Disclusion in Mandibular Protrusion

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Contemporary gnathological concepts[1–5] dictate that mandibular incisors contacting the lingual surface of the maxillary incisors should disclude the posterior teeth during direct mandibular protrusion from centric. "Improper" incisor disclusion has been associated with excessive posterior tooth wear, alveolar bone loss, tooth mobility due to traumatic occlusion and temporomandibular joint dysfunction.

If the anterior disclusive path is flatter than the posterior path, potentially harmful cusp contacts between opposing posterior teeth may occur when the mandible moves eccentrically. If the anterior disclusive path is slightly steeper, the posterior teeth will be separated from occlusion.[6,7]

It has been suggested that the condyle path during protrusion follows the slope of the articular eminence. An understanding of the relationships between the inclination and form of this eminence and the anterior discluding path may be important to orthodontists, since they have some capacity to control this relationship. However, studies are at odds concerning the relevance of the slope of the articular eminence.

Corbett *et al*[8] concluded that the condyle closely follows the anatomical contour of the articular eminence during protrusion.

Ramfjord[9] suggested that any relationship between the two slopes is negligible. Jankelson[10] concluded that the joint allows free movement anywhere within the limitations of the joint space and the surrounding capsule, ligaments and musculature, suggesting that the condyle head can follow a protrusive path that diverges from the eminence.

Huffer *et al*[2] used the cephalometric technique of Corbett *et al*[8] to determine the average slope of the articular eminence in 15 ideal occlusions. They found the anterior discluding path to be steeper in all but one case. Their concern over the role of anterior disclusion in freeing the posterior cusps during protrusion led to the suggestion that practitioners consider anterior disclusion as a treatment objective.

Ricketts[11] used laminography to study individuals with good occlusions or mild malocclusions, and found no significant relationship between the type of molar occlusion and the slope of the articular eminence.

Materials and Methods

This investigation examined the angular relationships between the posterior and anterior disclusive paths and the occlusal plane (OP). The occlusal plane is an appropriate reference because it is along this plane that the mandible separates from the skull during opening. Its inclination is related to the condyle and lower incisor angles necessary for protrusion without posterior tooth interference.

Two disparate population samples were used:

1) 24 skulls of Asiatic Indian origin
2) 17 orthodontically untreated American Whites (dental students) with near-ideal occlusions.

Some differences in the methods employed on these two groups were necessitated by the differences between living and skeletal subjects.

Skeletal subjects

The skulls were selected on the basis of the following criteria.

1) Intact bony components of the temporomandibular joints
2) No more than two missing teeth per quadrant (postmortem loss) anterior to third molars
3) No maxillary central incisors missing

Soft brass ligature wire was contoured on each skull along the most concave surfaces of left and right articular eminences and along the center of the lingual surfaces of both maxillary central incisors. The mandible was fixed to the skull with the teeth in maximum intercuspation (there being no way to reconstruct centric relation), and a standardized cephalometric radiograph was made.

Relevant anatomic structures and the wires were traced on frosted acetate film (Fig. 1). Where the wires on both eminentia or both incisors were visible, the average was drawn. Straight lines were drawn tangent to the curvature of the wires, and angles between those tangents and the occlusal plane measured with a protractor.

Living subjects

From a series of approximately 150 dental students, 17 were selected as having near-ideal occlusions, based on the criteria of an Angle Class I molar relationship, no missing teeth (disregarding third molars), good overbite and overjet relationships, minimal occlusal wear and no temporomandibular joint symptoms. No subject had received orthodontic or occlusal adjustment therapy, restricting the sample to naturally occuring good occlusions.

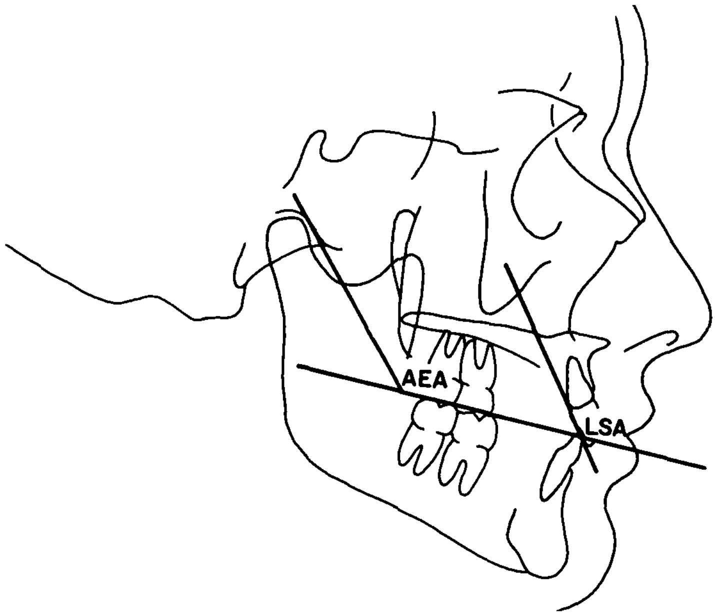

Fig. 1 Diagram illustrating angles measured in this study. The common reference plane is the occlusal plane. The Articular Eminence Angle (AEA) is formed by a tangent to the posterior slope of the articular eminence. The Lingual Surface Angle (LSA) is formed by a line approximating the orientation of the lingual surface of the upper central incisor.

The group consisted of 16 males and one female with a mean age of 27.2 ± 3.3 years.

With the subject reclined in a dental chair, prefabricated clutches constructed as detailed in the Denar Pantograph manual[12] were attached to the clutch former and inserted into the mouth to familiarize the subject with the device. Alginate was placed on the occlusal surfaces of the clutches, and the unit re-inserted with the subject biting in a retruded mandibular position. The clutches were aligned with the center of the clutch former coinciding with the maxillary midline.

After the alginate had set and the device was removed, the subject was trained to execute a straight protrusive movement and then return the mandible to the retruded position. With the mandible retruded, the Pantograph was assembled, styli activated, and the subject asked to execute a protrusive movement until maxillary and mandibular incisors were end-to-end. The styli then were released from the flags, and the mandible returned to a retruded position.

The above procedure was repeated until three identical lines had been scribed by the stylus in the protrusive movement.

Radiopaque paint (white tempera with amalgam particles) was applied to the line scribed on the left side of the maxillary facebow. The maxillary cast was marked with the same radiopaque paint on the lingual surface of the left central incisor, the buccal cusp tips of the left bicuspids and the mesiobuccal cusp tip of the left first molar. The cast was then seated in the alginate impression with the clutch still attached to the maxillary face-bow, and a standardized radiograph made of the entire assemblage.

Tangents were drawn to the lines formed by the disclusive condyle path and by the lingual surface of the central incisor on tracings of the radiographs. Definition of the anterior disclusive path was limited to the overbite of each subject.

A line representing the occlusal plane was aligned through the three dots on the left maxillary buccal cusp tips. The condyle disclusive angle (CDA) and the maxillary incisor lingual surface angle (LSA) were measured with a protractor (Fig. 1).

A laminograph of the left temporomandibular joint of each subject was exposed as detailed in the Quint X-Ray Sectograph manual.[13] These were traced and a line drawn tangent to the long contour of the articular eminence. The occlusal plane was again defined by a line drawn through the cusp tips of the buccal segments.

Results

Skeletal series

The mean values of the angle of the articular eminence (AEA) and the angle of the maxillary central incisors (LSA) were significantly different within and among individuals (Table 1). LSA/OP was 6.1° greater on average than AEA/OP. The correlation between the two angles was 0.83, indicating a strong positive covariation.

TABLE 1

Summary statistics of the skeletal series comparing the angle of the articular eminence (AEA) and that of the upper central incisor (LSA), each measured to the occlusal plane (OP). Measurements in degrees.

	AEA/OP	*LSA/OP*
Standard Deviation	9.1	8.3
Mean	131.7	125.2
Range	115-146	106-141
Difference in Means	6.5	
Mean of Individual Differences	6.1	
Paired t-test	6.1**	
Coefficient of Correlation	0.83**	

** $P < .01$ with 23 d.f.

In Table 2, the skeletal series is subdivided according to Angle's molar classification as determined by placing the dentition in maximum intercuspation. Eight of the skulls had a bilateral Class II molar relationship, while the other 16 were Class I. The means of AEA/OP and LSA/OP were within one degree of each other in the

TABLE 2

Comparisons between AEA/OP and LSA/OP in the skeletal series subdivided by Angle's molar occlusion classification.

	Class I *AEA/OP*	*(n = 8)* *LSA/OP*	*Class II* *AEA/OP*	*(n = 8)* *LSA/OP*
Mean	131.1	124.8	132.9	125.9
Standard Deviation	9.7	8.7	7.7	7.3
Range	115-146	106-141	122-146	119-139
Difference in Means	6.3		7.0	
Mean of Individual Differences	6.3		7.0	
Paired t-test	6.1**		2.7*	
Correlation Coefficient	0.91**		0.58*	

* $P < .05$ with 7 d.f.
** $P < .01$ with 15 d.f.

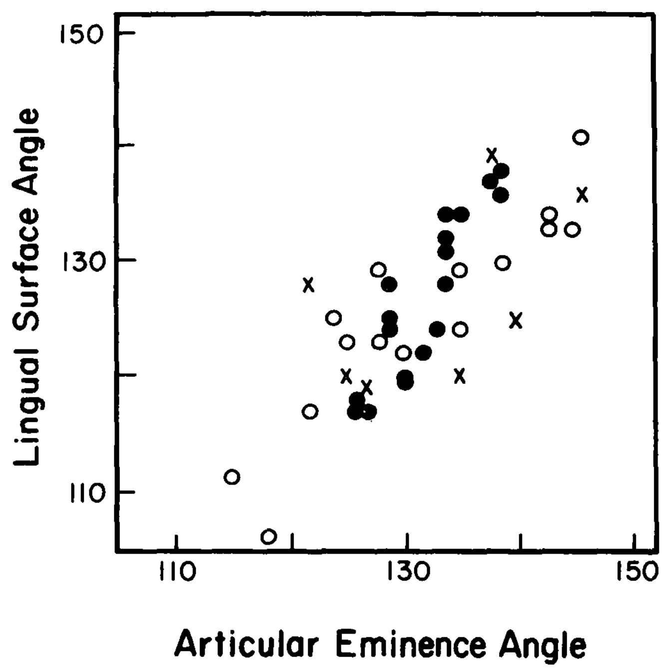

Fig. 2 A bivariate plot of the articular eminence angle and the lingual surface angle of the maxillary central incisors in 41 cases. The 17 molar class I living cases are plotted as closed circles. The 16 class I skeletal cases are plotted as open circles, and the 8 class II skeletal cases are plotted as X. Note that the class II cases tend to be more deviant than the others. Excluding the class II cases, the correlation is 0.91.

class I and II subgroups (Table 3). The difference between these angles was 6°-7° in each group.

The most striking difference was that the correlation between AEA and LSA was significantly lower in the Class II group. The statistical relationship between anterior and posterior disclusive angles found in Class I molar occlusions did not appear in this Class II series. (Fig. 2).

Living series

A major finding was that CDA/OP was equal to or greater than either AEA/OP or LSA/OP in all 17 cases. Since the paired t-test shows that CDA/OP is significantly higher than AEA/OP by about 5° on average, there is the strong suggestion that the condyle does not precisely follow the

TABLE 3
Comparisons between Class I and II subsets of the 24 Indian crania

Variable	*Difference Between Means*	*t-test*
AEA/OP	1.8	0.49†
LSA/OP	1.1	0.33†

† Not significant (P > .6).

contour of the articular eminence during protrusion (Table 4).

Also, in all these individuals AEA/OP was equal to or greater than LSA/OP, with a mean difference of 4.9°. Statistical confirmation of the rank order differences of these three angles is shown in Table 5.

Inspecting the bivariate correlations between these three angles (Table 5), the positive covariation between AEA/OP and LSA/OP stands out as being especially high ($r = .91$). It may be clinically useful to exploit this strong relationship to estimate an appropriate inclination of the lingual surface of the maxillary incisor (LSA/OP). Since the correlation between CDA/OP and LSA/OP also is of moderate intensity, it is desirable to include the statistical information on CDA/OP in making such an estimate for LSA/OP. The lingual surface angle was chosen as the dependent variable because it is the one angle of the three that the clinician can alter. The resulting multiple linear regression equation is:

$$LSA = 1.8\ AEA - 0.3\ CDA - 68.4$$

The two independent variables, CDA/OP and AEA/OP, explain 86% of the variation in LSA/OP ($R = 0.93$). However, inspection of the regression coefficients in the above equation and the partial correlations (Table 5) suggests that the apparent positive correlation between CDA/OP and LSA/OP actually derives from other covariations, whereas the strong correlation between AEA/OP and LSA/OP is uninfluenced by CDA/OP. (Fig. 3). Consequently, there is no appreciable loss of accuracy in using AEA/OP alone to estimate LSA/OP. This is also highly significant ($t = 8.5$, $P < .01$). The equation is'

$$LSA = 1.53\ AEA - 75.6$$

Using this equation to generate a table showing 'gnathologically based' angles for the lingual surface of the upper central incisor is a straightforward calculation when the angle of

TABLE 4

Summary statistics of the living normal series for the condylar disclusive angle (CDA), the angle of the articular eminence (AEA), and the angle of the lingual surface of the upper central incisors (LSA), each measured to the occlusal plane.

	CDA/OP	*AEA/OP*	*LSA/OP*
Mean	137.0	132.2	127.4
Standard Deviation	5.6	4.2	6.9
Standard Error	1.3	1.1	1.7
Range	128-148	126-139	117-138

TABLE 5

Differences among AEA/OP, CDA/OP and LSA/OP in the 17 American Whites with near-ideal occlusions.

	CDA-AEA		*AEA-LSA*		*CDA-LSA*
Difference in Means	4.8		4.8		9.6
Mean of Individual Differences	4.8		4.9		9.7
Paired t-test	4.5**		5.4**		5.8**
Correlation Coefficient	.64**		.91**		.44†
Coefficient Determination	.41		.83		.20
Partial Correlation	.64*	*	.91	**	—.45†

† Not significant ($P > .05$)
* $P < .05$
** $P < .01$

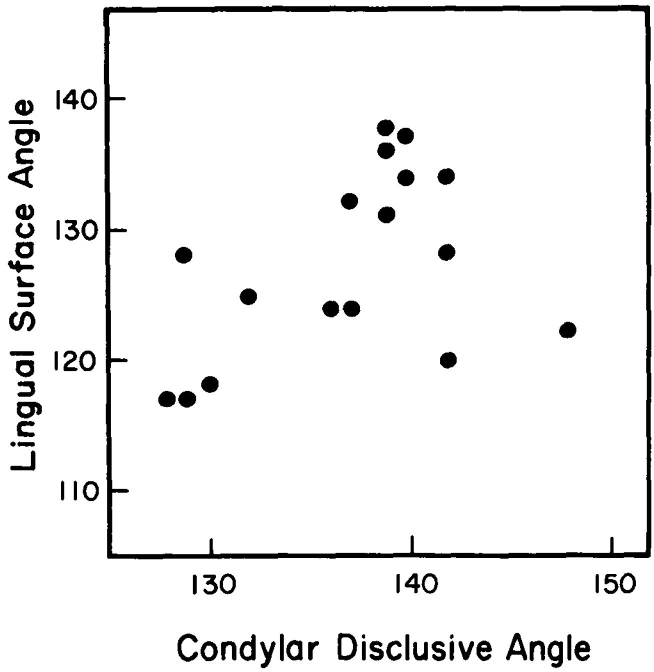

Fig. 3 A bivariate plot of the condyle disclusive angle and the angle of the lingual surface of the maxillary central incisors in 17 naturally-occurring molar class I subjects. The correlation is .44 which is not significantly different from zero. The disclusive angle is not a reliable predictor of lingual surface angle in these untreated good-occlusion subjects.

the articular eminence is known (see Table 6). For example, if AEA/OP is 133°, LSA/OP should be 128° (5° steeper than AEA) to satisfy the formula.

One purpose of including both Asiatic Indian skulls and living American Whites in this study was to assess the gnathologic similarities in two biologically disparate groups. Are the angular assessments made on one group unique to them, or can more fundamental generalities be proposed?

In these two samples, AEA and LSA were strikingly similar (Table 7). The average of AEA/OP differed by just 0.5°, with a standard deviation of 7° and a grand mean of 132°. For LSA/OP the difference was 2°, with a standard deviation of 8° and grand mean of 126°.

The key point is that the statistical relationship between these two angles was very high. When the molar Class II skulls are excluded (Table 2), the correlation between AEA and LSA is .91 in the Asiatic Indians and in the American Whites. This argues strongly for the contention that AEA and LSA do indeed develop in harmony

TABLE 6

Estimated prediction of LSA/OP from AEA/OP, using the formula LSA = 1.53 AEA-75.6

AEA/OP (degrees)	*LSA/OP (degrees)*
125	116
126	117
127	119
128	120
129	122
130	123
131	125
132	126
133	128
134	129
135	131
136	132
137	134
138	136
139	137
140	139

TABLE 7

Differences in mean angular values of AEA/OP and LSA/OP between the skeletal and living series.

Variable	*Difference Between Means*	*t-test*
AEA/OP	0.5	0.21†
LSA/OP	2.2	0.89†

† Not significant ($P > .3$).

in good occlusion cases regardless of the population sample being considered. As discussed below, there is a developmental explanation why this should be so.

Discussion

The integration of functional occlusal considerations with orthodontic treatment is by no means a recent concept, nor is the idea of an occlusion mutually protected via the anterior teeth. Yet, orthodontic treatment may be completed with minimal attention to the disclusion of posterior teeth by the incisors when the mandible moves eccentrically.

For gnathologically acceptable protrusive movements to occur, there must be harmony between the posterior and anterior anatomical components along which the condyles and lower incisors must slide.[6-7].

A prime finding in this study is the high positive correlation between AEA/OP and LSA/OP, both in a skeletal series of Asiatic Indians and in living American Whites ($r = .91$). This close covariation supports the earlier conclusions of Corbett *et al*[8] and of Huffer *et al.*[2]

However, the two angles are significantly different from one another. The mean difference is 6.3° in Indians with Class I molar relationship and 4.9° in American Whites with good occlusions (grand mean 5.6°). Invariably, the mean anterior disclusive angle (LSA) is steeper, which agrees with the findings of Ricketts.[11] These averages are all very close to the 5° difference thought by McHorris,[7] Wasson[5] and others to be ideal.

The high AEA-LSA correlation indicates that AEA/OP can be used as a clinically relevant guide to the optimal inclination of the lingual surface of the upper central incisors, since LSA be altered by mechanotherapy and AEA generally cannot.

The series used to derive the predictive equation consists of near-ideal occlusions, so the implication is that LSA/OP should be inclined at or near the angle calculated from AEA/OP as tabulated in Table 6, with due consideration of the standard deviations of those angles.

The high degree of covariation raises the developmental question of which structure, the articular eminence or incisor axial inclination, is the initiator and which is the respondent? In the newborn the eminence is rudimentary and the articular fossa faces laterally and only slightly downward.[14-17]

Because of the combined effects of accentuated bony deposition above the tympanic membrane anterior to the root of the zygomatic process and posteriorly onto the mastoid plate, and resorption on the cerebral surface of the temporal squama, the position of the fossa in relation to the horizontal plane changes.[18-21] By about six months, the articular eminence extends 5-6mm below the roof of the fossa.[19]

When eruption of the deciduous incisors begins, neuromuscular regulation of jaw relationships is very important for development of the occlusion. Consider that emergence of the first incisor causes very little change in neuromuscular function, but as soon as the antagonist incisor erupts, it is inevitable that the two teeth contact one another during jaw movements.

When this occurs, the first step in occlusal reflex learning begins. A path of opening and closure which provides optimal function and minimal incisor interference is quickly learned. Thus, the anterior limit of mandibular function is established within the first 6-8 months of postnatal life.[22,23]

The above suggests that these two critical events, differentiation of the articular eminence and the onset of incisor occlusion, occur simultaneously at about six months. Weinmann and Sicher[24] likewise have argued that, "it is clear that this change (of the eminence) coincides with the beginning of masticatory function," and Wright and Moffett[19] found that adult-like contours of the fossa and eminence are attained coincident with emergence of the first incisors.

In the living series, where the condyle disclusive angle could also be measured, the correlation between CDA and LSA was 0.44, but this relationship is explained away when the AEA-LSA correlation is taken into account via partial correlations (Table 5). This statistical assessment and the finding that the mean difference between CDA/OP and LSA/OP was 9.7°, show that the condyle does not follow a path delineated by the tangent to the exact anatomical configuration of the eminence as suggested by Corbett *et al*[8].

Possible explanations for divergence of the condyle path in ideal occlusions include:

1) bilateral asymmetry between the condyles and/or the eminences
2) anatomy and angulation of the condyles relative to the glenoid fossa
3) configuration of the disc
4) position of the disc during condyle translation
5) resultants of vectors of force of the musculature responsible for mandibular disclusion.

When comparing the two different samples examined here, several substantial similarities are apparent. The mean angle of the articular eminence in the skulls and in the living series has a trivial difference of 0.5°. The grand mean of 132° is very close to Ricketts'[11] group average of 136°. The lingual surfaces of the maxillary central incisors in the two groups differ by just 2.2°.

Clinically, the most relevant finding is the high positive correlation between AEA and LSA, which was identical in the two groups ($r = .91$). This indicates that the relationship is a real biologic phenomenon, not just happenstance. Moreover, this absence of a statistically significant difference between these two ethnically diverse groups suggests a fundamental biomechanical constancy in the development of the gnathological system.

Conclusions

1. There is a strong positive correlation between the angle of the articular eminence and the lingual surface of the maxillary central incisor in individuals with good occlusions.
2. In the living series—where the condyle disclusive path is measurable—findings also indicate that:
   a) The condyles may not follow the exact tangent to the configuration of the eminence in protrusive movements.
   b) The anterior disclusive angle is steeper than the posterior disclusive angle in ideal occlusions, with a greater difference than has been previously suggested.
   c) Angulation of the articular eminence relative to the occlusal plane may be useful in establishing an angulation for the maxillary central incisors.

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