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Rotational Growth and Incisor Compensation

A cephalometric and dental serial study of 29 untreated subjects over 9 years, using Björk's method of superimposition, finding statistical relationships between rotational growth of the mandible and anterior mandibular crowding.

KEY WORDS: • CROWDING • GROWTH • INCISOR • MANDIBULAR ROTATION •

Although there have been many growth studies and large collections of data involving aspects of dentofacial development in orthodontics, most tend to be two-dimensional, based on cephalometric radiographs or on dental study casts, as seen in the book "Standards of Human Occlusal Development" (MOYERS ET AL. 1976). This view of facial growth has been largely based on the studies of such workers as BROADBENT (1937) AND BRODIE (1941), who developed the concept of proportionate enlargement of the face downward and forward from the base of skull in an incremental fashion. More recently, it has become recognized that the structures within the skull on which this concept is based may also change (ENLOW 1968).

In growth studies based on lateral cephalometric radiographs, although anteroposterior and some vertical changes with growth and development may be well documented, other important aspects of vertical growth have not been addressed. The work of BJÖRK (1955), who used metallic implants in the mandible for the superimposition of radiographs, paved the way for more accurate vertical analysis. His method of superimposition on recognized anatomical landmarks in the mandible, based on the earlier implant studies, has made a valuable new research tool available to the clinician (BJÖRK 1969)..

The type and degree of mandibular rotation, the condylar growth direction, and the degree of remodeling of the lower border of the mandible are some of the parameters of such an analysis. Although the relative stability of the so-called "natural reference points" has been questioned (MATTHEWS AND WARE 1978, MATTHEWS AND PAYNE 1980), it would appear that it is acceptable within the context of the definitions used.

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The many possibilities include independent movement of all anatomical structures relative to one another, movement of all anatomical structures in the same direction at the same speed, and relative stability of the relationships of anatomical structures to one another. The latter seems to be the most likely, as demonstrated by ODEGAARD (1970) AND JULIUS (1974).

There have been many attempts at examining dentofacial development in all three dimensions, individually and together, with and without computerization. Although there are many notable works in this area of research (WALKER 1972, SAVARA 1972, RICKETTS ET AL. 1972), it seems that unless a similar measurement is shared by each of the dimensions under examination, an absolute correlation would not be possible.

This study involves both standard lateral skull cephalometric radiographs in occlusion, and dental study casts. The dental cast measurements supply information on the transverse or lateral dimension to supplement the vertical and anteroposterior measurements already available from the radiographs.

— Materials and Method —

The sample consists of serial records of 29 untreated subjects, obtained by LEIGHTON (1960) at King's College Hospital Dental School. The mean age was 11.21±1.11yrs at the initial radiograph and 19.90±1.41yrs at the final. The variation in radiographic technique was minimized since the films were taken by the same operator. However, the original cephalostat was replaced during the study, so two different enlargement correction factors were required.

In the collection of the sample, stringent criteria of quality were observed in both the standard lateral skull cephalometric radiographs in occlusion and the dental study casts. Any records of inadequate quality were discarded.

This study covers three aspects:

1 Conventional examination with respect to the S–N plane on radiographic tracings, using angular measurements.

2 Examination under the Björk method of superimposition on mandibular anatomical structures on radiographic tracings, with defined X and Y axes, using both angular and linear measurements.

3 Examination of dental study casts, using linear measurements.

Radiographic points were identified for tracing according to KROGMAN AND SASSOUNI (1957) with the following exceptions:

Ar Articulare, the point at the intersection of the contour of the external cranial base with the dorsal contour of the condylar process of the mandible (BJÖRK AND PALLING, 1954).

I The point where the long axis of the most prominent mandibular incisor intersects the incisal edge (MILLS, 1966).

L The point where the long axis of the most prominent mandibular incisor intersects the root apex (MILLS, 1966).

Q Distal contact point of the first permanent mandibular molar, defined as the point where the perpendicular to the occlusal surface of the tooth meets the distal contour (PERERA, 1977).

The following defined anatomical structures in the mandible were also traced:

- The anterior tip of chin.

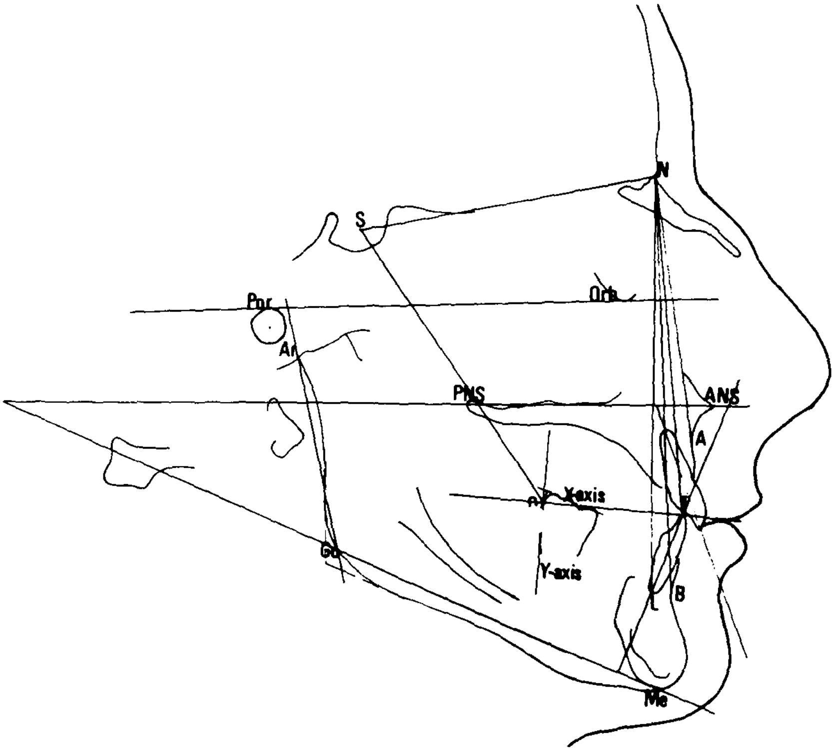

Fig. 1 A typical cephalometric tracing

- The inner cortical structures of the inferior borders of the mandibular symphysis.
- The detail structures of the mandibular canal.
- The lower contour of the third molar germ from the time that mineralization of the crown was visible until the root formation began.

On these selected landmarks, the lines and planes shown in Fig. 1 were drawn.

The first and the final radiographic tracings were superimposed on mandibular structures and the following angular and linear measurements determined:

1 The degree and type of mandibular rotation relative to the S-N line of the initial radiographic tracing.

2 Condylar growth direction relative to the ramus line of the initial radiographic tracing.

3 Change in position of points I, L, and Q relative to their initial positions on the radiographic tracings.

These are shown in Figs. 2 and 3.

The dental study cast measurements are shown in Fig. 4.

Angular measurements were recorded to the nearest 0.5°. In obtaining the change in position of the points I, L and

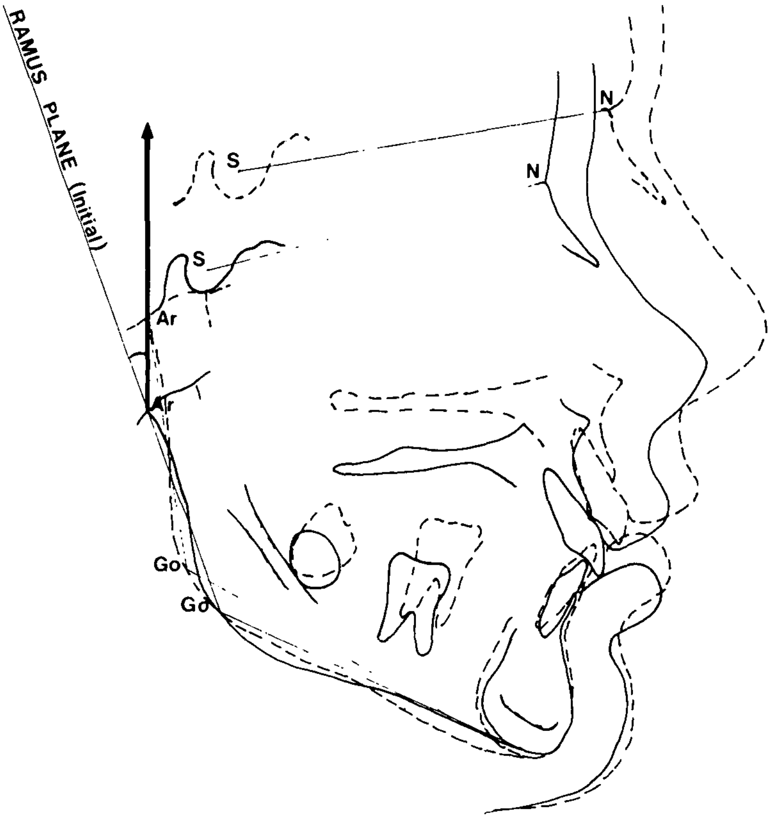

Fig. 2 Degree and the type of mandibular rotation, with the condyle growth direction shown with reference to the ramus plane of the initial tracing

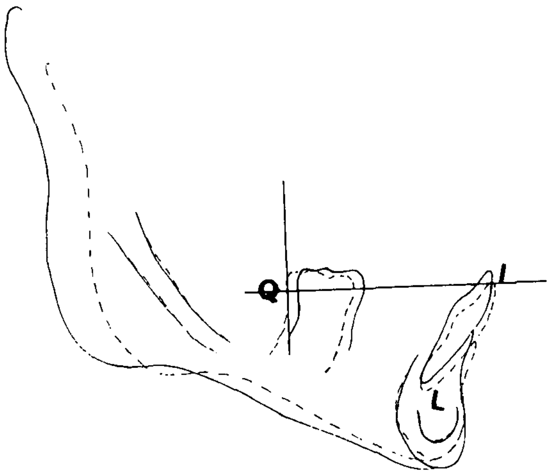

Fig. 3
Change in position of points I, L and Q, relative to their original position.

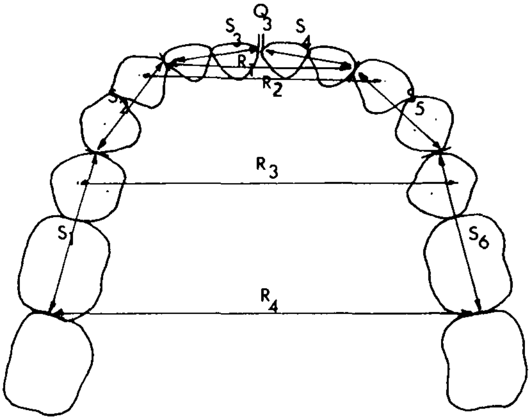

Fig. 4
Dental study cast measurements.

Q relative to the X and Y axes of the initial tracing, a modified dial caliper reading to the nearest 0.02mm was utilized. To help obviate errors that would result if the measurements were not parallel to the X and Y axes of the initial tracing, the superimposed tracings were placed on a graph paper in such a manner that the ordinates and the abscissae were coincident prior to measurement.

The dental study cast measurements were obtained using the method of Perera (1981). On the basis of these measurements, the change in incisor crowding or spacing was quantified as the difference between $\Sigma R_1+S_3+Q_3+S_4$ on the first and final study cast (Fig. 4). When the initial measurement was greater than the final, the incisors were said to have "crowded," and vice-versa. This criterion was used because the incisors can procline or retrocline to some extent, at the expense of the inter-lateral linear distance, before any change is seen in the perimeter measurement (Fig. 5).

In a retrospective cephalometric analysis, most systematic errors are not within the researcher's control. Some of the errors involved, such as the positioning of the patient's head within the cephalostat and the radiographic technique, can be examined only if the patient were to be radiographed repeatedly on the same occasion.

Other errors can be evaluated by a double determination of the measurement used or tracings obtained. This growth study is part of a major study carried out earlier (Perera, 1977), in which the distribution characteristics and the random error of the method were determined using the method described by Dahlberg (1940). Errors of the method for some of the parameters examined in a sample of patients who had lateral skull cephalometric radiographs repeated on the same day were also obtained, and are presented in Table 1.

— Results —

These are presented in the form of tables showing three different analyses:

a) Conventional cephalometric measurements (Table 2).

b) Björk's method of superimposition (Table 3).

c) Dental cast measurements (Table 4).

Standard statistical tests were used in the examination of the results. Where relevant, each significant test and the correlation coefficients are accompanied by the 'P' level.

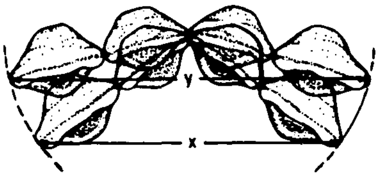

Fig. 5 Diagrammatic demonstration that the incisors can procline or retrocline at the expense of the inter-lateral linear distance without a change in the perimeter measurement.

Table 1

Errors of the Method Determined
(after Dahlberg, 1940)

N= 157 radiographs

S-N-A	1.21°
S-N-B	0.91°
S-N-I	0.54°
S-N-L	0.56°
N-S-Q	0.61°
Max/mand	0.67°
Ar-Go-Me	0.69°
LI/mand	0.97°
UI/max	0.82°
Rotational growth	1.90°
Condyle growth direction	2.10°

Linear measurements

to X axis (vertical measurement)		
I—0.46mm	L—0.41mm	Q—0.81mm
to Y axis (horizontal measurement)		
I—0.33mm	L—0.47mm	Q—0.21mm

Repeat Radiographs (N= 19)

S-N-A		0.35°
UI/max		0.66°
LI/mand		0.81°
Ar-Go-Me		0.25°
to X axis (vertical mm)		L—0.69
to Y axis (horiz. mm)	I—0.44	L—0.45

Mandibular Dental Casts (N= 159)

Q_3	0.02mm
S_3	0.28mm
S_4	0.38mm
R_1	0.56mm

Table 2

Cephalometric Measurements
N=29

		S N-A	S-N-B	S-N-I	S-N-L	N-S-Q	LI/Md	UI/Mx	Mx/Md	Ar-Go-Me
Initial	x̄	81.97	78.65	82.14	76.29	70.79	91.79	111.55	27.95	130.31
	SD	4.70	3.80	4.67	3.83	3.54	7.10	6.45	4.35	4.25
Final	x̄	82.47	80.07	83.33	77.93	68.78	92.05	112.64	25.14	127.26
	SD	4.20	3.62	4.12	3.87	3.14	7.69	6.97	5.62	4.78
Change	x̄	0.50	1.42	1.19	1.66	−2.01	0.26	1.19	−2.81	−3.05
	SD	2.13	1.77	1.92	2.03	1.77	4.38	4.31	3.19	2.19
	't'	1.26	4.31***	3.39**	4.35***	6.15***	0.34	1.52	4.74***	7.50***

Table 3

Analysis based on Björk's Method of Superimposition
(Björk 1969)
N=29

Angular Measurements (Fig. 2)

Mean mandibular rotational growth (closing)	4.09°±4.06°
Mean condylar growth direction (anterior)	0.16°±10.82°

Linear Measurement Changes (Fig. 3)

	I	L	Q
to X axis (vertical measurement)			
Mean	2.72	2.71	3.46
SD	1.79	2.09	2.44
't'	8.18***	6.98***	7.64***
Y axis (horizontal measurement)			
Mean	0.99	−0.07	3.21
SD	1.54	1.57	1.75
't'	3.46***	0.24***	9.88***

— Discussion —

The results show that while the S-N-A angle does not change to any significant extent, there is a mean increase of 1.5° in the S-N-B angle. The expected reciprocal decrease in the A-N-B angle average 1°.

Associated with this change, the mandibular incisor position also changed, with the root apex coming forward, and the S-N-L angle increasing by 1.7°. This is in keeping with Björk's concept of an increase in relative mandibular prognathism with age.

Surprisingly, however, the angle of the lower incisor to the mandibular plane shows hardly any change.

One would also expect the S-N-I angle to increase somewhat, in a manner comparable to the increase in the S-N-L angle. This appears to be the case, although to a slightly lesser extent, as the S-N-I angle increased by 1.2°.

Examining the changes in the mandibular incisor region as measured from the dental study casts, it is seen from Table 4 that the incisors have crowded by an average 0.7mm. Although it has been shown that the keystoning effect in the

Table 4

Dental Cast Measurements
(N=29)

		S3	S4	Σ(1-6)	R1	Σ R1+S3+Q3+S4
Initial	x̄	11.27	11.46	88.14	21.62	45.17
	SD	0.76	0.78	3.96	1.33	2.89
Final	x̄	11.16	11.33	85.97	21.30	44.45
	SD	0.73	0.73	4.18	1.23	2.78
Change	x̄	−0.11	−0.13	−2.17	−0.32	−0.72
	SD	0.44	0.45	1.80	0.61	1.36
	't'	1.47	1.68	6.43***	2.82**	2.78**

mandibular incisor region could overcome some small changes in the incisor position (Mills 1964, Ricketts 1964), this potential may be limited.

Thus, with the forward displacement of the mandibular symphysis with growth, as indicated by the increase in the S–N–B angle, the lower incisors would be pushed forward relative to the upper incisors. This is resisted by occlusion with the upper teeth; the S–N–I angle increased less than the S–N–B, with increased crowding of the mandibular incisors.

Reciprocally, the effect on the upper incisors would be to procline them. This appears to occur also, as their mean angulation increased by 1.2°.

Considering the changes in the dentoalveolar structures relative to the base of skull, it is seen that angles subtended by the sella-nasion plane would be affected by changes in the vertical position of either nasion or sella Turcica.

If the change in an angle subtended at nasion (S–N–I, S–N–L, etc.) were to increase due to change in the orientation of S–N over the period of examination, one would expect an angle subtended at sella Turcica to decrease. This appears to be the case, as the N–S–Q angle decreased by 2.0° in this untreated sample.

So it would appear that either there has been marked upward vertical growth at sella Turcica or downward vertical growth at nasion, or that the dental structures moved forward relative to S–N. Furthermore, when the $\Sigma S_{1\text{-}6}$ measurement which represents the arch perimeter is examined, it is seen to have diminished by 2.2mm (Table 4, Fig. 4).

Admittedly, some of the arch perimeter reduction could be due to the closure of spaces during the change from the deciduous to the permanent dentition ("leeway space"), and some due to the loss of mesiodistal tooth widths with attrition (Lammie and Posselt 1965). Essentially, it is a result of forward movement of the buccal segments in addition to the previously established forward movement of the labial segments.

This is confirmed by examination of the maxillary/mandibular plane angle and the gonial angle, which show reductions of 2.8° and 3.1° respectively. Both of these changes indicate forward movement of the mandible relative to the maxilla.

With the crowns of the incisors restricted by the facial musculature, so that they cannot keep pace with the bone changes, they would become crowded.

The associated rotational growth is of the closing type (4.1°±4.1°) (Table 3), and the condylar growth direction is vertical relative to the initial ramus plane. These figures compare very favorably with the results of similar studies (Björk 1972, Bailey 1975).

A similar picture is seen when the results of the coordinate analysis are examined. In the horizontal plane of measurement (Table 3, Fig 3), point I moves forward approximately 1mm and point Q 3mm, whereas, point L remains stable relative to its original position.

In the vertical plane of measurement, both points I and L move upward by approximately 2.7mm±1.8mm 2.1mm, while point Q moves upward 3.5±2.4mm.

This greater upward movement at the back of the dental arch relative to the front is to be expected with the closing type of rotational growth. This difference in the vertical movements at the front and the back of the dental arch in the untreated patient could be used as a better indicator of the type and the nature of rotational growth. It has the obvious advantage of eliminating any compensatory changes which could mask or exaggerate the rotational growth if measured to a reference far from the superimposed

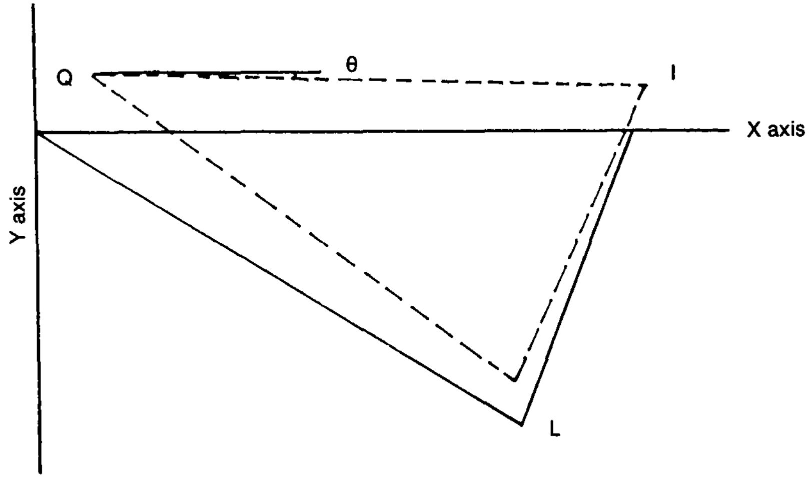

Fig. 6 **Measurement of the rotational growth direction relative to the dental reference points in an untreated patient**

anatomical features in the mandible (Fig.6).

Thus, the mandibular incisors appear to maintain their relationship to the upper face as they move forward, with the S-N-I and the S-N-L angles increasing equally. However, since the mandible rotates forward, the lower incisors would tend to retrocline relative to the face, were it not for the compensatory proclination.

This compensation is limited by the facial musculature and the occlusion that determine the area of balance.

Once these compensations have exceeded the limits of that balance, the mandibular incisors will begin to crowd. Therefore, crowding within the arch would have to be at the expense of a reduction in the rectilinear distance between the lateral incisors and the arch perimeter, as has been shown by LUNDSTRÖM (1968) AND KNOTT (1972). This appears to be the case, as the inter-lateral distance (R_l) and the arch perimeter ($\Sigma S_{l;} ms_6$) reduce at significant levels (Table 4, Fig. 5).

Rotational growth, therefore, would appear to play a key role in the causation of crowding in the mandibular incisor region. The greater the closing rotational growth *within* the mandible, the greater will be the compensatory proclination necessary to keep the incisors within the area of balance.

Thus, if the relationship between the degree of rotational growth and the change in the incisor position is examined, high correlation would be expected. Table 5 shows the correlations examined and their levels of significance.

— Summary —

Growth and development of the dentofacial structures was examined in a sample of 29 subjects over a period of approximately nine years. This was based

on both standard lateral skull radiographs in occlusion and dental study casts. The former supplied information in the vertical and anteroposterior dimensions. The latter were oriented and measured in the lateral or third dimension, and the measurements related to those in the other two dimensions.

These measurements were analyzed using a conventional cephalometric analysis and an analysis based on Björk's method of superimposition on defined anatomical structures. The results indicate that closing rotational growth in the mandible is closely related to the incisor crowding that commonly occurs during this period. These changes appear to be mediated through a compensatory proclination of the mandibular incisors within the symphysis that is associated with this rotation.

Table 5

Mandibular Rotational Growth Correlation Coefficients with Measured Parameters

S–N–I	0.34 *
S–N–L	0.60 ***
N–S–Q	0.55 ***
Gonial angle	−0.57 ***
Lower incisor/mandibular plane	0.38 *
Condylar growth direction	0.61 ***
Secondary incisor crowding	0.51 **
Point I to Y axis (mm)	0.44 **
Point L to Y axis (mm)	−0.49 **
Point Q to Y axis (mm)	0.52 **
Point I to X axis (mm)	0.27
Point L to X axis (mm)	0.34 *
Point Q to X axis (mm)	0.28

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