

**AN EVALUATION OF
MANDIBULAR BORDER
MOVEMENTS
THEIR CHARACTER
AND SIGNIFICANCE**

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An evaluation of mandibular border movements: Their character and significance**Harry C. Lundeen, D.D.S.,*Edwin F. Shryock, D.D.S.,M.S.,** and Charles H. Gibbs, Ph.D.*****

Recording methods for mandibular movements have been advocated and used to form, mill, or adjust the condylar control mechanisms of articulators.¹⁻³ While the reasons for acceptance or rejection of these procedures are varied, studies have not clearly demonstrated what these movement have in common, how they differ from each other, or how they may or may not affect the character of cusp movements.

In the first part of this study mandibular border movement data were analyzed to determine the average movement pathway of 163 subjects. By calculation, pathways were expanded around the average to demonstrate the shape of the range of movement necessary to include most subjects. The second part involved molar cusp movement analysis utilizing border movement pathways of representative subjects coupled with variations in anterior guidance.

**MANDIBULAR BORDER
MOVEMENT
ANALYSIS
(Part I) Method**

Recording instrumentation. Using the instrumentation developed by Lee,² three-dimensional border movements were recorded as the mandible was guided from centric relation through (1) right lateral, (2) left lateral, and (3) protrusive movements, (Fig. 1, A and B). An intraoral central bearing screw and opposing concave maxillary table separated the teeth to facilitate smooth recordings and provide room for clutch attachment. This common procedure is used by most border movement recording instrumentation. Tests have shown that the resulting increased vertical dimension produced by the central bearing screw and plates does not significantly affect the recordings.³

This system records movements in plastic blocks engraved by air-turbine drills. Two blocks were spaced 220 mm apart along the

hinge axis, and a third block was centered anterior to the head. The accuracy of this method has been discussed by Lundeen and Wirth.⁴

Sample Description. The 163 subjects ranged from 20 to 65 years of age. Approximately two thirds of the subjects were patients for whom occlusal therapy was indicated. The other third of the group was made up of dental students, faculty members, secretaries, and dental assistants from the College of Dentistry for whom no dental treatment was indicated. None were edentulous. The number of men and women in the group was nearly equal. Unusual or bizarre movement patterns produced by patients with histories of trauma or severe dysfunctional symptoms were excluded from the sample.

Data analysis. All recordings were aligned to the subject's hinge axis and the axis-orbital plane. The movement patterns engraved in plastic blocks were digitized and stored on magnetic tapes utilizing the method developed by McCoy, Shryock, and Lundeen.⁵ A computer program developed by Lauffer⁶ was used to analyze the data.

Results

The data were analyzed in frontal and sagittal aspects for horizontal planes of 0.5, 1.0, 2.0, 3.0, 4.0, and 5.0 mm superior and inferior to centric relation. At each horizontal plane, the average point for the 163 subjects was calculated. A histogram showing the frequency distribution of the 163 subjects points was plotted as in Fig. 2. At each horizontal plane a histogram was used to partition the 163 data points of the subjects into a

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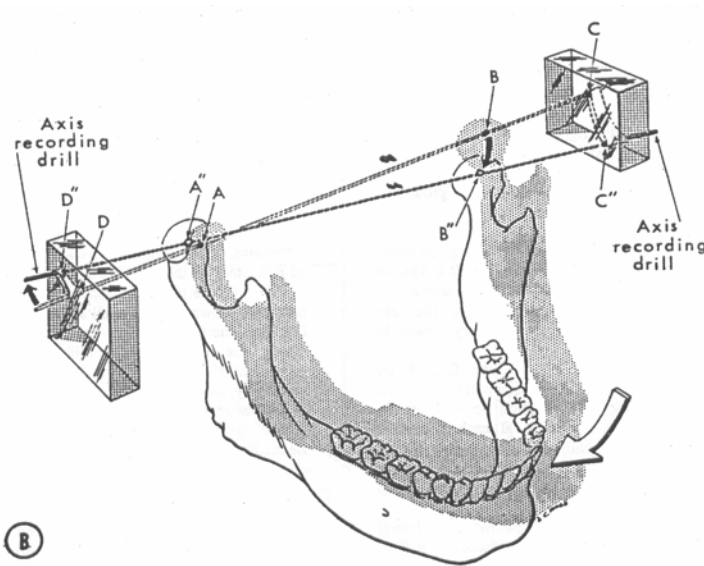
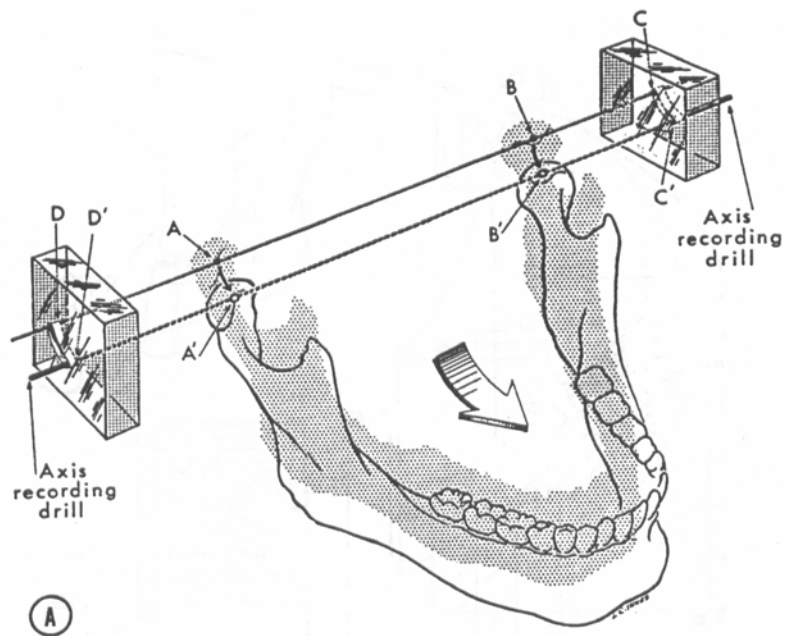


Fig. 1 The Lee pantograph system was used for engraving mandibular movements in solid plastic using air-turbine drills for protrusive (A) and lateral (B) movements
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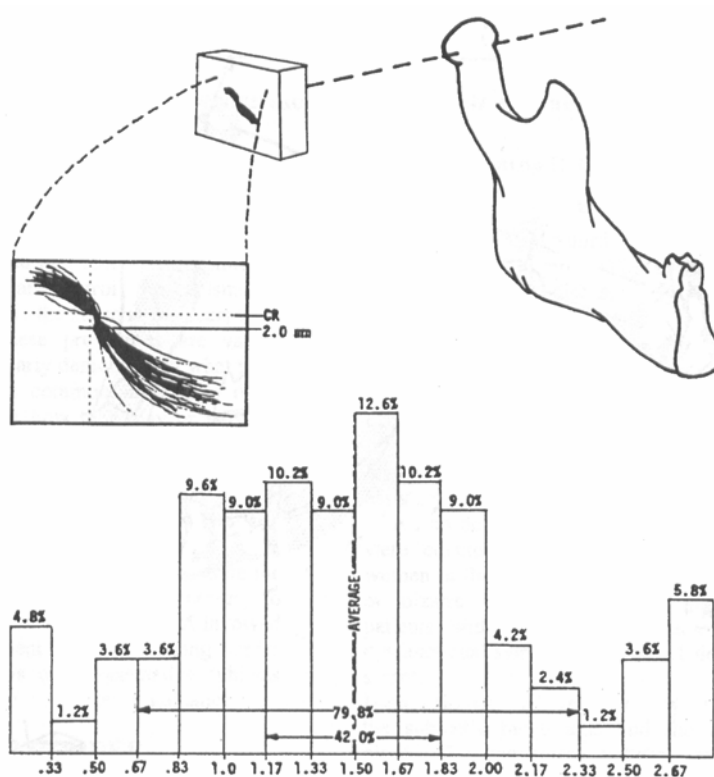


Fig. 2. The data at the right side recording book were analyzed on the 2.0mm horizontal plane in the sagittal aspect. The data were analyzed in both frontal and sagittal aspects at seven different horizontal planes superior and inferior to centric relation. A histogram was constructed at each of the horizontal planes to partition the 163 subject data points around the average pathway, with a center group containing 40% and two groups on either side of the center group each containing 20%.

center group containing 40% and two groups on either side of the center group, each containing 20%. Thus at each horizontal plane 80% of the total sample was partitioned around the mean in three groups. The sizes of the groups were derived by arbitrary means to include a majority of the sample.

The average pathway was formed by connecting the average points at each horizontal plane. The 20%, 40%, and 20% partition points from the histogram were also connected at each horizontal plane to form pathways enclosing 20%, 40%, and 20% of the sample (Fig. 3, A to F). The standard deviations of the sample were also calculated at each horizontal plane.

All four nonworking pathways in lateral movement (Fig. 3, C and D) were steeper than their counterparts in protrusive movement (Fig. 3, A and B). The nonworking pathways represent magnified

extensions of the hinge axis recorded approximately 55 mm lateral to the subject's condyle.

Of particular interest are the nonworking pathways shown in the frontal aspect in Fig. 3, C and D. The amount of Bennett movement differed only during the first several millimeters of condyle movement, and then the pathways remained essentially parallel arcs of circles during the remainder of the movement. When the mandible was firmly guided to the right or left border movements, the Bennett movement occurred close to the centric relation position. Once the Bennett movement had occurred in the early part of the lateral excursion, the working condyle did not continue to exhibit further sagittal displacement but merely rotated throughout the remainder of the lateral border movement.

The effect of the rotating condyle is shown in part

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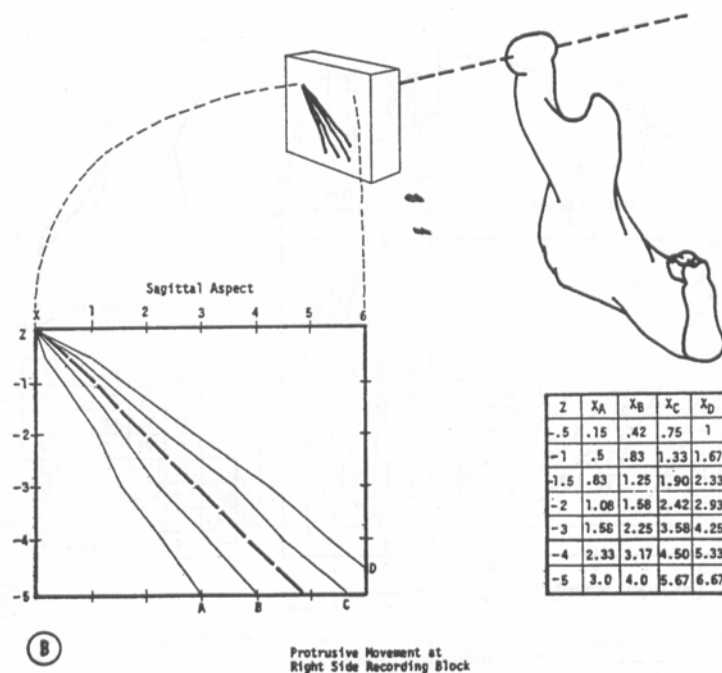
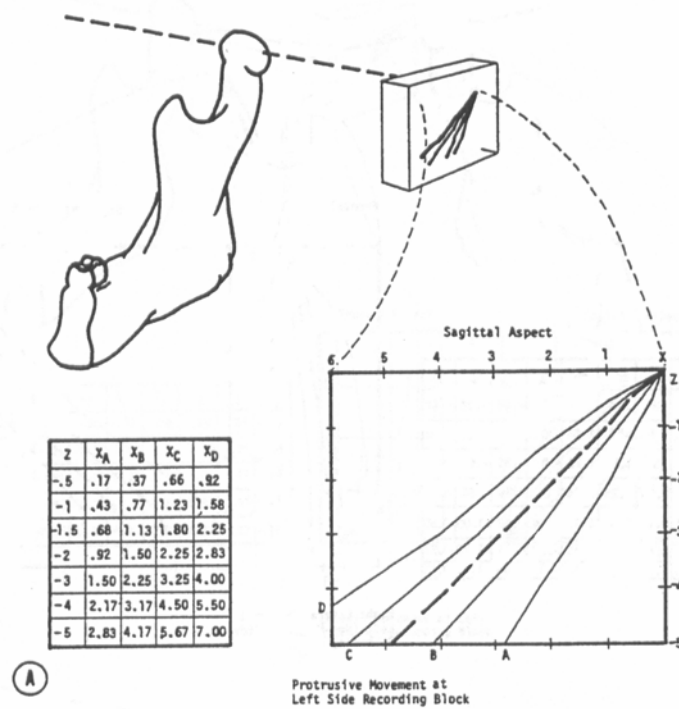


Fig. 3, A and B. Condylar border movement information was transferred into computer memory. A computer program was used to analyze the data. In each of the illustrations the average pathways for the left and right sides are shown by broken lines. Pathways enclosing 20%, 40% and 60% of the sample are shown by the solid lines.

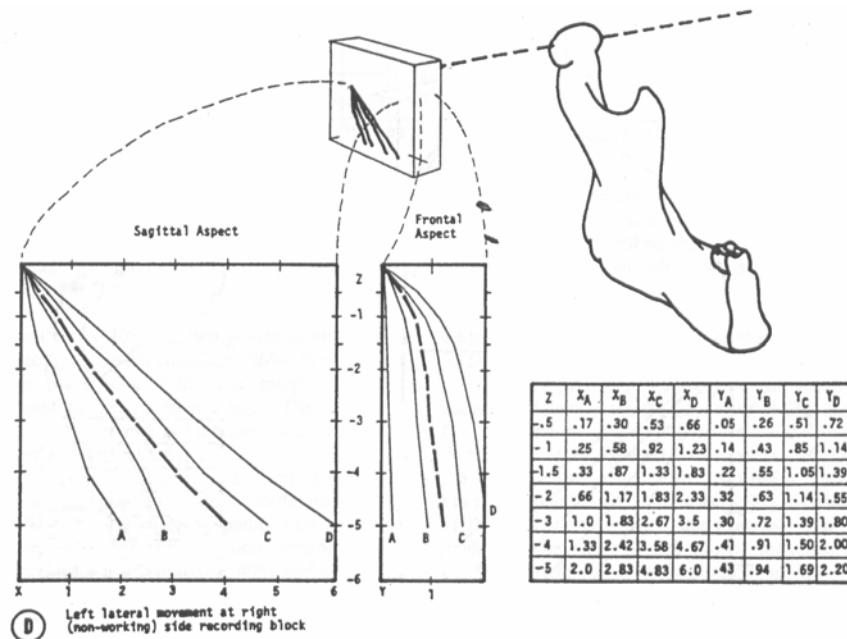
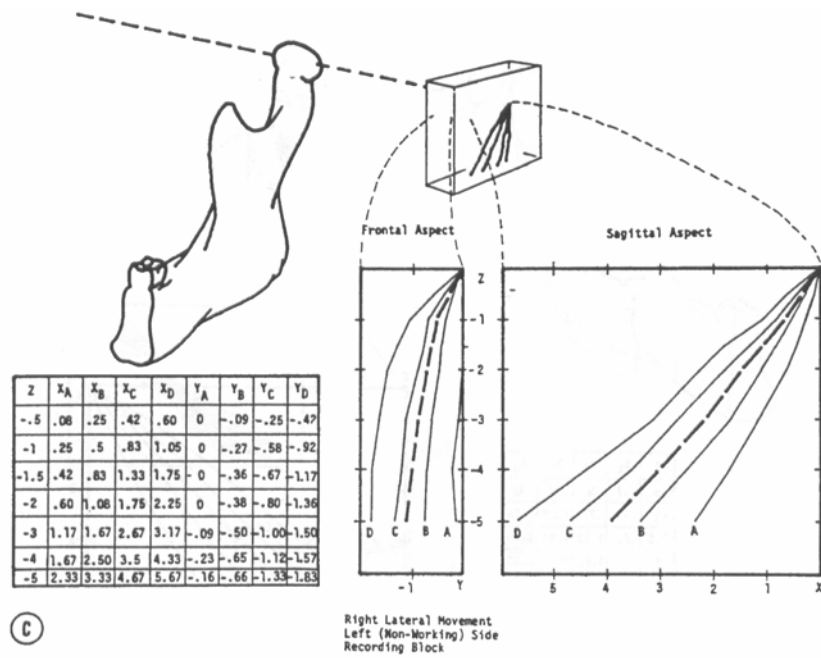
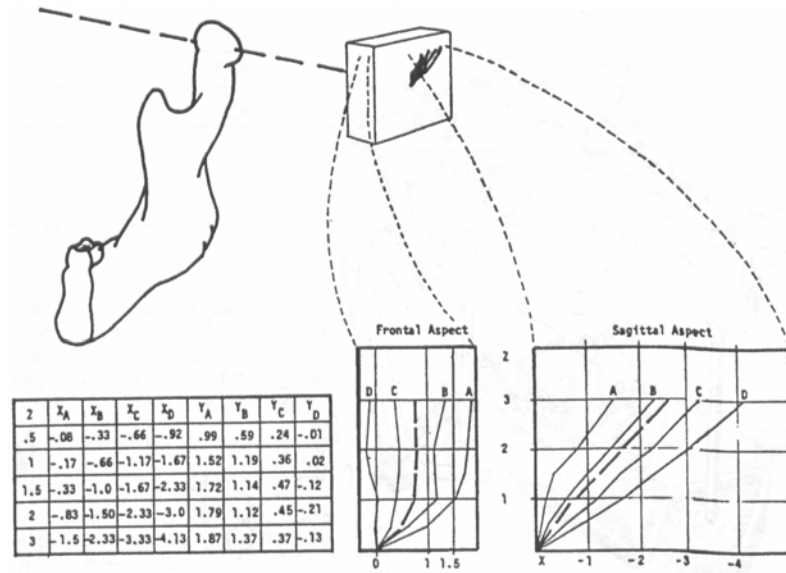
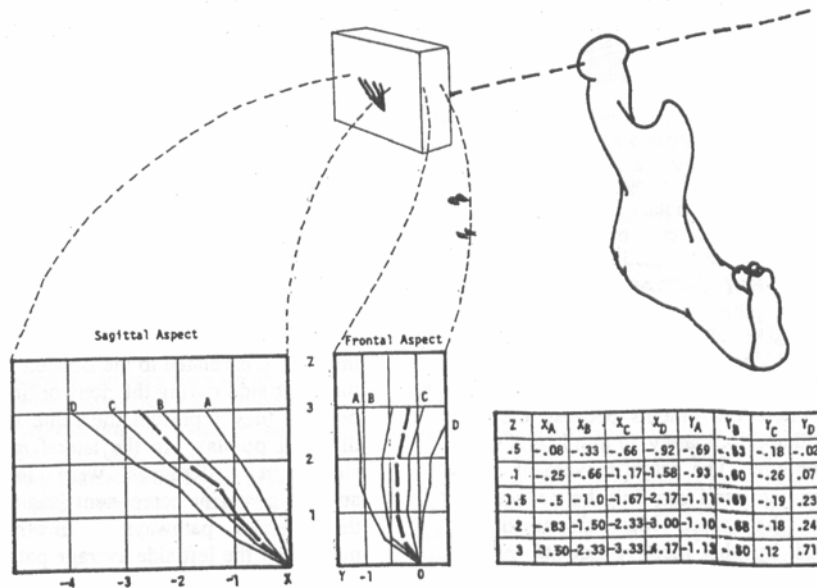


Fig 3, C and D. Condylar border movement information was transferred into computer memory. A computer program was used to analyze the data. In each of the illustrations the average pathways for the left and right sides are shown by broken lines. Pathways enclosing 20%, 40% and 20% of the sample are shown by the solid lines.



(E)



(F)

Right Lateral Movement at Right
(Working) Side Recording Block

Fig. 3, E and F. Condylar border movement information was transferred into computer memory. A computer program was used to analyze the data. In each of the illustrations the average pathways for the left and right sides are shown by broken lines. Pathways enclosing 20%, 40% and 20% of the sample are shown by the solid lines.

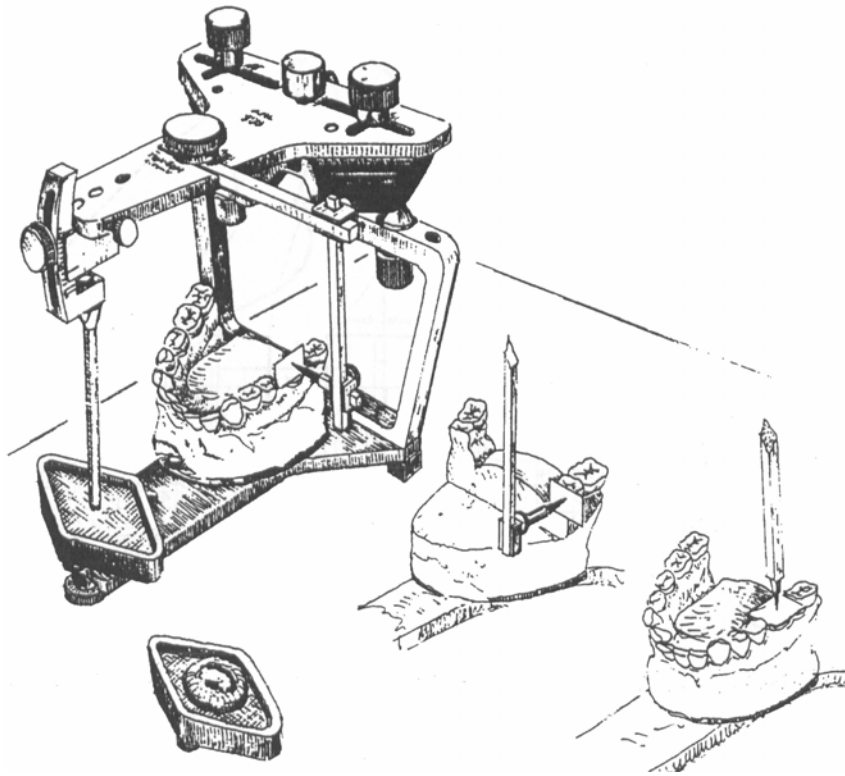


Fig. 4. A mechanical plotter was made by attaching a recording stylus to the maxillary member of a Dentonamics articular. The stylus was adjusted to trace in three planes at a point corresponding to the tip of the mesiolingual cusp of the maxillary first molar. The condylar controls were varied by interchanging certain preselected motion analogues of patients. The anterior guide tables could be varied from 0 to 60 degrees for protrusive movement and 0 to 40 degrees for lateral movement.

in the working-side movement recordings (Fig. 3, E and F). The shapes of the working-side pathways are not true representations of the working condyle movements because they are also recorded approximately 55 mm lateral to the subject's condyle. The actual movement of the working condyle itself can only be deduced by considering the total jaw movement as demonstrated by the reversion to motion analogues made by the transfer machine.

When comparing right and left side recordings the greatest significant difference in the average pathways occurred in the Bennett movement component. More Bennett movement and more deviation in Bennett movement occurred on the left side than on the right side for the working movement, and vice-versa for the nonworking movement. The magnitude of

Bennett movement on one side in working movement is related to the Bennett movement on the other side during the nonworking movement, because they represent the same movement (at different points). In the lateral movements no significant differences were found in the anterior-posterior component (sagittal aspect) of the average pathways. In the protrusive movement the left side average pathway showed more deviation than the right side average. However, their mean values were not significantly different.

The average pathway on the right side was statistically compared with the average pathway on the left side at horizontal planes of 0.5, 1.0, 1.5, 2.0, 3.0, 4.0 and 5.0 mm superior and inferior to centric relation. Possible differences of standard deviation

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Table I. Condylar control selections used in Part II

Test	Nonworking Condylar pathway (degrees)	Accompanying Bennett movement (mm)
1	40	0
2	47	2.50
3	65	0.75
4	52	3.50

were tested with the *F*-ratio, and possible differences in means were tested with a two-tailed Student's *t*-test. Significance was tested at the 5% level, with a sample size of 163. A proper pooled estimate of the standard deviation was used for calculation of the *t* statistic.

CUSP MOVEMENT ANALYSIS

(Part II) Method

The second part of this study was designed to measure changes in movement pathways of molar cusps produced by variations in condylar movement pathways when coupled with simultaneous variations in the anterior guidance.

Mechanical plotter. A mechanical cusp-plotter similar to the one described by Aull⁷ was made by attaching a telescoping stylus, adjustable in three planes, to the upper member of a Dentonamics articulator* (Fig. 4). The point of the stylus was positioned at the tip of the maxillary first molar mesiolingual cusp. A mandibular cast was mounted in the articulator, approximating an average patient's cast position. Flat recording tables covered with pressure-sensitive paper were constructed on the mandibular first molar in the sagittal, frontal, and horizontal planes. A millimeter grid placed over the tables provided the scale for measurement of the stylus tip movements.

Condylar movement pathways were varied by interchanging certain preselected patient articulator control blocks of the Dentonamics articulator system. Variations in the anterior guidance were simulated by interchanging two articulator incisal guide tables. One was made flat, representing a 0-degree anterior guidance. The other was custom-formed in acrylic resin to approximately simulate a 60-degree protrusive and a 40-degree lateral discluding angle for the mandibular anterior teeth.

Description of test movements. The three protrusive test pathways selected had condylar movement pathways of 20-, 30-, and 50-degree angles relative to the axis-orbital plane. The protrusive anterior guidance was changed from 0 to 60 degrees with each test.

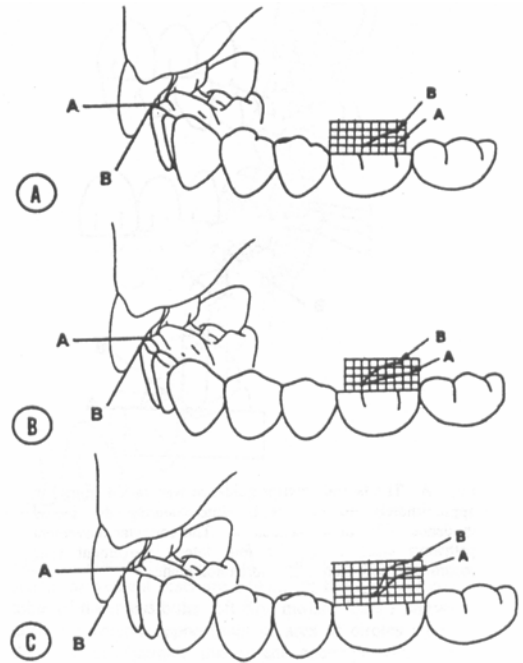


Fig. 5. The protrusive movement was analyzed using 20-, 30- and 50-degree condylar movement pathways. The anterior guidance was varied from 0 to 60 degrees for each test represented by lines A and B, 20-degree protrusive condylar pathway. B, 30-degree. C, 50-degree.

Four lateral movement tests were made in both frontal and horizontal planes, using the condylar control selections shown in Table I. The lateral anterior guidance was changed from 0 to 40 degrees with each test.

The lateral condylar movement pathways as recorded on patients usually have curved shapes. In the analysis study of cusp movement the pathways are expressed in degrees relative to the axis-orbital plane to make their comparison simpler. A line was drawn from the hinge axis point to a point located along the nonworking condyle pathway at approximately two thirds of the total distance traveled. The Bennett movement represents the lateral working side condyle displacement occurring during the first 3 to 5 mm of operation-guided nonworking-side condyle movement.

* Dentonamics Inglewood Corp., Los Angeles, CA

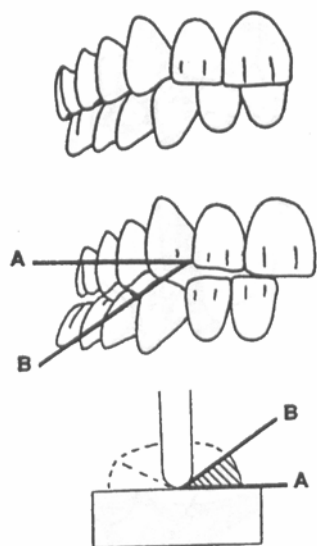


Fig. 6A. The lateral anterior guidance was varied from 0 to approximately 40 degrees by interchanging the incisal guidance tables of the articulator. The condylar movement pathways were varied for four lateral movement tests recorded in both frontal and horizontal planes.

Results

Protrusive movement (sagittal plane) (Fig. 5)

Test 1: The 20-degree protrusive condylar pathway coupled with the 0-degree anterior guide table (line A) produced a molar cusp movement pathway that was nearly flat or parallel to the occlusal plane. When the 60-degree anterior guide table was used, the molar cusp movement pathway demonstrated a gradual or progressive type of jaw opening of 1.75 mm at a distance of 4 mm cusp travel.

Test 2: The 30-degree protrusive condylar pathway showed approximately 0.75 mm jaw opening at a distance of 4 mm cusp travel when the 0-degree anterior guide table was used (line A). The jaw opening increased to 2.5 mm with the 60-degree anterior guide table (line B).

Test 3: The 50-degree protrusive condylar pathway coupled with the 0-degree anterior guide (line A) showed 2.5 mm opening with the 60-degree anterior guide (line B).

Lateral movement (frontal plane) (Fig. 6, A to E)

Test 1. A 40-degree nonworking condylar pathway with no Bennett movement coupled with the flat anterior guide line (line A) showed flat working pathways with only slight jaw opening accompanying the nonworking movement. Repeating the same movement with the 40-degree anterior guide table produced steep separation lines starting immediately at the intercuspal position (line B).

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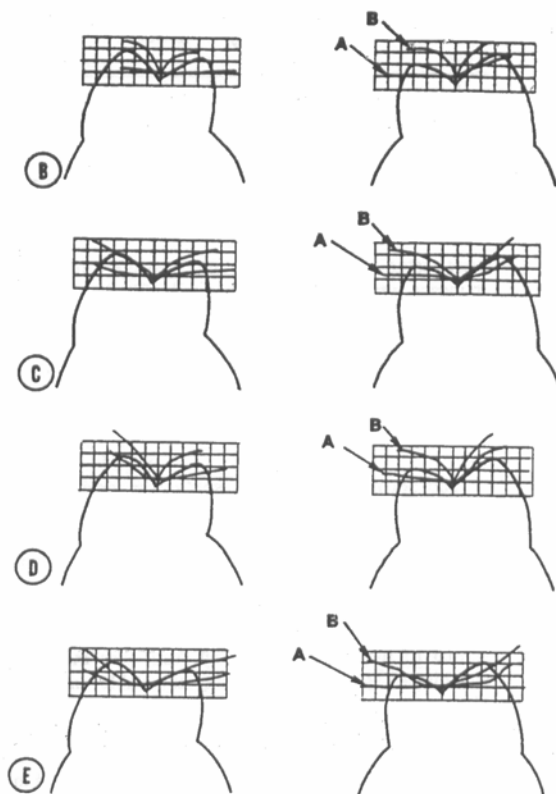


Fig. 6, B to E. B, Test 1 had a 40-degree nonworking condylar pathway with no Bennett movement. (Frontal plane). C, Test 2 had a 47-degree nonworking condylar pathway with a 2.5 mm accompanying Bennett movement (Frontal plane). D, Test 3 used a 65-degree nonworking condylar pathway with a 0.75 mm Bennett movement (Frontal plane). E, Test 4 had a 52-degree nonworking condylar pathway with a 3.5 mm Bennett movement (Frontal plane).

Test 2. A 47-degree nonworking condylar pathway with 2.5 mm of Bennett movement again showed fairly flat molar cusp pathways when the flat anterior guide was used (line A). The 40-degree anterior guide did not produce the steep separation pathways as seen in the first test showing the effect of Bennett movement (line B).

Test 3. A 65-degree nonworking condylar pathway with 0.75 mm Bennett movement showed the steepest molar cusp pathways when coupled with the flat anterior guide table. The steep nonworking condylar pathway shows its greatest influence on the nonworking molar pathway resembling those in Test 1 (line B).

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Test 4. The 52-degree nonworking condylar pathway with 3.5 mm Bennett movement produced very flat molar cusp pathways with the flat incisal guide table (line A). The 40-degree anterior guide table did not appreciably change the molar cusp pathways, showing the dramatic influence of excessive Bennett movement (line B).

Lateral movement (horizontal plane) (Fig. 7)

Movement pathways were made by adjusting the stylus to record on a flat table located on the occlusal surface of the mandibular first molar. Only the flat incisal guide table was used because changing to the 40-degree anterior guide table did not appreciably affect the pathways due to the telescoping of the stylus.

Test 1. When no Bennett movement accompanied the lateral movement, the stylus drew pathways in the form of arcs of circles on the mandibular molar. The working and nonworking pathways form an approximate right angle with their apex pointing anteriorly.

Test 2. The increasing magnitude of the Bennett movement has the same effect here. Excessive Bennett movement can permit molar cusp travel in a transverse direction across the molar occlusal surface.

Test 3. A Bennett movement of 0.75 mm produced lines that resembled those in test 1. The nonworking side showed more of the Bennett movement effect than was seen on the working side.

DISCUSSION (PARTS I AND II)

The effects of the intercondylar distances were not evaluated because the Lee instrumentation operates at a fixed recording distance of 220 mm and a fixed intercondylar articulator width of 110 mm.

The stylus of the cusp movement plotter could have been adjusted to record on the maxillary molar. The results would be identical to the pathways produced on the mandibular molar except for their reversed directions.

The character of the working-side condylar movement of the articulator was not measured in Part II of this study. The working-side recordings of Part I show that the tips of the recording drills travel mainly in an outward, upward, and backward direction. When this magnified movement made at a width of 220 mm is transferred to the solid articulator control block at a width of 110 mm, its magnitude is greatly reduced and not easily measured with this system. Further studies are needed to determine the working-side condyle's influence on molar cusp pathways when coupled with varying degrees of working-side tooth contact.

CONCLUSIONS

1. A comparison of protrusive and lateral condylar border movement pathways of 163 subjects revealed considerable similarity when the frequency of 80% of the pathways was compared with the average pathway.
2. A description of the pathways of posterior cusps during lateral contact gliding movement must

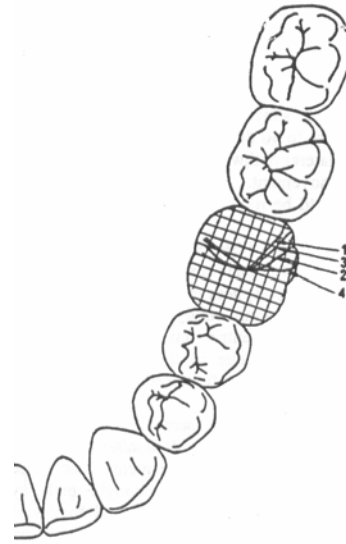


Fig. 7. The horizontal plane recordings for the four lateral movement tests are shown on the flat occlusal table of the mandibular left first molar. Test 1 shows cusp movements represented as arcs of circles when there is no Bennett movement accompanying the lateral movement. Test 4 was made using an articulator control block with an excessive amount of Bennett movement of 3.5 mm.

consider three simultaneously acting guidance factors: (1) the nonworking condyle pathway, (2) the amount of Bennett movement or the working-side condyle displacement, and (3) the anterior guidance or working-side tooth contacts.

3. A Bennett movement of 2.5 to 3.5 mm caused a dramatic flattening of lateral movement pathways of the molar cusp as seen in the frontal plane. The steepness of neither the anterior guidance nor the nonworking condylar pathway had much influence on the molar cusp pathway in the presence of this excessive Bennett movement.
4. Viewed in the horizontal plane, excessive Bennett movement contributed to the greatest potential for collisions of molar cusps during lateral movements. This phenomenon was more pronounced on the nonworking side.
5. When the Bennett movement was 0.75 mm or less the tracing in the frontal plane showed that the 40-degree anterior guidance became the dominant influence over molar cusp lateral movement pathways.

PRACTICAL SIGNIFICANCE

1. Patients with excessive Bennett movement and little or no anterior guidance present the greatest challenge in occlusal rehabilitation procedures
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because the cusp movement pathways of their posterior teeth are very shallow. The elimination of eccentric cusp interferences can be very difficult. In this study it was shown that increasing the lateral anterior guidance to 40 degrees produced only a slight change in the lateral pathways in the presence of a 3.5 mm Bennett movement. The completely adjustable articulators would be most helpful for these types of patients.

2. Patients with very little Bennett movement, 0.75 mm or less, have molar cusp movement pathways that reflect the steepness of the anterior guidance and the nonworking condylar pathways. The potential for eccentric cusp interference is markedly reduced due to the steep immediate posterior cusp separation seen close to the intercuspal position.
3. A condylar movement screening device that would quickly and simply determine a patient's approximate Bennett movement and the inclination of the nonworking condylar pathway would provide useful diagnostic and treatment information. Those patients identified with an average or less Bennett movement coupled with an acceptable anterior guidance could have occlusal restorations fabricated using semiadjustable articulators with a minimal risk of eccentric-type interferences.
4. Viewed in the horizontal plane, the 0.75 mm or less Bennett movement tests showed lateral molar cusp pathways with a minimum possibility for interference on the nonworking side.
5. The influence of the nonworking condylar pathway is most evident in the frontal plane tracing tests made with the 0-degree anterior guidance. The molar cusp pathways were mainly affected on the nonworking side and only slightly on the working side.
6. In this study of 163 subjects the average Bennett movement was 0.75 mm, with 80% approximately 1.50 mm or less.

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