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An evaluation of the method of structural growth prediction

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Summary. The method of structural growth prediction introduced by Björk (1963) was investigated using two sets of lateral cephalograms of 42 children, taken before and after the pubertal growth period with a four year interval. Growth direction was evaluated on the first cephalogram by eleven different observers, using Björk's anatomical characteristics. The intra- and interobserver reliability for scoring the different structures was acceptable. There was no absolute correlation between the scores for the different criteria and mandibular growth rotation during the four years of observation. This does not mean that the method is useless but, in cases showing relatively small rotational changes, as in this material, the method does not work well. Further study of the structural characteristics is needed in cases showing extreme anterior or posterior growth rotation.

Introduction

Orthodontic treatment usually involves a combination of tooth movement and facial growth changes. These changes may be variations of natural growth or may be treatment-induced. The growth direction, and whether or not it is favourable, is specially important in extreme vertical and sagittal deformities.

Growth prediction is difficult because of the wide range of morphological differences, the varying growth directions during the growth period, the varying influence of modifying environmental factors, variation in the timing of the different areas of active growth and lack of correlation between the size of the facial structures at an early age and the ultimate adult size (Harvold, 1968; Linder-Aronson, 1970; Harvold *et al*, 1972; Lundström and Woodside, 1980). At an early age it is difficult to define all the morphological problems that may be involved in a specific deformity (Björk, 1963) but the opportunity to solve these problems could be missed if treatment is not initiated during the growth period.

Growth prediction should ideally describe the sagittal and vertical intermaxillary relationships at the end of the growth period on the basis of the morphological features at any time during the growth period, and should also estimate the intensity and timing of growth, variations in direction, and the ultimate size. This is clearly unrealistic as it requires a multifactorial approach far beyond practical limits, and is related to the entire facial area with all its growth areas.

Clinical experience has shown that the growth of the mandible has a considerable effect on the intermaxillary relationship, and the direction of mandibular growth may influence both treatment planning and treatment results (Björk, 1963; Lundström and Woodside, 1980).

Björk (1969) showed that growth of the mandible occurs at the condyles and that differences in the displacement of the mandible during growth should be ascribed to differences in the direction of growth at the condyles. He observed that the differences in growth direction are associated with certain morphological characteristics in the mandible which can be identified in the individual and thus give an indication of the future position of the mandible and the intermaxillary relationship.

Björk's method of growth prediction has been used, with some modification, in Bergen since 1964 (Hasund, 1977). However, retrospective assessment of treated cases often shows disagreement between the prediction and the actual results. This may be a consequence of treatment-induced change in the original and expected growth direction, inadequate interpretation of the structural characteristics that form the basis for the growth prediction, or lack of reliability of the method itself.

This study investigates the reliability of the method of structural growth prediction of the mandible and compares intra- and interobserver reliability in relation to scoring of the different morphological characteristics.

Material and methods

The material comprised 42 children (11 boys and 31 girls) who attended the Orthodontic Department, University of Bergen, for a routine orthodontic check; this included lateral cephalograms, plaster models, orthopantomograms and hand-wrist radiographs.

None of the children needed orthodontic treatment. They all displayed a skeletal maturity of stage MP_3 or $MP_{3\ cap}$ (Helm et al, 1971). The mean age was 11 years 4 months. All the children were examined again four years later and new cephalograms were taken under the same conditions as the originals.

A tracing of each radiograph was made and superimposed on the natural reference structures of the mandible (Björk, 1969). The growth rotation of the mandible relative to the cranial base was then read from the angle between the nasion-sella lines at the two ages (Fig. 1). This procedure was repeated after two weeks and the mean of the two recordings was used in subsequent calculations.

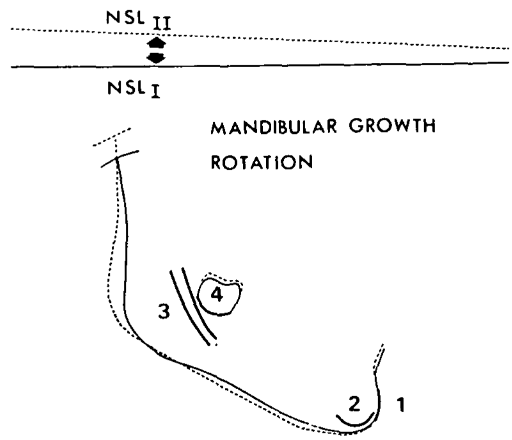

Figure 1 Mandibular growth rotation relative to cranial base measured from the angle between the NS-lines at two stages (I and II) after superimposition on natural reference structures: (1) tip of the chin; (2) inner cortical structure at the inferior border of the symphysis; (3) trabecular structures related to the mandibular canal; (4) the lower contour of a molar germ from the time mineralization of the crown is visible until the roots begin to form.

The method error (Table 1) shows that there was no systematic difference between the two evaluations.

As the interpretation of the results was highly dependent on an accurate recording of the growth rotation, the superimposition was repeated by a second examiner to test for inter-examiner disagreement. No systematic difference was found between the two sets of superimpositions (Table 2) but the variation was somewhat greater for the inter- than for the intraobserver comparison.

Table 1 Distribution of the differences between the first and the second evaluation of the growth rotation (n=42)

	$\bar{d}$	S_d	min	max	t
Growth rotation	0.12	0.48	−0.5	1.0	1.61

Table 2 Distribution of the differences between the evaluations of growth rotation by two examiners (n=42)

	$\bar{d}$	S_d	min	max	t
Growth rotation	0.23	0.94	−2.0	2.0	1.56

Anterior growth rotation gives a positive value and a posterior rotation gives a negative value. In this sample the values ranged from −2.0 ° to 7.3 ° with a mean of 3.5 ° (Fig. 2).

The first series of radiographs was given to eleven observers who were asked to predict the future growth using Björk's criteria with some modifications (Hasund, 1977). Seven of the observers were post-graduate orthodontic students and four were experienced orthodontists. All had previously used the structural analysis for growth prediction and all had been trained in interpretation of the criteria by the same teacher.

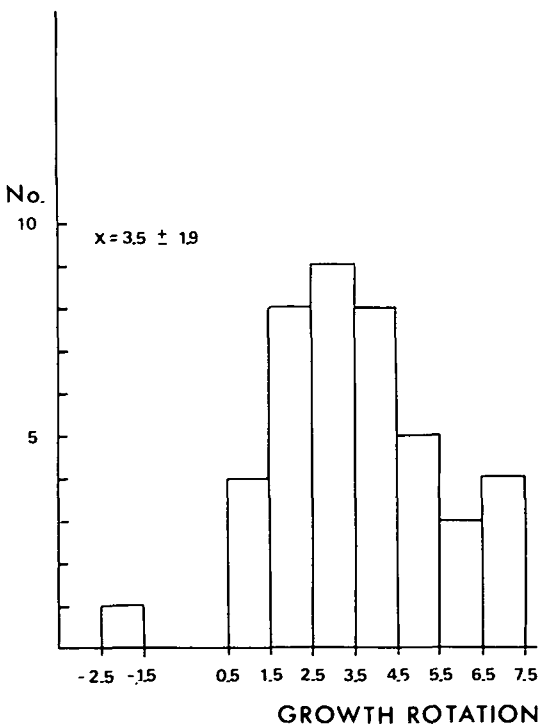

Figure 2 Distribution of mandibular growth rotation. Negative values indicate posterior growth rotation, positive values indicate anterior growth rotation.

The criteria used were:

Inclination of the condylar head.

Curvature of the mandibular canal.

Shape of the lower border of the mandible and symphysis.

Inclination of the symphysis.

Lower anterior face height.

Size of the gonial angle (introduced by Ødegaard, 1970).

Björk's original criteria, inter-incisal angle and inter-premolar and inter-molar angles, were not included in the prediction as they are not routinely used in the Bergen modification of the method.

The observers were instructed to score the criteria in the following way:

—Strong tendency for anterior rotation: 3

—Intermediate tendency for anterior rotation: 2

—Little tendency for anterior rotation: 1

—No tendency for anterior or posterior rotation: 0

—Little tendency for posterior rotation: −1

—Intermediate tendency for posterior rotation: −2

—Strong tendency for posterior rotation: −3

The procedure was repeated by all the observers with an interval of at least two weeks and the mean results were used in the statistical calculations.

The paired t-test was used to compare the first and second evaluation of growth rotation and also to determine any significant difference in the evaluation of growth rotations by the two examiners.

To estimate the covariation between the first and second evaluation of each of the criteria of the structural analysis, Pearson's correlation coefficient (r) was calculated. The same procedure was used to correlate growth rotations with each of the predictor criteria.

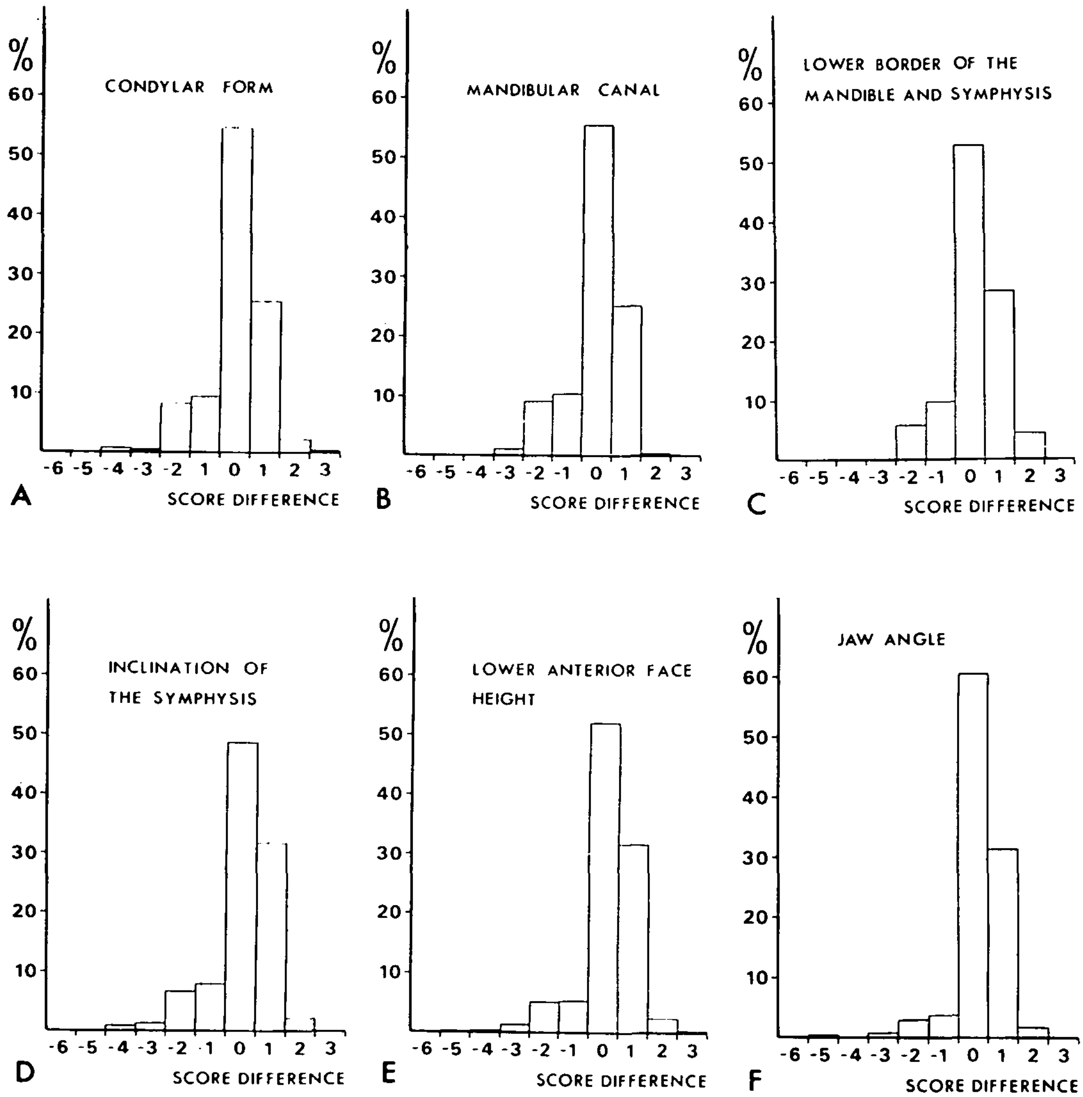

Figure 3 Percentage deviations between the first and second evaluations. A positive value indicates a scoring difference in the same direction, and a negative value in the opposite direction.

Results

Intra-individual reliability

There was a relatively high correlation between the first and second recordings (Table 3). The coefficients for all the different criteria were significant at the 1 % level.

The deviations between the first and second evaluations (Fig. 3A–F) show that, for the majority of the criteria, a difference of more than two units is found in only about 10 % of the total number of evaluations.

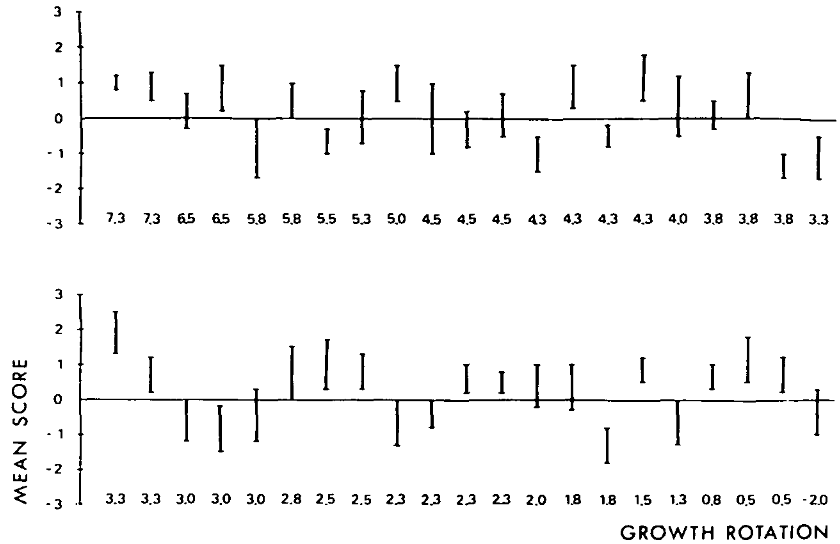

Figure 4 Interobserver variation in scoring for each case in relation to the actual growth rotation. I = range of mean scores evaluated by 11 observers.

Table 3 Mean scores of the first and second evaluation of the criteria of the structural analysis and the correlation coefficients (n=462)†

Criteria	Evaluation I Mean score	Evaluation II Mean score	r
Inclination of condyle	0.06	−0.06	0.64**
Curvature of the mandibular canal	0.27	0.24	0.65**
Shape of the lower border	0.45	0.48	0.67**
Inclination of the symphysis	0.23	−0.19	0.71**
Anterior lower face height	0.44	0.44	0.74**
Size of the gonial angle	−0.10	−0.04	0.89**

$^{**}p<0.01$
†11 observers: 42 cases: n=42×11=462

Inter-individual reliability

In Figure 4 the inter-individual variation in scoring is shown for each case. The mean score differences between the observers is seldom more than one unit which means that, when all the different criteria are evaluated together, as they should be in clinical use, the interobserver differences are relatively small.

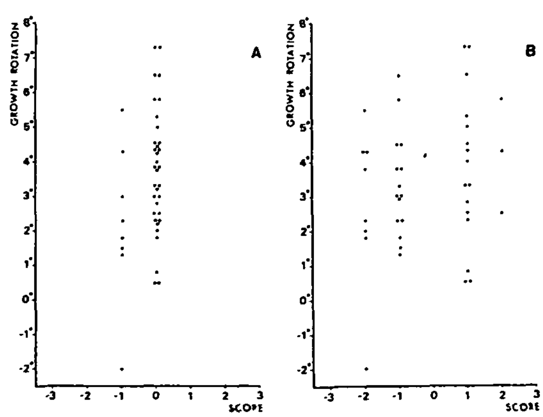

Figure 5 Evaluation of condylar form in 42 cases by one experienced orthodontist (A) and one postgraduate student (B).

The reliability of structural growth prediction

As shown in Figure 4 there seems to be no covariation between the mean of the scoring criteria and the magnitude of growth rotation of the degree found in this investigation. This is further supported by correlation analysis, where the mean score of the different structural criteria is correlated to the growth rotation (Table 4).

The scatter diagrams (Figs. 5–11) show how one experienced orthodontist and one

Table 4 Correlation between growth rotation and the mean score of the different criteria in the structural growth prediction method (n=462)

Structural criteria	r
Inclination of the condyle	0.09
Curvature of the mandibular canal	0.00
Shape of the lower border	0.05
Inclination of the symphysis	0.06
Anterior lower face height	0.07
Size of the gonial angle	0.00

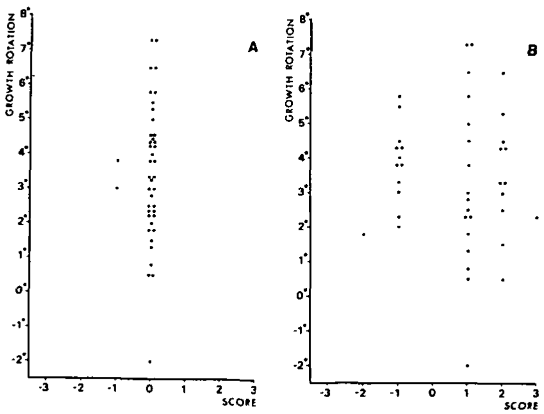

Figure 6 Evaluation of the mandibular canal in 42 cases by one experienced orthodontist (A) and one postgraduate student (B).

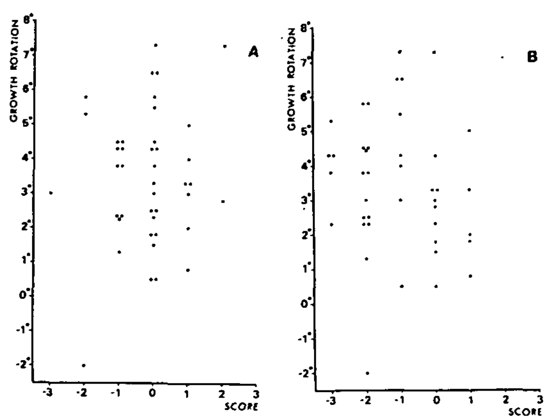

Figure 8 Evaluation of the inclination of the symphysis in 42 cases by one experienced orthodontist (A) and one postgraduate student (B).

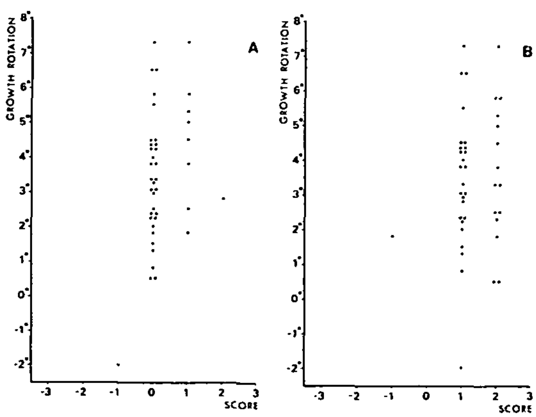

Figure 7 Evaluation of the lower border of the mandible and the symphysis in 42 cases by one experienced orthodontist (A) and one postgraduate student (B).

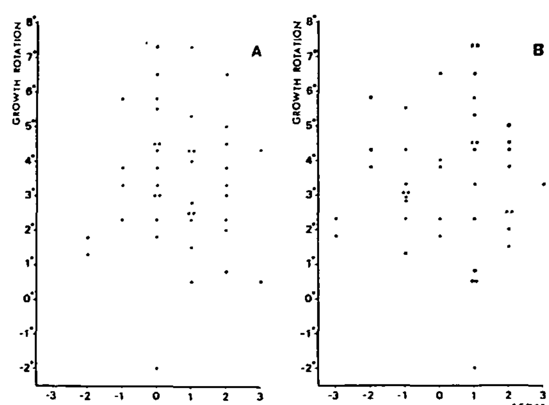

Figure 9 Evaluation of the lower face height in 42 cases by one experienced orthodontist (A) and one postgraduate student (B).

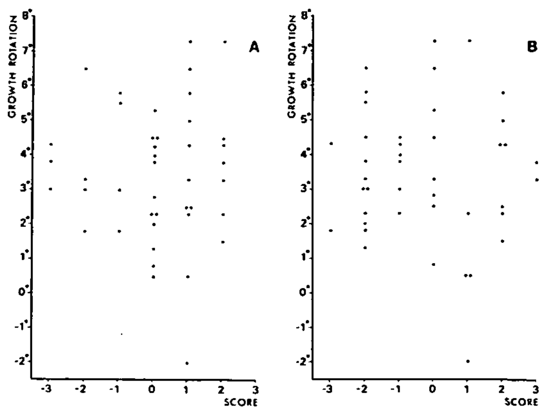

Figure 10 Evaluation of the jaw angle in 42 cases by one experienced orthodontist (A) and one postgraduate student (B).

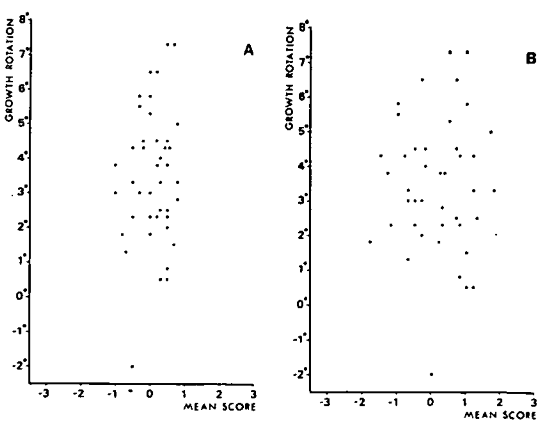

Figure 11 Evaluation of all six structures in 42 cases by one experienced orthodontist (A) and one postgraduate student (B).

postgraduate student evaluated the different structural criteria in all 42 cases.

Discussion

The growth direction of the mandible is an important factor in planning orthodontic treatment. Björk (1963) proposed a structural method for prediction of mandibular growth rotation based on information gained from implant studies. He found that a forward inclination of the condyle is related to vertical growth of the condyle with a resulting anterior rotation of the mandible. In cases with vertical growth he observed that the curvature of the mandibular canal tended to be greater than that of the outline of the mandible, including the gonial angle. The opposite was found in cases with a backward shape of the condyle, characteristic of sagittal growth, resulting in posterior rotation of the mandible.

He also found that the shape of the lower border of the mandible reflected the direction of growth. In vertical condylar growth there was a pronounced apposition below the symphysis which resulted in a thick cortical layer and anterior rounding. In sagittal condylar growth the cortical layer was thin and there was no rounding. The inclination of the symphysis was also important. In vertical condylar growth the symphysis swung forward and resulted in a prominent chin while in sagittal growth it swung backwards with a receding chin. In vertical growth, the anterior rotation will result in a relative decrease in the anterior face height whereas a posterior rotation results in an increase.

Ødegaard (1970) also found that the size of the gonial angle was related to condylar growth direction; vertical growth resulted in an acute angle and sagittal growth in an obtuse angle.

It seems probable that these features would be easily evaluated in extreme anterior or posterior growth rotation, but how will this apply in cases without marked deviation? Evaluation is also complicated by the fact, pointed out by Björk (1969), that, in the same case, some of the features may indicate posterior rotation while others indicate anterior rotation.

Björk observed in his material a mean anterior rotation of about 6 ° from the prepubertal to the post-pubertal period. In the present material the mean was only 3.5 ° which indicates that scores for anterior growth rotation should be relatively low, and this seems to be in accord with the mean scores shown in Table 3.

An additional source of uncertainty is the absence of a standard reference for the different characteristics. The different observers own experience forms the basis for the predictions. In the present study all the observers had been instructed in evaluation of the different characteristics by the same teacher but their clinical experience differed considerably; seven were postgraduate students and four were experienced orthodontists. Any difference between the two groups in the ability to predict the actual growth correctly could mean that the exact prediction method is dependent on a certain level of clinical experience. The two groups were tested against each other but no statistical differences could be found. Table 3 shows that there is a high degree of correlation between the first and the second scoring which means that the different structural criteria are defined consistently by the same observer. This is supported by the fact that in only 10–12% of the cases was the score difference more than two units. The inter-observer comparison also supports the hypothesis that the structural criteria are well defined (Fig. 4). The scores were on the same side of the baseline in the majority of cases but the differences between the observers were never more than two units which means that the observers generally agreed on whether the structural criteria indicated anterior or posterior rotation but varied somewhat when quantifying the tendency. It should be noted that the mean scores were rated as positive and negative irrespective of whether the actual growth displayed an anterior or posterior rotation. However, this may only apply as long as no extreme case is found in the material. It is likely that the structural characteristics are most obvious in extreme cases and will be most uniformly rated in these individuals. It is not surprising that the correlation coefficients between the scores of the structural criteria and the growth rotation were low in material representing average growth. Due to the ellipsoid form of a correlation matrix it is natural that points in the centre would show low correlations whereas the extremes are much better correlated. Unfortunately these extremes were lacking in the present material.

Thus, lack of correlation does not indicate that the method is useless but may mean that it is not necessary to use it in ordinary cases or that it should be used only to verify that no definite criteria indicating anterior or posterior rotation are present.

Another factor that may bias growth prediction evaluation is that, when assessing the properties of the method, growth must really have taken place from the time of prediction until the control radiographs are taken, and it must be possible to show the actual growth with some precision. In this study the first problem was overcome by using children with maturation stage MP_3 or $MP_{3\,cap}$ (Helm et al, 1971) which means that they have most of the pubertal growth spurt ahead of them. The second series of radiographs was taken four years later. This should ensure that all growth changes of the pubertal period are incorporated.

The most exact method of showing growth changes on cephalograms is to superimpose on metallic implants which makes it possible to demonstrate stable areas and those areas undergoing growth changes. By this method, Björk (1963) was able to show that certain structures within the mandible are relatively stable during adolescence and can be used as a basis for superimposition. In this study the cephalograms were superimposed on the inner cortical structures at the inferior border of the symphysis, the trabecular structures related to the mandibular canal, and the tip of the chin. Any rotational changes are reflected in changes in the NSL-line. The ability to show growth rotations will depend on the accuracy of this method. It was shown that both the intra- and interobserver variability was satisfactory (Tables 1 and 2).

This investigation confirms that the structural characteristics introduced by Björk are quite capable of showing mandibular growth rotations. It also shows that there seems to be no absolute correlation between structural growth prediction and the degree of growth rotation in cases showing average changes. The method should be used primarily to determine whether any typical signs of anterior or posterior growth rotation are present. If not, the case will most probably follow the mean growth direction.

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