.70	4.76	190.40
		Deep mass.	0.30	2.04	81.60
Med. pter.	4.37 ± 0.96	Med. pter.	1.00	4.37	174.80
Temporalis	8.23 ± 1.13	Ant. temp.	0.48	3.95	158.00
		Post. temp.	0.23	1.89	75.60
Lat. pter.	2.39 ± 0.45	Inf. lat. pter.	0.70	1.67	66.90
		Sup. lat. pter.	0.30	0.72	28.70
		Ant. dig.‡	1.00	1.00	40.00

*Whole muscle abbreviations: Med. pter, medial pterygoid; Lat. pter., lateral pterygoid.
†Muscle group abbreviations: Sup. mass., superficial masseter; Deep mass., deep masseter; Ant. temp., anterior temporalis; Post. temp, posterior temporalis; Inf. lat. pter., inferior lateral pterygoid; Sup. lat. pter., superior lateral pterygoid; Ant. dig., anterior digastric.
‡Cross-section according to Pruim et al.[42]

dimensional computer-assisted modeling. This indirect technique assumes that the mandible is a rigid, loaded beam, and consequently that the principles of static equilibrium theory can be used to solve the distribution and direction of muscle-induced forces at the teeth and condyles.[27-31] These and other studies[32-36] suggest that the temporomandibular joint (TMJ) is generally load bearing under normal conditions and that the nonworking condyle is usually more heavily stressed during unilateral function. Differential loading of the TMJ seems to be a function of working and nonworking-side muscle recruitment patterns,[37] a shift in bite point loading,[29] or both.[31,38] Modeling has predicted that anteriorly positioned and/or medially or laterally directed bite forces yield the greatest



SCALING FACTORS		15
LEFT	Med. Pter.	0.07
	Post. Temp.	0.62
	Ant. Temp.	0.66
	Sup. Mass.	0.18
	Deep Mass.	0.36
	Sup. Lat. Pter.	0.20
	Inf. Lat. Pter.	0.59
	Ant. Dig.	0.51
RIGHT	Med. Pter.	0.76
	Post. Temp.	0.06
	Ant. Temp.	0.07
	Sup. Mass.	0.27
	Deep. Mass.	0.26
	Sup. Lat. Pter.	0.08
	Inf. Lat. Pter.	0.14
	Ant. Dig.	0.38

SCALING FACTORS		LEFT CANINE	LEFT GROUP FUNCTION	LEFT G.F. & S.B.C.
LEFT	Med. Pter.	0.13	0.07	0.09
	Post. Temp.	0.43	0.62	0.59
	Ant. Temp.	0.39.	0.66	0.54
	Sup. Mass.	0.11	0.18	0.12
RIGHT	Med. Pter.	0.70	0.76	0.73
	Post. Temp.	0.07	0.06	0.08
	Ant. Temp.	0.07	0.07	0.23
	Sup. Mass.	0.27	0.27	0.26

Fig. 2. Natural teeth tasks (10 through 15) and corresponding muscle scaling factors. Shaded regions indicate complete set of muscle scaling factors for task 15 (see text); all other abbreviations same as for Fig. 1.

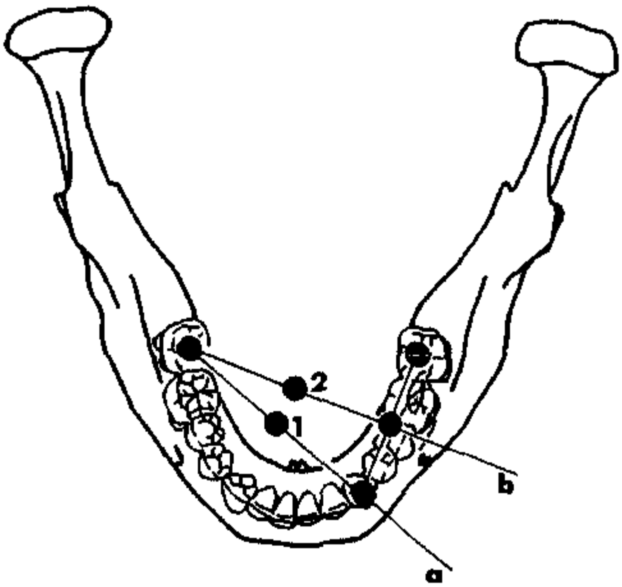


Fig. 3. Mandibular bite point localization. Filled circles indicate simulated bite points; hatched circle indicates lower left second molar.

joint loads,[29] and that medially directed bite forces mostly affect the nonworking-side joint and lateral forces the working-side joint.[31]

In this study we used a computer-assisted three-dimensional model[28, 39] to examine the influence of vertically and laterally directed eccentric tooth clenching (with and without a SBC) on stress distribution between the TMJs. Of particular interest was articular loading when canine guidance and group function contact patterns were simulated with and without cross-arch second molar support, since these conditions are often encountered clinically.

MATERIAL AND METHODS

Our model was based upon one described previously by Nelson.[28] Three-dimensional coordinates were specified for the centroids of the areas of origin and insertion of the muscle groups, the centers of the right and left condyles, and the points of contact of the mandibular dentition. Nine pairs of muscles were simulated, including the superficial and deep masseter, medial pterygoid, anterior, middle, and posterior temporalis, superior and inferior heads of the lateral pterygoid, and the digastric muscles. The coordinates of the attachment sites of all muscles except the digastric muscles were partially derived from the work of Baron and Debussy,[40] which was based on measurements carried out on five human skulls (see Nelson, 1986[28]). Digastric muscle orientations were derived from other studies.[41,42] The contact points for each tooth, including third molars, were selected by comparing relative tooth morphology and cuspal positions on dried skulls and drawing them within the confines of the dental reference

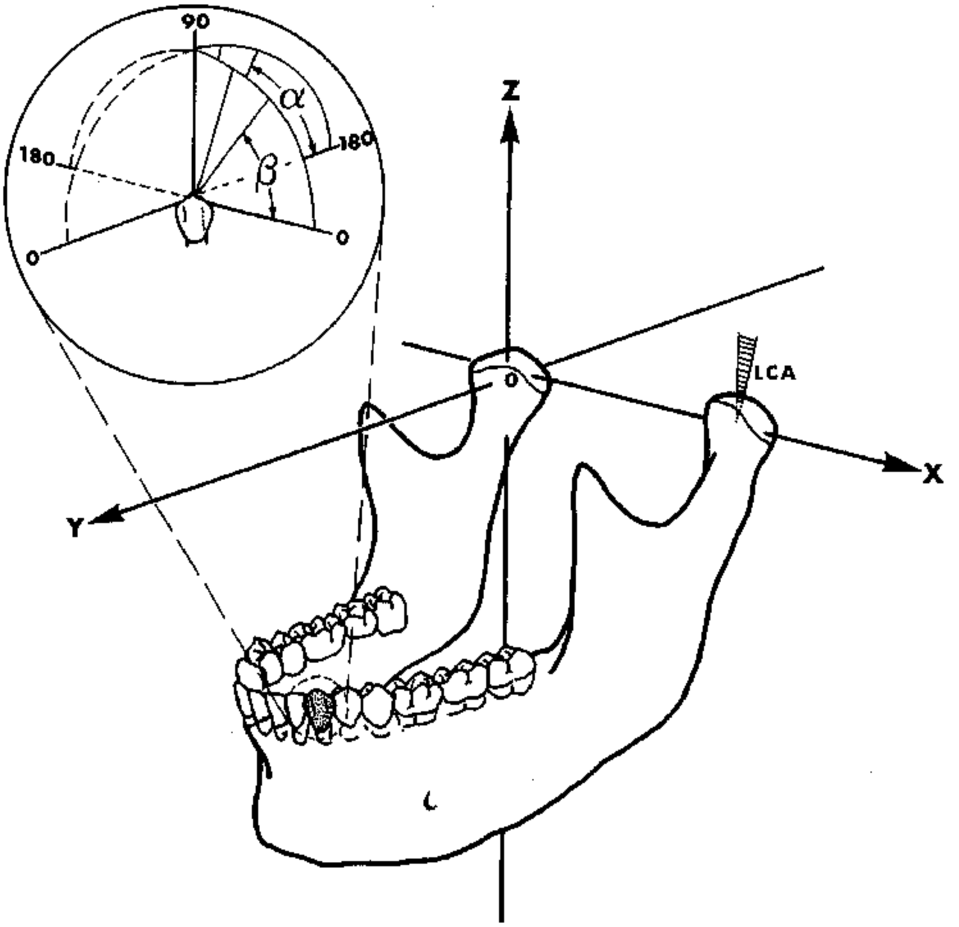


Fig. 4. Reference system used by model. *LCA*, Left condylar resistance angle; α, lateral tooth resistance angle; β, frontal tooth resistance angle; x, y, and z, Cartesian orthogonal coordinate system with its origin at center of right condyle.

points of Baron and Debussy.[40] Molar contact points corresponded to mandibular mesiobuccal cusps. The origin of the reference system lay at the center of the right condyle.

Force analysis for any simulated task required the determination of the contribution by each muscle to the overall forces of the system. The resultant vector of muscle force (M_{ir}) during isometric contraction was given by the product

$$[X_{Mi} \cdot K] \cdot EMG_{Mi} = M_{ir}$$

where X_{Mi} is the cross-sectional diameter of muscle M_i in cm^2, K is a constant for skeletal muscle (expressed in N/cm^2), and EMG_{Mi} is the ratio or scaled value of the muscle contraction relative to its maximum response for any task.[42,43] The product $[X_{Mi} \cdot K]$ is referred to as the weighting factor given to the muscle M_i, and the value EMG_{Mi} as its scaling factor. Although there seems to be a considerable variation in the estimation of K, a mean value of 40 N/cm^2 was chosen as the weighting constant (K) for this study.[43]

Weighting factors assigned to each muscle and their derivation from determinations of whole muscle cross-sectional areas were the same as those established by Nelson[28] and are given in Table I. The whole muscle group cross-sections were originally derived from the work of Weijs and Hillen[43] and represent the bilateral mean cross-sectional areas of the four main masticatory muscle groups (masseter, medial pterygoid, temporalis, and lateral pterygoid muscles) of the sample used in their study. The assumed cross-sectional values for the digastric muscle were obtained from the work of Pruim et al.[42]

The scaling factors used for each muscle are shown in Figs. 1 and 2. The values for superficial masseter (sup. mass.), medial pterygoid (med. pter.), anterior temporalis (ant. temp.), and posterior temporalis (post. temp.) muscles were derived from the work of MacDonald,[44] those for inferior lateral pterygoid muscle (inf. lat. pter.) activity, from Wood et al.,[45] and those for deep messeter muscle (deep mass.) were taken from Belser and Hannam.[46] The values for superior lateral pterygoid muscle (sup. lat. pter.) and anterior digastric muscle (ant. dig.) were taken from Gibbs et al.[47]

The clenching tasks simulated in this study were the same as those used by MacDonald.[44] His electromyo-

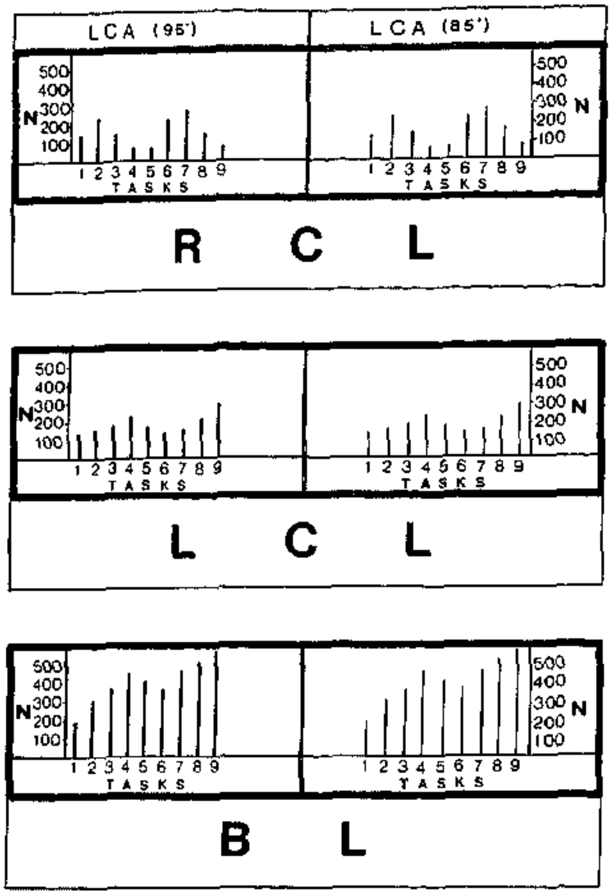


Fig. 5. Magnitudes of condylar and bite loads for acrylic resin shim tasks (1 through 9). *RCL*, Right condylar load; *LCL*, left condylar load; *BL*, bite load; *N*, newtons; *LCA*, left condylar resistance angle.

graphic data for these tasks thus provided the basis for most of the scaling factors that were used. Although not all muscle data were ideally matched, they nevertheless represented the best estimates available for man. A complete set of scaling factors for all nine pairs of muscles was obtainable only for left-sided group function on natural teeth (Fig. 2). The remaining tasks were modeled with data for the superficial masseter, medial pterygoid, and anterior and posterior temporal muscles (Fig. 1).

Nine tasks involving acrylic resin shims and five tasks on natural teeth were chosen for modeling condylar and bite loads. The acrylic resin shim tasks simulated clenching without eccentric jaw movements and slightly increased vertical dimension of occlusion, whereas the natural teeth tasks were included to reproduce unaltered occlusal situations (Figs. 1 and 2).

Five points of optional tooth contact were considered (Fig. 3). Points ipsilateral to the working side were located at the lower left canine and at a point intermediate between the latter and the ipsilateral second molar. A contralateral (balancing) contact was positioned at the lower right second molar. Of the remaining two theoretic contact points, one was located on an imaginary line midway between the working-side canine and the balancing second molar (line a, point 1, Fig. 3), and the other was placed midway between the intermediate working-side contact and the balancing second molar (line b, point 2, Fig. 3). For mathematic purposes, models of the kind used in this study require bite forces to be represented by single vectors. Isolated contacts on the working or balancing side thus can be simulated easily, but multiple working-side contacts or simultaneous bilateral contacts must be assigned a force vector representing the resultant of all tooth loads normally present for the act modeled. This is possible only when the proportional distribution of parallel forces between the respective sites is known. Since matched muscle and tooth load data are presently unavailable for distributed tooth contacts, the tooth force resultants representing group function on the working side were placed midway between the canine and the second molar, and the resultants for cross-arch simulations midway between the respective contact sites. It was thus possible to model muscle-generated tooth loads on the working and balancing sides, and midway between them for both canine and group function working-side clenches.

For all simulations involving acrylic resin shims, tooth force resultants were assumed to be oriented perpendicular to the plane of occlusion. To increase the safety margin of the predictions with natural teeth, tooth force resultants were assumed to be aligned obliquely to the occlusal plane, between lateral tooth resistance angles (α) of 105 degrees and 120 degrees, and frontal tooth resistance angles (β) of 60 degrees and 75 degrees respectively (Fig. 4). The ranges of values for both angles (α, β) represented a theoretic range of tooth resistance forces acting on the distobuccal cusp ridge of the lower left canine. With higher values of α and β, a more retrusive and steeper tooth resistance angle was obtained (Fig. 4).

The simulation used static equilibrium theory according to principles previously described by others.[27-29, 31, 36, 48] It was assumed that under isometric or near-isometric conditions of jaw muscle function all forces applied to the mandible were in static balance and that the sums of all rotational and translational forces were zero irrespective of the viewing plane. For mathematic convenience, the center of the right condyle was selected as the fulcrum about which all moments were determined. All mathematic calculations were carried out using a program written in FORTRAN IV on a Hewlett-Packard (HP) 9000-series-350 minicomputer (Hewlett-Packard Co., Palo Alto, Calif.). The model solved for the reaction forces that occurred at three points of resistance (right and left condyles plus the single assumed tooth contact position) as a consequence of the muscle force generated.

Since each of these three resistance forces had three orthogonal components, it was necessary to constrain the system to make it statically determinate. Each of the three

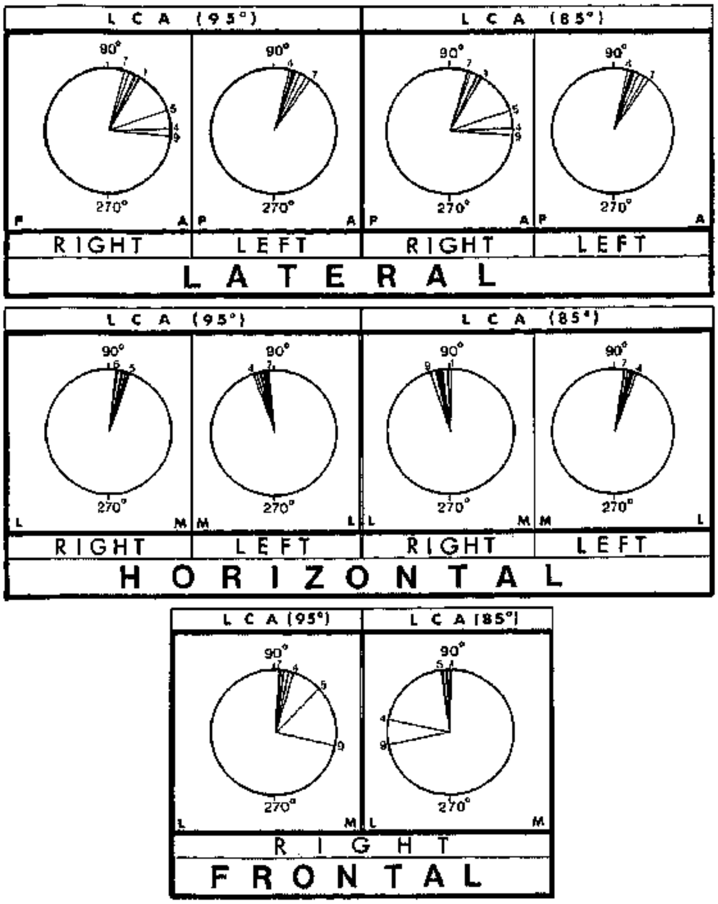


Fig. 6. Directions of right and left condylar resistance forces for acrylic resin shim tasks (1 through 9) expressed in three orthogonal planes. *LCA*, Left condylar resistance angle; *A* and *P*, anterior and posterior; *L* and *M*, lateral and medial. Only extreme orientations of tasks represented by numerals are shown.

orthogonal components of the tooth resistance force was considered to be of known proportions relative to the other, thus reducing three unknowns to one variable. This was achieved by the specification of the three-dimensional angulation of resistance force at the chosen bite point. The mediolateral and vertical components of the left condylar force were also expressed in a single term, which was equivalent to specifying the angulation of the left condylar reaction force when viewed coronally. The indeterminate nature of the distribution of lateral components of force between the two mandibular condyles has already been described by others[28, 29, 48] and is due to the coaxial locations of the condyles when viewed in the lateral plane. In some studies, this problem has been overcome by arbitrarily distributing the total lateral component of articular force (which is calculable) evenly between both condyles.[30, 31] In our calculations, we assumed that forces on the left condyle were resisted between 85 degrees and 95 degrees from the horizontal plane when viewed coronally (left condylar resistance angle [LCA]) (Fig. 4). This approach was based on epidemiologic findings regarding mandibular condyle morphology.[49, 50]

RESULTS

The magnitudes and directions of loads generated at both condyles and the simulated points of tooth contact are presented separately for the two categories of occlusal tasks.

Acrylic resin shims

The magnitudes of right and left condylar loads and the bite load for LCAs of 85 degrees and 95 degrees are shown in Fig. 5. Canine guidance alone (task 1) produced the lowest values and an even distribution of condylar loads. A progressive shift of the bite point to the contralateral side caused an increase in bite load and left condylar load and a decrease in right condylar load. This was true for both canine guidance and group function with SBCs (tasks 2 through 4 and 7 through 9, respectively). Group function with SBC yielded the highest values overall. Changes to

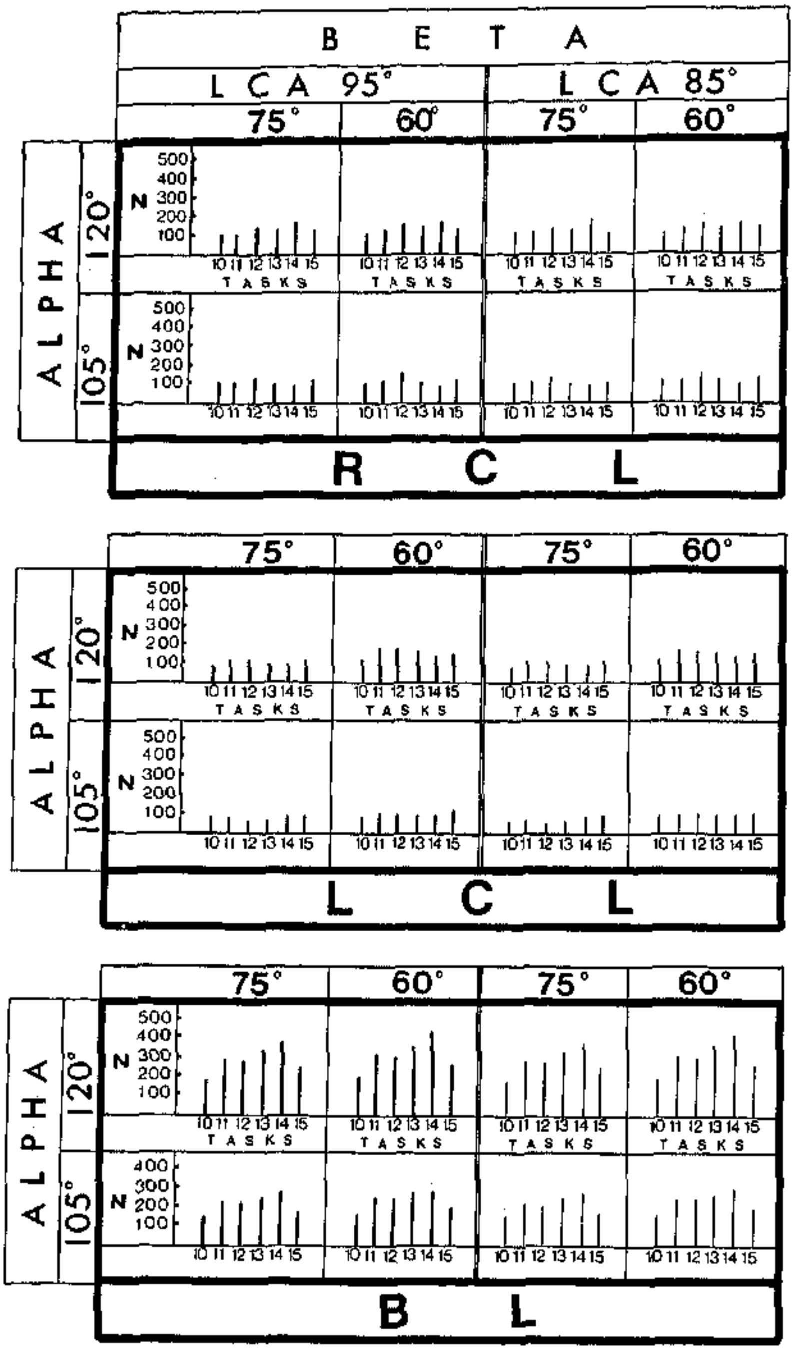


Fig. 7. Magnitudes of condylar and bite loads for natural teeth tasks (10 through 15). *LCA,* Left condylar resistance angle; *alpha,* lateral tooth resistance angle; *beta,* frontal tooth resistance angle; *N,* newtons.

LCA produced little apparent differences in the results.

The directions of condylar resistance forces are given in Fig. 6. For the right condyle (LCA = 95 degrees), most tasks (1 through 3 and 6 through 8) yielded forces oriented between 60 and 75 degrees projected laterally, 79 and 88 degrees frontally, and 72 and 83 degrees horizontally. The left condyle showed loading directions between 56 and 77 degrees projected laterally and 97 and 107 degrees horizontally. Those tasks involving loads placed on SBCs showed the most anteriorly and medially directed loads at the right condyle (tasks 4, 5, and 9). For LCA = 85 degrees, placing the load on SBCs with canine guidance and group function resulted in the most anteriorly and laterally directed forces at the right condyle (tasks 4 and 9).

In summary, group function with SBC yielded the highest forces at the load point and both condyles, followed in

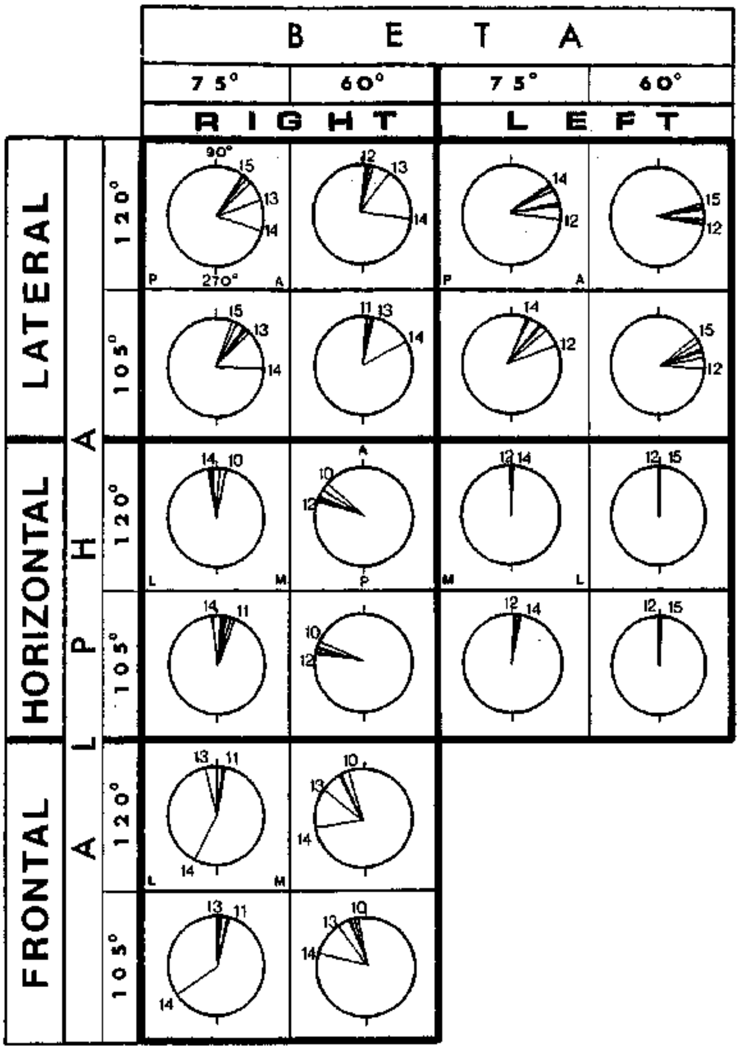


Fig. 8. Directions of right and left condylar resistance forces for natural teeth tasks (10 through 15) expressed in three orthogonal planes for LCA = 95 degrees. *Alpha,* Lateral tooth resistance angle; *beta,* frontal tooth resistance angle; *A* and *P,* anterior and posterior; *L* and *M,* lateral and medial. Only extreme orientations of tasks represented by numerals are shown.

lecreasing order by group function alone, canine guidance ith SBC, and canine guidance alone. Movement of the cclusal load toward the balancing side produced greater, nteriorly oriented forces on the working condyle.

atural teeth

The magnitudes of right and left condylar loads and the ite load for LCA of 85 degrees and 95 degrees are shown n Fig. 7. Condylar loads and the bite load showed the lowst magnitudes for a lateral tooth resistance angle (α) of 105 egrees and a frontal tooth resistance angle (β) of 75 egrees. The highest magnitudes resulted when α was 120 egrees and β was 60 degrees. The change of LCA from 95 o 85 degrees showed similar results. An increase in β from 0 to 75 degrees and a decrease in α from 120 to 105 degrees roduced a slight decrease in magnitudes, that is, the more vertical the tooth loads, the less their magnitudes. Canine guidance (task 10) and group function (task 11) yielded similar, low condylar loads, although group function produced higher bite loads. Similar magnitudes in condylar and tooth loads were observed when group function was modeled either with a partial or a complete set of muscle scaling factors (tasks 11 and 15, respectively).

When the bite point was shifted contralaterally, the more retrusively directed the tooth resistance angle α, the higher the magnitudes of the contralateral condylar and bite loads and the lower the magnitudes of the ipsilateral condylar load (tasks 12 through 14). For these tasks, increases in condylar and tooth load magnitudes were observed with more laterally inclined frontal tooth resistance angles (β).

The directions of condylar loads are shown in Figs. 8 and 9 for LCA = 95 degrees and 85 degrees respectively. For the

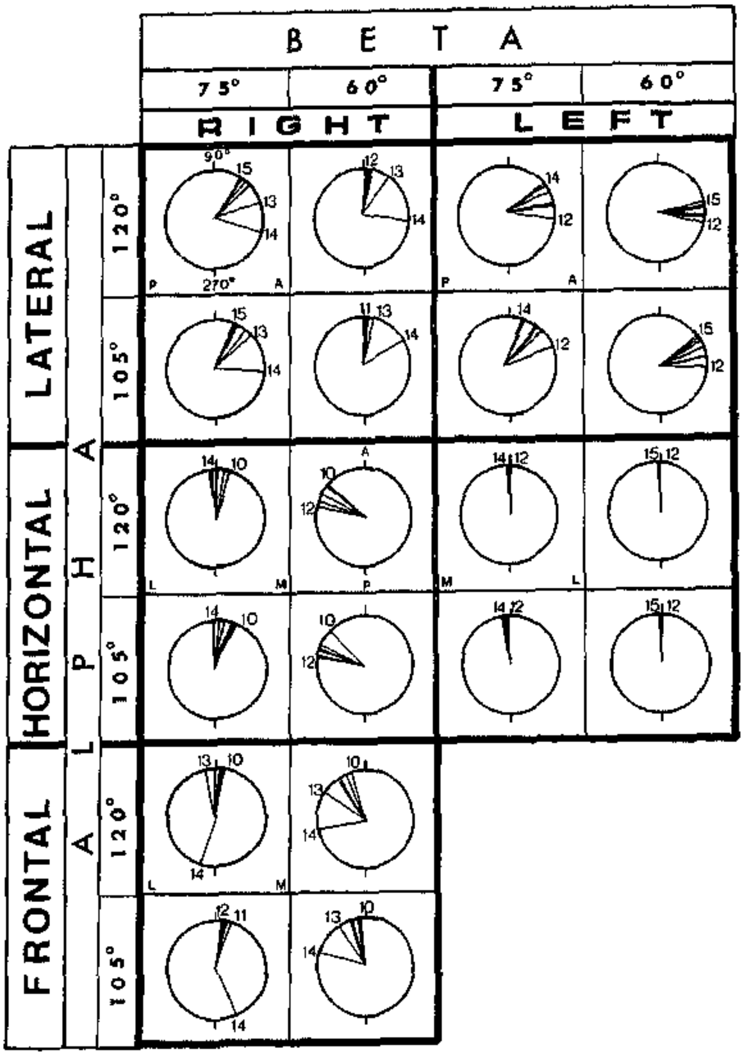


Fig. 9. Directions of right and left condylar resistance forces for natural teeth tasks (10 through 15) expressed in three orthogonal planes for LCA = 85 degrees. *Alpha,* Lateral tooth resistance angle; *beta,* frontal tooth resistance angle; *A* and *P*, anterior and posterior; *L* and *M*, lateral and medial. Only extreme orientations of tasks represented by numerals are shown.

right condyle with LCA = 95 degrees, most tasks (10 through 12 and 15) produced anteriorly, medially, and superiorly oriented loads. When α increased and β decreased, the loads were more inferiorly directed. A change in β from 75 to 60 degrees resulted in more laterally directed forces in the group as a whole. For task 14, a change of α from 105 to 120 degrees caused a more inferior and lateral orientation of the right condylar load.

The left condyle showed anterior and superior loading directions for most tasks (10, 11, and 13 through 15). For group function with SBC (tasks 12 through 14), task 12 yielded the most inferiorly directed load orientation, and a shift of the bite load toward the SBC (task 14) caused the left condylar resistance angle to be more superiorly directed.

In summary, simulated changes in the angle of resultant tooth force (simulating facet angulation) greatly influenced condylar forces. As the occlusal load moved toward the balancing side, greater and more laterally oriented forces were produced on the balancing condyle. A more retrusive and/or lateral inclination of the bite load produced higher magnitudes of loads for all tasks, but canine guidance alone had the lowest values. For nearly vertical tooth resistance angles, a shift of the bite load toward a SBC during canine guidance or group function showed similar results as with the use of acrylic resin shims, that is, a decrease in balancing condylar load and an increase in working condylar and bite load.

DISCUSSION

The model used in this study assumed that for each occlusal task, realistic tensions could be assigned to the jaw muscles. The inclusion of experimentally derived values for the physiologic parameters that determine the relative forces generated by the individual muscles, and therefore the overall total muscle force resultant vector, provides some insight into how the mandible functions in real terms. Other models commonly derive muscle forces by hypothesizing bite force values and assuming the minimization of joint and/or muscle force.[27, 29, 31, 32] Although most of these models include most of the pertinent muscle groups as well as three-dimensional coordinates and cross-sectional sizes, the information they provide often contradicts actual measurements of muscular activity during various occlusal tasks.[16-24, 44, 47] The use of partial and complete sets of muscle scaling factors for group function alone (tasks 12 and 15, respectively) produced similar results not only in magnitudes but also in direction of condylar and bite loads. This was surprising, since the calculations for task 15 involved not only the main jaw-closing muscles but also muscles such as the anterior digastric and the inferior lateral pterygoid. It seems that for certain isometric biting conditions, the model may be more sensitive to the bite force moment arm and to a lesser extent the number and relative magnitudes of the muscle forces, which would corroborate the conclusions of Throckmorton and Throckmorton,[35] who used a two-dimensional model.

The use of interocclusal acrylic resin shims constrains clenching so that it is perpendicular to the occlusal plane. According to the model, simulated clenching on a SBC during either group function or canine guidance affected articular loading differently than clenching on natural teeth. Not only were overall condylar and bite load magnitudes higher with acrylic resin shims than with clenching tasks on natural teeth, but the condyles were also loaded differently for each situation. With acrylic resin shims, higher magnitudes were found at the working-side condyle than the balancing-side condyle during clenching on SBC, whereas the reverse was true for bite loads placed on natural tooth inclines. In the former case, the SBC seems to have acted in a supporting or bracing fashion for its unilateral counterpart(s) and allowed muscle activity to increase bilaterally during clenching.[44]

During unilateral clenching and chewing, compressive loads are normally thought to be greater on the balancing-side joint.[37] For clenching tasks on cuspal inclines of natural teeth, this relationship seemed to be maintained, especially for nonvertical angles of bite loads at the SBC. In these situations, more laterally oriented condylar loadings were found, which could occur during mastication. Experiments on primates and other animals have shown that the lateral aspects of the balancing-side joints are more heavily stressed than the medial portions because of a twisting effect of the mandibular corpus around its axis during the power stroke in mastication.[51-53] Hence it is functionally possible for a mandibular condyle to be differentially loaded on its lateral aspect. Examinations of human TMJs removed at autopsy suggest that deviations in form (DIF) or osteoarthrosis (OA) may develop in the TMJ because of an increase in unfavorable biomechanical loading,[54, 55] and that DIF and OA are usually located in the lateral and central aspects of the TMJ,[56, 57] the former affecting mainly the condyles and the latter being more frequent in the temporal components[58, 59] or disks.[60] OA has been shown to be positively and significantly correlated with the extent of dental attrition and age among Australian aborigines, being more pronounced in older persons with more worn dentitions.[59] Studies on contemporary skull material, however, have not shown such a statistical correlation.[61, 62]

Regional dental wear appears to be a general physiologic phenomenon found in all mammals.[63] Facets on balancing molars are usually located on lower lingual and upper buccal inclines of supporting cusps and seem to be relatively frequent.[64, 65] A common problem encountered in simulations is the precise matching of muscle contraction patterns to the specific angle and location of tooth contact modeled. In this study we chose a variety of angles for each simulation. Placement of the bite load on a distolingual incline of a buccal cusp of a balancing-side lower second molar simulated a retrusively directed clench (α = 105 to 120 degrees). Conversely, the placement of the bite load on a mesiolingual incline of a buccal cusp of this lower second molar assumed more protrusive tooth loads (α = 60 to 75 degrees). Bite loads on this incline produced posteriorly oriented condylar loads, whereas the reverse was true for placement of bite loads on a distolingual incline. In general, when the bite load was placed eccentrically, condylar loads increased in magnitude and were laterally oriented on the balancing condyle. These directions were more lateral when LCA was 85 degrees. When the bite load was assumed to be directed more retrusively on a SBC, an increase in the balancing condylar load and a decrease in working condylar load was noted, although these changes in magnitude were small. Collectively, these observations demonstrate the sensitivity of theoretically derived condylar loads to small changes in the variables assumed to be responsible for them, for example, the specific levels of muscle activation for the task at hand. The limitations imposed on this simulation by our use of averaged data should therefore be borne in mind when interpreting its results. Until precisely matched data sets are made available through experiment, predictions from models such as ours should be viewed only as general indicators of behavior, and in qualitative rather than quantitative terms.

CONCLUSION

The simulations done with the model suggest that unilateral canine support, whether on natural teeth or on acrylic resin shims, is associated with low articular and occlusal loads.

Clenching on balancing-side interocclusal acrylic resin shims apparently affects articular loading differently than clenching on natural teeth. In the former case, the SBC seems to act in a supporting fashion for its working-side counterpart. This observation may be significant with respect to the use of occlusal splints.

During unilateral clenching and chewing, compressive loads are normally thought to be greater on the balancing side. Tooth clenching with cross-arch contact on cuspal inclines seems to maintain this relationship and apparently cause more laterally applied articular loading on the nonworking side. The simulation offers a possible explanation for the greater incidence of pathology commonly reported in the central and lateral aspects of temporomandibular joint articulating surfaces.

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