The Relation of the Condylar Path to the Articular Eminence in Mandibular Protrusion

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INTRODUCTION

The relationship between the form of the articular eminence and temporomandibular joint (TMJ) function has not been clearly established. Stallard and Stuart[7] have proposed that "the muscles operating the mandible . . . . hold the condyles against the eminence throughout all condylar operations" and would expect the condylar head to follow exactly the anatomical form of the articular eminence when the mandible is moved into protrusion. However, Jankelson[4] suggests that, "the joint allows free movement anywhere within the limitations of the joint space and the surrounding capsule, ligaments, and musculature." This would allow the condylar head to follow a path in protrusion that could be divergent from the form of the eminence.

A first requirement in understanding the influence of the articular eminencia on mandibular movements would be to determine the relationship which exists between them and their corresponding condylar paths. Many investigators[2,5,6,7] have developed techniques to record and assess condylar movement. That these techniques do, in fact, accurately record condylar movement has been assumed primarily because the recordings or measurements have been repeatable on the same patient. Anatomical evidence supporting the proposal that the condylar recordings represent a form-function relationship, evidence related to the form of the condylar head, articular disc, or articular eminence, is lacking. If a relationship between the anatomical form of the articular eminence and the protrusive condylar path could be established, the credibility of such recordings would be enhanced and the influence of the articular eminence in mandibular movement might be better understood. In addition, if there were a close correlation between the shape of the articular eminence and condylar recordings, the necessity of performing the elaborate recording procedure to obtain protrusive condylar movement data might be eliminated.

An understanding of the form and function of the TMJ could be vital to many aspects of dentistry, including gnathology, periodontics, and orthodontics. It is the purpose of this report to correlate the form of the articular eminence with the movement of the condyles in protrusion. A cephalometric technique, showing the relation of the condylar head to the articular eminence at selected protrusive positions, will be presented and compared with gnathologic recordings of the movements of the condyles in mandibular protrusion.

METHODS AND MATERIALS

Nine patients with near ideal occlusions ranging in age from twenty-two to thirty-seven consisting of three females and six males, all having a Class

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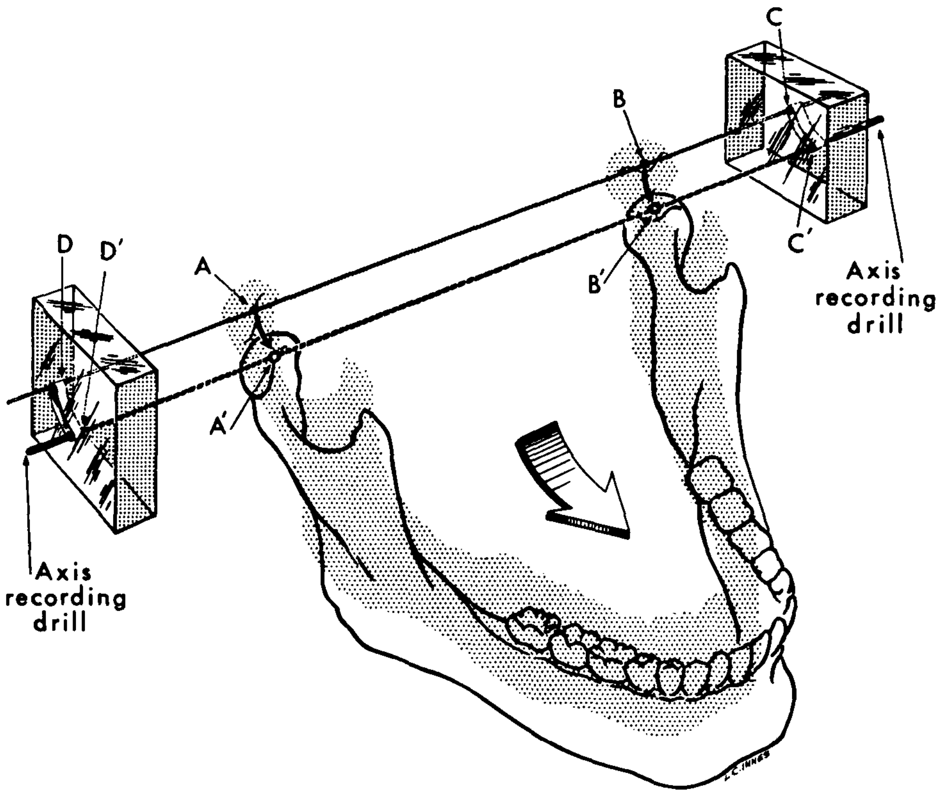

Fig. 1 A diagram showing the relationship of the hinge axis to a protrusive recording. The shadowed area represents the position of the mandible when it is in centric relation. Points (A), (B), (C), and (D) represent the position of the hinge axis in centric relation, and points (A'), (B'), (C') and (D') represent a hinge axis position with the mandible protruded. The paths of points (C) to (C') and (D) to (D') are represented by grooves in the plastic blocks at the tips of their respective recording styluses. The superior surface of the plastic block was made parallel to the axis-orbital reference plane. (From Lee, Robert L.: J. Prosth. Dent. 22:209-223, 1969.)

I molar relationship with normal overjet and overbite and no history of TMJ distress, were selected for study. All patients were subjected to the tattooing and recording procedure described by Lee[5]. The protrusive paths of the condyles were recorded as they responded to protrusion of the mandible (Fig. 1). Hinge axis and orbital locations were tattooed in order to establish an axis-orbital reference plane parallel to the superior surface of the plastic block.

The patients were then subjected to a series of three standardized cephalometric radiographs. The first exposure was made with the patient biting in his acquired centric position, a second with the teeth in an end-to-end relation, and a third with the mandibular incisors positioned anterior to the upper teeth. To transfer the hinge axis and orbital tattoo locations onto the radiograph, radiopaque markers were placed over the respective tattoos before the x-rays were taken. Since the radiopacity of the area surrounding the TMJ was high, it was also necessary to increase radiation to the TMJ while maintaining a normal exposure in other areas. An aluminum foil filter was designed

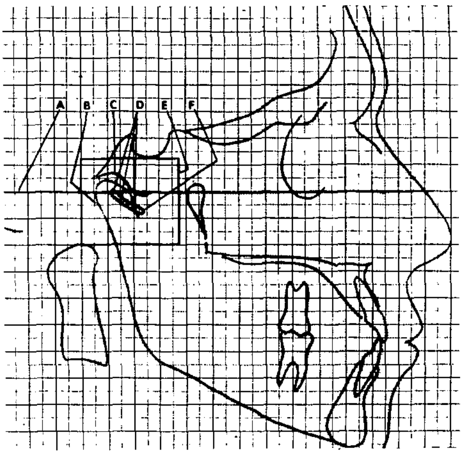

Fig. 2 The finished tracing on which has been recorded in precise relationship A) the axis-orbital reference plane, B) the condylar head of the mandible while in its centric position, C) the articular eminence, and D) the hinge axis point position at three selected intervals along the protrusive condylar path. The tracing has been superposed over an outline of the plastic recording block (E) with its protrusive condylar engraving (F) and registered upon the posterior hinge axis point position. The superior surface of the recording block was made parallel to the axis-orbital reference plane in order to correctly relate the articular eminence and the hinge axis point positions to the condylar engraving.

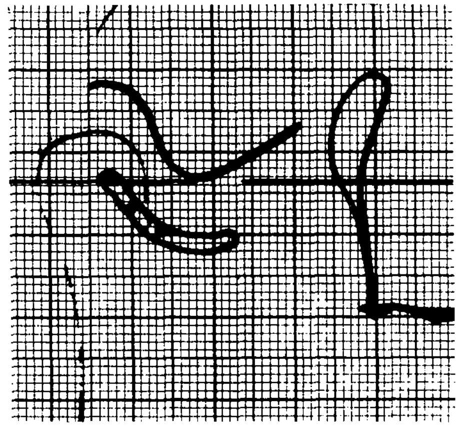

Fig. 3 Completed tracing placed over millimeter graph paper. The axis-orbital reference line is parallel to the abscissa. Vertical distances between the eminence and condylar path curves were recorded at one millimeter intervals along the abscissa. (Figs. 2 and 3 were not taken from the same point.)

for this purpose. In conjunction with this filter, intensity and duration of exposure which gave the best consistent image of the articular eminence were empirically determined on a dried skull and thereafter used for all cephalograms.

Using the film made with the teeth in a centric position, a routine cephalometric tracing was made which included the hinge axis and orbital tattoo positions and the axis orbital reference plane (Fig. 2). The tracing was then superposed on the mandible of the second exposure (teeth end-to-end), and the hinge axis dot position was transferred to the film. This procedure was repeated using the third exposure (mandible in maximum protrusion). From this exposure the mandibular ramus and condyle were also traced. The tracing was then superposed on the exposure which had the clearest articular eminence, and the eminence traced. Finally, the tracing was superposed on the cranial landmarks of each of the three exposures, and the three hinge axis dots were transferred to the tracing paper. At this stage the tracing presented the axis-orbital reference plane, the location of the axis point at three positions along the protrusive condylar path, and the configuration of the articular eminence in relation to the cranium (Fig. 2).

Engraved plastic blocks of the left and right protrusive condylar paths were obtained for each patient. The engraving which best fit the three axis point positions was tranferred to the cephalometric tracing and compared with the three dot condylar path obtained from the x-ray technique (Fig. 2).

The tracings of all nine patients were then placed on millimeter graph paper so that the axis-orbital reference plane was parallel to the abscissa. The most posterior point on the superior surface of the engraved condylar path was selected as the origin (Fig. 3). The corresponding point on the articular eminence was described by a numerical value equal to the distance along the ordinate which separated these two lines. Similar measurements were made at millimeter intervals along the abscissa to describe the location of both the engraved line and the eminence.

The data obtained were then analyzed statistically by a computer to determine the most appropriate type equation to mathematically describe the separate curves of the articular eminence and of the protrusive condylar path. Best fit linear, quadratic, and cubic equations were developed. The linear equation, $y=b+mx$ where y and x are the ordinate and abscissa respectively, b is the intercept on the ordinate and m the slope of the line, had two coefficients, b and m. The quadratic equation, $y=b+m_1x+m_2x$ where m_2 is the rate of change of slope, had three coefficients b, m, and m_2 and the cubic equation $y=b+m_1x+m_2x+m_3x$ where m_3 is the rate of the change of slope, had four coefficients b, m_1, m_2, and m_3. The coefficients of these equations were then used to determine the significance of any correlation between the two mean curves for the group. In addition, the coefficients of the equation best describing the articular eminence of each patient were purposely paired with the coefficients of the equation best describing the protrusive condylar path of a different patient and resubmitted to the computer to determine any possible correlation between curves selected at random and thereby establish the credibility of the results previously obtained. The computer was also programed to plot the two mean curves on a graph (Fig. 4).

To determine the accuracy with which the articular eminence had been traced

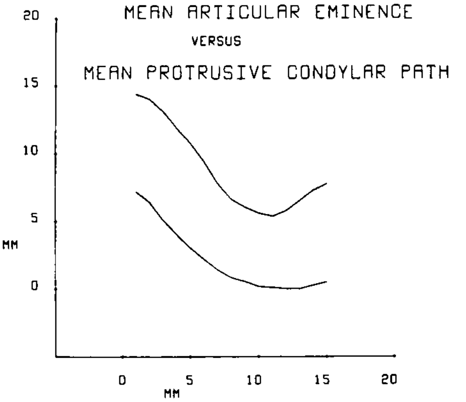

Fig. 4 Graph of the mean articular eminence and mean engraved protrusive condylar path of all nine patients. Ordinate and abscissa values are in millimeters.

from the x-ray, three dried skulls with disarticulated mandibles were positioned in the head holder and x-rayed using standardized cephalometric technique. Subsequently, their mandibular fossae were painted with a separating medium and filled with dental plaster. The casts were removed and reduced along a vertical plane up to the maximum depth of the mandibular fossae. The casts were then compared with the articular eminences as traced from the x-ray.

Results

When the casts made from the mandibular fossae of the three dried skulls were compared with the corresponding radiographic tracings, the discrepancies observed between cast and tracing were less than 0.5 mm. For each patient the greatest discrepancy in millimeters which occurred between any one of the three hinge axis dot positions and a line bisecting the engraved condylar path longitudinally was recorded in Table 1.

As can be seen from the data in Table 2, the m_1 and m_2 coefficients of the quadratic equations describing the articular eminence and protrusive condylar path of the same patient have

TABLE 1

Greatest vertical discrepancy in millimeters which occurred between any one of the three hinge axis dot positions and a line bisecting the engraved condylar path longitudinally.

	Spatial Discrepancy in Millimeters					
	0.0 mm.	0.5 mm.	1.0 mm.	1.5 mm.	2.0 mm.	2.5 mm.
Total Number of Patients	4	4	0	1	0	0

TABLE 2

Correlation analysis data for coefficients of the quadratic equation using articular eminence and protrusive condylar path from the same patient. (Based on 9 patients)

Data Group	Mean of Eminence Variable	Mean of Condylar Path Variable	Correlation Coefficient	Student T Test	Level of Significance
b coefficient	16.16	8.67	0.3651	1.03	0.3338
m_1 coefficient	-1.17	-1.36	0.8294	3.92	0.0056
m_2 coefficient	0.00	0.04	0.8502	4.27	0.0036

TABLE 3

Correlation analysis data for coefficients of the quadratic equation using the articular eminence of one patient and the condylar path of another. (Based on 9 patients)

Data Group	Mean of Eminence Variable	Mean of Condylar Path Variable	Correlation Coefficient	Student T Test	Level of Significance
b coefficient	16.16	8.67	0.3679	1.04	0.3299
m_1 coefficient	-1.17	-1.36	0.0506	0.13	0.8971
m_2 coefficient	0.00	0.04	0.1015	0.26	0.7949

very high correlation coefficients and levels of significance. The data in Table 3 show that when correlation analyses are run between the m_1 and m_2 coefficients of quadratic equations describing the articular eminence and protrusive condylar paths of different patients, the correlation coefficients and levels of significance are very low.

Discussion

The plaster models of the articular eminences of the three skulls corresponded closely to the tracing of these eminences which were obtained from the cephalogram. With an appropriate filter and some experience, the articular eminence can be located from the cephalogram as accurately as most cephalometric landmarks. The three dots, representing three positions of the condylar head, were closely related to a line bisecting the engraved condylar path longitudinally. In eight of the patients representing twenty-four x-rays determining condylar positions, all these positions were within 0.5 mm of the bisecting line (Table 1). In the ninth patient one of the three dots deviated from the mean engraved condylar path by 1.5 mm. Thus by two different techniques, one based on bony landmarks and the other based on functional movement, the same protrusive condylar path was obtained. This indicates that the method of Lee[5] not only records a reproducible condylar path for a particular patient but the recorded path is consistent with three static condylar positions as determined by x-ray. Since repeated protrusive-retrusive excursions did not alter the form of the engravings and since they agree so precisely with the condylar path derived from the three x-rays, it is not unreasonable to expect that the protrusive condylar path is consistent in its relation to the cranium. Thus this study supports Stallard and Stuart[7] rather than Jankelson.[4]

Cohen[1] has suggested that left and right protrusive condylar paths are the same. However, the engravings usually displayed visible differences between the two sides. Since in the cephalometric technique right and left sides were not distinguished, the engraving which best fit the cephalometrically derived condylar path was used.

Of the best fit linear, quadratic, and cubic equations, the quadratic was found to most accurately describe the protrusive condylar path and articular eminence. The linear equation was probably inadequate because it considered only slope while the cubic equation introduced more variables than were necessary. The b coefficient of the quadratic equation showed a low level of significance (Table 2). Since the b coefficient describes the locations at which the eminence curve and the condylar path curve intersect the ordinate, the data indicate that the eminence curve and the condylar path curve intersect the ordinate at different points. This finding suggests that the condylar and eminence vertical positions vary among patients. The m_1 coefficient, expressing the slope of the curve, and the m_2 coefficient, expressing the rate of change of slope, displayed very high correlation coefficients with corresponding high levels of significance. In addition, the levels of significance and the correlation coefficients in the mismatched group (Table 3) were extremely poor. These data suggest that, in protrusion, the condylar head follows closely the anatomical form of the articular eminence.

Summary and Conclusions

It is possible to develop an x-ray technique using a lateral cephalogram to consistently and accurately trace the articular eminence and approximate protrusive condylar path. Radiographically derived protrusive condylar paths and gnathologically recorded protrusive condylar paths were found to be the same. Corresponding articular eminence and protrusive condylar path curves were mathematically expressed and their linear relationship statistically described. It was concluded that in protrusion the condylar head of the mandible follows closely the anatomical form of the articular eminence.

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