Maxillary rotation during human growth: Annual variation and correlations with mandibular rotation

A metal implant study

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For a longitudinal study of the maxillary rotation, based on lateral headplates, a material of 22 patients with metallic implants in both jaws has been used.
It has been established that the degree of maxillary rotation shows variations in direction and in intensity each year. It is smaller, in absolute value, than the degree of mandibular rotation. Due to the fact that the direction of the maxillary and mandibular rotations are not always the same, it appears that the interaction between the maxillary and mandibular rotations plays an important role in the vertical and sagittal relationships of both jaws.

Key-words: Orthodontics; anatomy

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In previous studies *Bjørk* (1966, 1972) has stated that the maxilla could present two different patterns of rotation: one following an anterior direction which he described as an «anterior rotation» and a second one following a posterior direction described as a «posterior rotation». In these studies *Bjørk* has considered the first and the last cephalograms of each series.

The purpose of the present investigation was to reveal the annual variation in the degree of maxillary rotation, and further to study the relationship between maxillary and mandibular rotation.

MATERIAL AND METHOD

The sample consists of twenty-two patients (nine girls and thirteen boys) with metallic implants, which belonged to the same material as that used in a previous study of mandibular rotation (*Lavergne & Gasson,* 1976). The number of patients is reduced because some had only mandibular implants, while others had lost some of their maxillary implants.

None of the patients showed any pathologic conditions, but various types of malocclusion, treated and untreated, were represented.

The age distribution of the sample is given in Fig. 1. The technique of placing the metal

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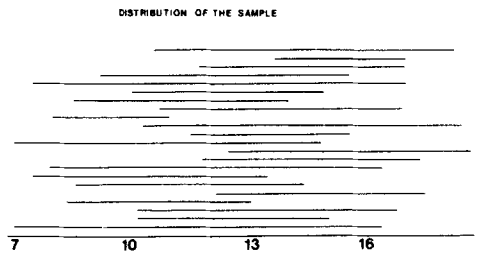

Fig. 1. Age distribution of the sample. Each line represents a period of observation.

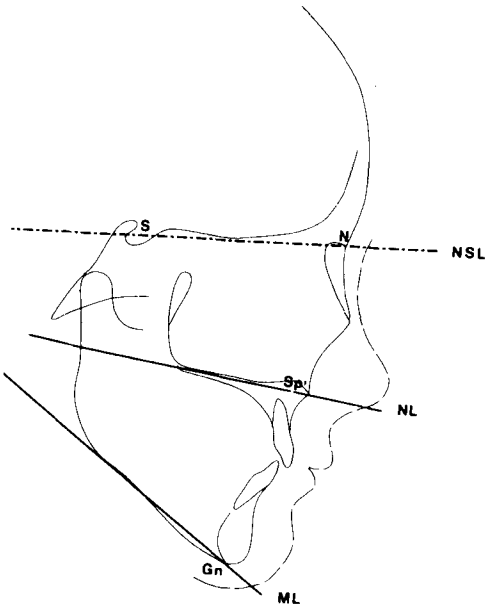

Fig. 2. Reference points and lines. NL: nasal line – ML: mandibular line – N-Sp': anterior ratio – Sp''-Gn.

implants has been previously described by *Bjørk* (1965).

Reference points and lines used in this investigation are shown in Fig. 2.

All the measurements were made by each of the authors, and the mean was used in the preparation of the tables. All the means were expressed in degrees per year. The measurement of the degree of maxillary rotation was carried out using the technique earlier described by *Ødegaard* (1970), adapted to the maxilla.

On each annual cephalometric head-plate the following measurements were made:

1) the degree of rotation of the maxilla relative to NSL.
2) the degree of rotation of the maxilla relative to NL.
3) the degree of rotation of the mandible relative to NSL.
4) for the vertical relationship between the jaws, ML–NL was used as angular value, and the Anterior Ratio (N-Sp'/Sp'-Gn) as linear value, according to the cephalometric analysis reported by *Hasund* (1974).
5) the relationship between both jaws in the sagittal direction by the use of the ANB angle.

Based upon the measured data, three studies have been undertaken:

- The differences between the successive rotational values, represent the variation in the degree of maxillary and mandibular rotation. These measurements were plotted on diagrams. A negative slope represents a posterior rotation and a positive slope corresponds to an anterior rotation. The Spearman Rank correlation Test has been used to study the degree of harmony between the mandibular and maxillary rotation.
- The variation of ML–NL and the Anterior Ratio is used to determine the opening or the closure of the bite in relation to the relative rotational movement of both jaws, between the first and the last head-plate.

  In this study an opening (OB on the diagrams) or a deepening (DB on the diagrams) of the bite has been defined when ML–NL and the values of anterior Ratio indicate the same tendency. When ML–NL and the anterior Ratio vary in an opposite direction it has been defined as a stable vertical development (S on the diagrams).

  A diagram has been constructed with the degree of mandibular rotation along the X axis, and the degree of maxillary rotation along the Y axis. Each individual is repre-

sented on the diagram with a stable vertical bite (S), an opening (OB) or a deepening (DB) of the bite.

- A similar diagram has been built on the basis of the variation of the ANB angle. The normal tendency during growth is a decrease in the ANB angle. In this study of the ANB variations, the patients, therefore have been divided into three groups:

  Group 1, comprised of patients whose ANB is increasing

  Group 2, comprised of patients whose ANB annual percentage of diminution is less than 15%

  Group 3, comprised of patients whose ANB annual percentage of diminution is more than 15%.

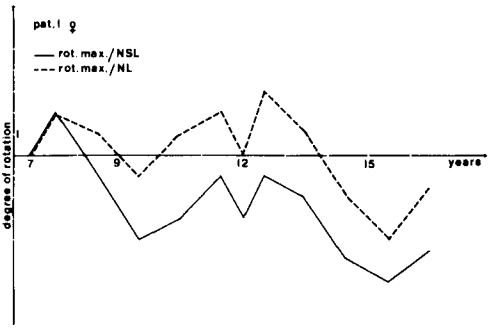

Fig. 3. Diagram of maxillary rotation. The case exhibits a good correlation between the degrees of rotation related to NSL and to NL. This diagram has been built with the first value as origo and the following plotted in relation.

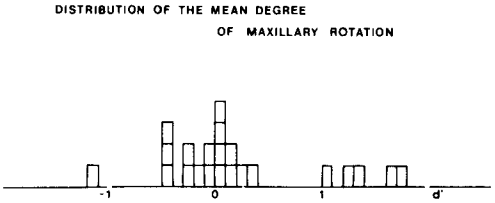

Fig. 4. Distribution of the mean degree of rotation (related to NSL). The positive values indicate anterior rotation and negative values indicate posterior rotation.

RESULTS

Maxillary rotation

This investigation revealed that the rotation of the maxilla is not constant either in direction or in intensity during the growth period studied (Fig. 3). Among the individuals, nine showed a posterior rotation and thirteen an anterior rotation when only the first and the last cephalograms were considered and the rotation was measured relative to NSL.

The distribution of the mean degree of annual rotation relative to NSL (Fig. 4) showed that the degree of rotation was rather small with a range from – 1°16 to + 1°75, and a mean value calculated to 0°21.

The thirteen individuals with anterior maxillary rotation showed a mean degree of annual rotation of 0°61 when related to NSL with a range from 0° to + 1°75, and when related to NL a mean value of + 0°69 was found with a range from 0° to + 2°25. For the nine individuals with posterior rotation the mean degree of rotation was – 0°37 when related to NSL with a range from – 1°16 to 0°. Measured in relation to NL, a mean of – 0°32 was found with a range from – 0°91 to 0°.

A Spearman Rank Test was used to test the similarity of the curves describing the rotation measured in relation to NSL and NL. The test indicated a significant correlation at the 0.01 level in fifteen cases, five cases showed a correlation at the 0.05 level and two cases did not show any significant correlation.

Relationship between the rotation of both jaws

Nineteen individuals showed a mean degree of anterior mandibular rotation relative to NSL of 1°. When related to ML, a mean value of + 0°16 was found. Three individuals with a posterior rotation showed a mean of – 0°39

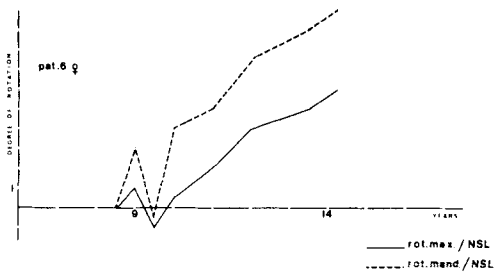

Fig. 5. Rotational diagram of the mandible and the maxilla. A case with a high correlation between the rotation of the maxilla and of the mandible.

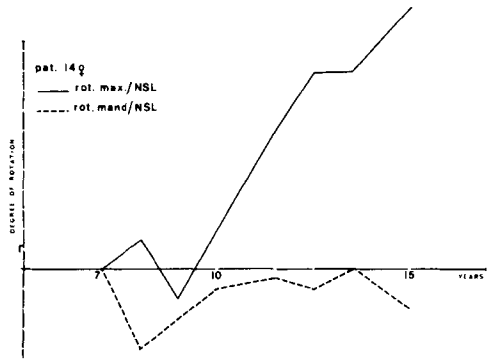

Fig. 6. Rotational diagram of the mandible and of the maxilla. An example of no correlation between the rotation of the mandible and of the maxilla.

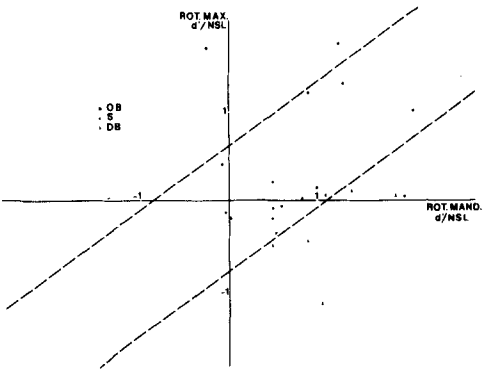

Fig. 7. Interaction of maxillary and mandibular rotation on the vertical relationship of the jaws.

when related to NSL, and of – 0°59 when related to ML. The mean degree of mandibular rotation for the whole sample was 0°81, related to NSL.

The study of the relationship between the direction of maxillary and mandibular rotation demonstrated one case (4.5%) where both the mandible and the maxilla did rotate in a posterior direction. The mean maxillary rotation relative to NSL was in this case – 0°16, and the mean mandibular rotation relative to NSL was – 0°58. In eleven cases (50%), both the mandible and the maxilla showed an anterior rotation with a mean maxillary rotation relative to NSL of + 0°54, and a mean mandibular rotation relative to NSL of + 1°30. In two cases (9.5%), the maxilla manifested an anterior rotation while the mandible had a posterior rotational direction with a mean rotation in relation to NSL of + 1°02, and – 0°16 respectively. In eight cases (36%), the maxilla exhibited a posterior rotation and the mandible an anterior rotation. The mean degree of maxillary rotation relative to NSL was – 0°32 and the mean degree of mandibular rotation relative to NSL was + 0°48.

The Spearman Rank correlation Test revealed that in nine individuals there was a correlation between the direction of rotation of both jaws at the 0.01 level. In four individuals, a correlation at the 0.05 level was found and nine cases showed no correlation (Figs. 5, 6).

Rotation and changes in vertical and sagittal jaw relatinships

In the following, the terms «deepening» or «opening of the bite» correspond to the basal relationships between the jaws, without any reference to the dento-alveolar component.

The relationship between the degree of rotation of both jaws and the deepening or opening of the bite are given in the diagram in Fig. 7. The lower right zone, comprised mostly of individuals with deepening of the bite (DB), corresponding mostly to the area of anterior mandibular rotation and posterior maxillary rotation. The upper left zone which corresponds mainly to the posterior mandibular ro-

tation associated with an anterior maxillary rotation, comprised mainly of individuals showing an openining of the bite (OB). The middle zone contains individuals with stable basal vertical dimensions (S) and corresponds to harmonious rotational movements between both jaws.

When using the variation ANB as a basis for a similar diagram for the sagittal dimension (Fig. 8), a division into three zones also appears: the lower right area corresponds to a large decrease of ANB, the upper left area corresponds to an increase of ANB and the middle area corresponds to a moderate decrease of ANB.

In order to increase the material with posterior mandibular rotation, it was decided to take transitory periods of mandibular posterior rotation of some patients of this sample, as a basis for a new diagram (Fig. 9).

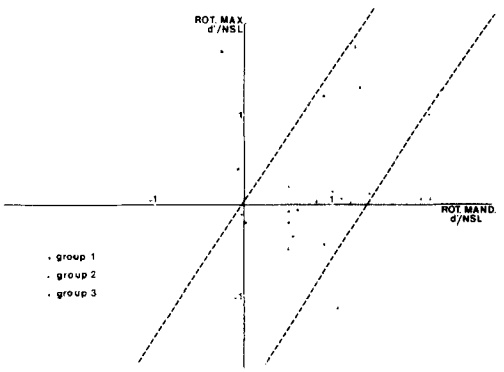

Fig. 8. Interaction of maxillary and mandibular rotation on the sagittal relationship of the jaws.

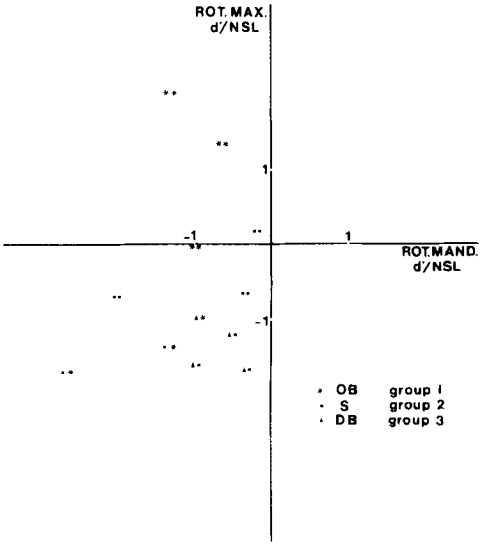

Fig. 9. Interaction of maxillary and mandibular rotation on the vertical and sagittal relationship of the jaws when the mandible has a posterior rotation. The symbol on the left corresponds to the vertical changes and on the right to the sagittal changes.

DISCUSSION

It has been shown by studying the maxillary rotation in a longitudinal material that this phenomenon is not univocal but exhibits variation in direction from one year to the next. This variation in the rotational pattern has also been shown for the mandible (*Lavergne & Gasson*, 1976). Compared to the mandibular rotation, in which the value relative to ML had a mean half the value relative to NSL. The value of the maxillary rotation relative to NSL and to NL were very close (0°61 and 0°69). This may be explained by the fact that the degree of maxillary rotation exhibited a small amplitude. Furthermore the maxillary rotation did not manifest such a clear division into two periods as was previously seen for the mandibular rotation (Lavergne & Gasson, 1976). This may be explained by the effects of the treatment, especially when using the head-gear.

The comparison between the maxillary and the mandibular rotations showed that, in absolute value, the former is always less pronounced than the latter. Moreover, the respective direction of the maxillary and the mandibular rotation is not necessarily the same each year. All together, the correlation between the rotation of both jaws in the present work does not seem to be as high as that found by *Bjørk* (1972). The difference may be explained by more extreme variants in *Bjørk's* non-treated material.

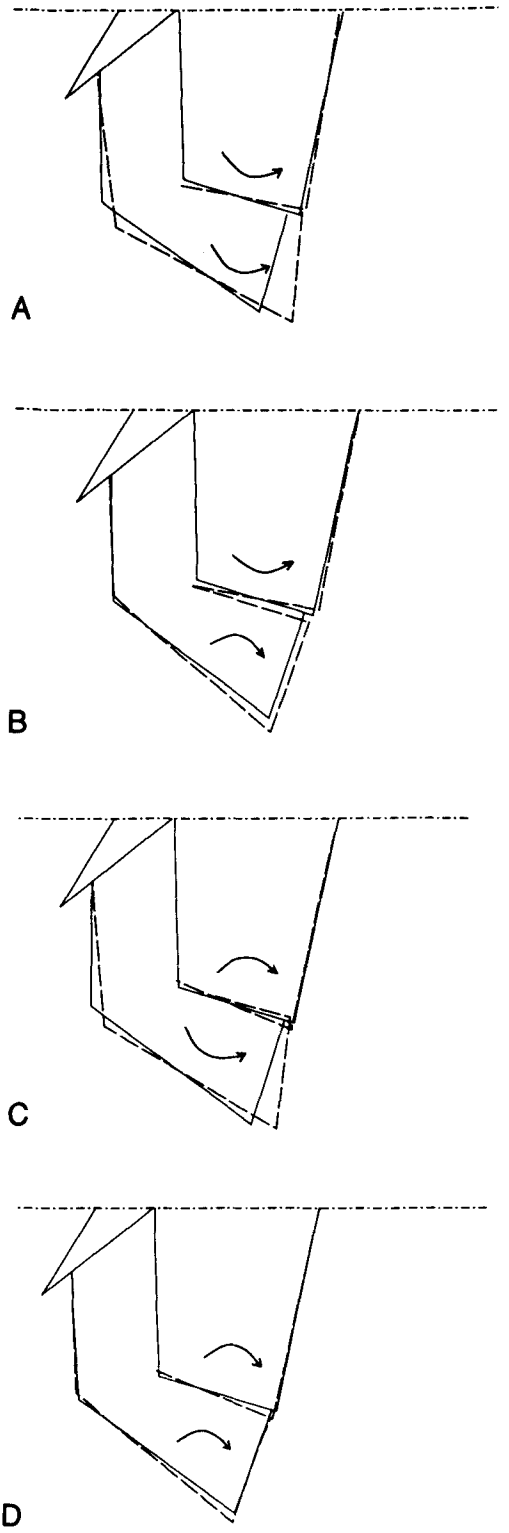

Fig. 10. The four patterns of rotation. a) anterior maxillary and mandibular rotation – harmonious growth in sagittal and vertical dimensions. b) anterior maxillary rotation and posterior mandibular rotation – tendency to opening of the bite and to an increase of ANB. c) posterior maxillary rotation and anterior mandibular rotation – tendency to deepening of the bite and to a high decrease of ANB. d) posterior maxillary and mandibular rotation – when both rotations are harmonized in intensity, the vertical and sagittal relationship remain stable.

With regard to the relationship of the jaws, and based upon Figs. 7, 8 and 9, the following conclusions may be made. A harmonization, mainly in the direction of the mandibular and maxillary rotation is necessary for a stable vertical interjaw relationship. To obtain a stable vertical relationship between the jaws, the maxilla and the mandible must present the same pattern in their rotations, either in an anterior or a posterior direction.

A moderate decrease of the ANB angle, which seems to be the main trend in man (*Riolo et al.* 1974), also requires a harmonious maxillary and mandibular rotation. It seems that in cases where both jaws are rotating in an anterior direction, the degree of mandibular rotation must be higher than the degree of maxillary rotation in order to get a moderate decrease of the ANB angle. This explanation is supported by the fact that, as a general rule, the degree of mandibular rotation is higher than the degree of maxillary rotation (*Bjørk*, 1972). In posterior rotation of both jaws, a harmonious sagittal development seems possible if the degree of maxillary rotation is more marked than the degree of mandibular rotation. The fact that the cleavages on Figs. 7, 8 and 9 are not absolutely within the borderline of the three zones, may suggest that the harmonization of rotation is not the only factor acting on sagittal and vertical relationships of the jaws.

From a theoretical point of view, the four following patterns of rotation can be described.

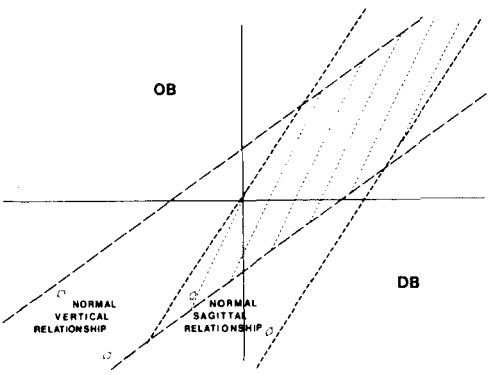

Fig. 11. Superimposition of Figs. 7, 8 and 9.

1) *The maxilla and the mandible both rotate in an anterior direction* (Fig. 10 a). A decrease of the ANB angle seems to be the rule, except in cases with a very high degree of maxillary rotation associated with a small degree of mandibular rotation. The higher the ratio mandibular rotation/maxillary rotation, the higher the decrease of the ANB angle to be expected. The vertical relationship remains unchanged most of the time, except in cases in which the rotational ratio is small. This combination results in an opening of the bite. In cases with a high rotational ratio, on the other hand, a deepening of the bite may be expected.

2) *The combination of the maxilla rotating in an anterior and the mandible in a posterior direction* (Fig. 10 b). In this connection a tendency towards an opening of the interbasal angle (ML–NL) and an increase of the ANB angle can be seen.

3) *The maxilla exhibits a posterior rotation and the mandible an anterior rotation* (Fig. 10 c). In this rotational pattern, there is a tendency towards a deepening of the ML–NL angle and a decrease of the ANB angle.

4) *Cases with the maxilla and the mandible both rotating in posterior direction* (Fig. 10 d). The diagrams in Figs. 9 and 11 show that this pattern covers only a small part of the lower left quadrant where the vertical and sagittal relationships remain relatively stable. From the diagram can be read that a rather large area indicates stability for one or other of the dimensions. On the other hand a rather small area indicates a stable development for both the vertical and the sagittal dimensions.

These four patterns are illustrated in Fig. 12 by the four superimpositions taken from the present material.

Fig. 11 shows that the zone in which the sagittal and vertical relationships are relatively stable, is rather small. It covers mainly the upper right quadrant where both maxilla and mandible are rotating in an anterior direction, an area around the origo, and to a lesser extent the lower left quadrant where the maxilla and the mandible are both rotating in posterior direction. It must be emphasized that these zones' limits are given as indication. Further studies with a larger sample are needed to precise them.

The present investigation shows that the normal facial development includes a harmonization of the rotational movement of both jaws. Fig. 11 indicates that some rotational combinations seem to give a more favourable development of the face.

The experimental results on apes, with the use of heavy extra-oral forces against the maxilla, have shown the possibility of influencing the degree of maxillary rotation (*Droschl*, 1973; *Elder & Tuenge* 1974). Moreover, the formula which has been suggested in an earlier study (*Lavergne & Gasson*, 1976), supports the possibility of action on the mandibular rotation.

The diagram in Fig. 11 constructed from the results of the present investigation seems to portray the clinical findings in connection with the use of the «rotational head-gear» (*Flaaten*, 1974). On this basis, the diagram may be recommended as a guide in the treatment planning of malocclusion.

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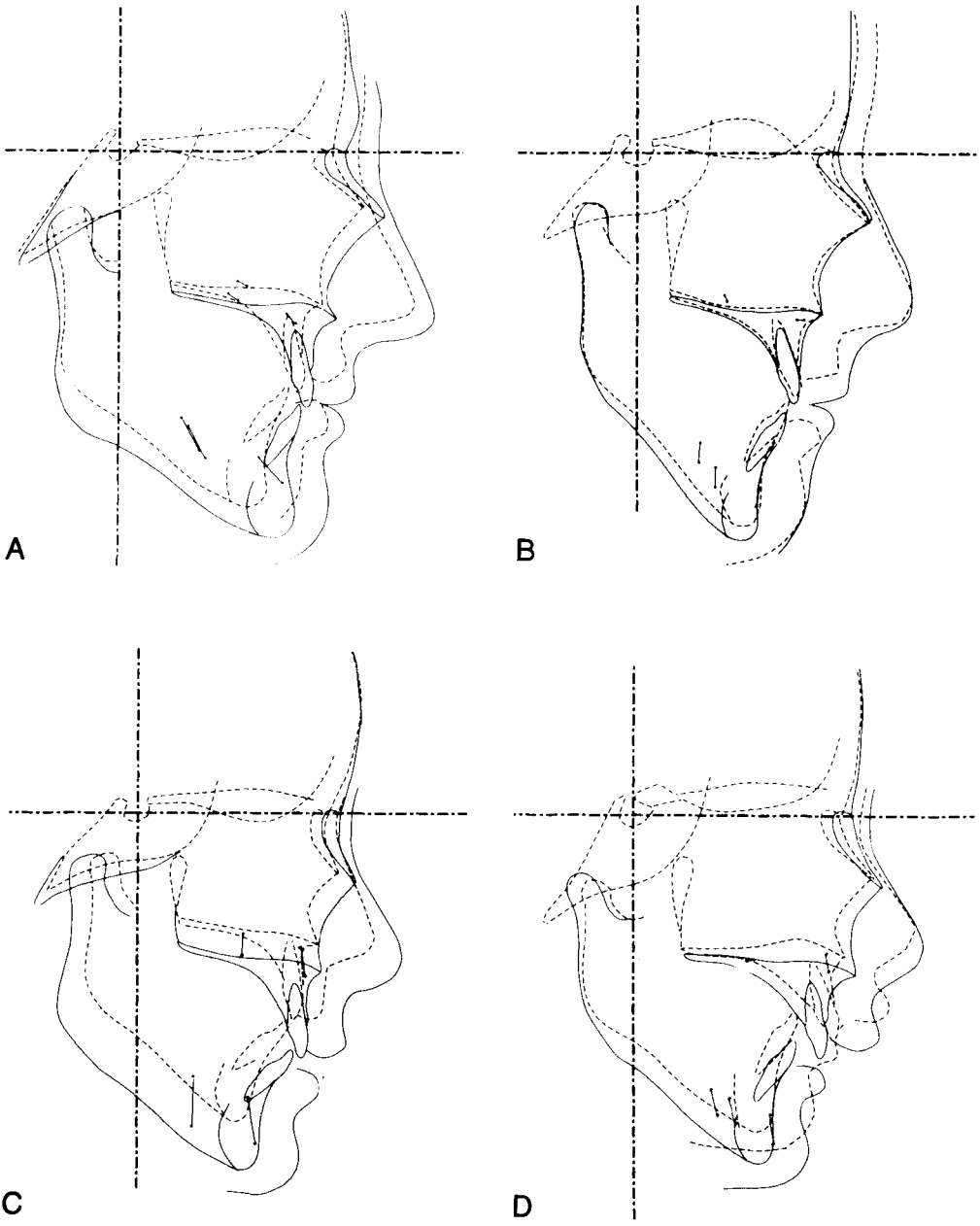

Fig. 12. Superimposition illustrating the four patterns of rotation of Fig. 10. a) patient 12. M. 1.9.66–14.11.73. b) patient 26. F. 31.8.64–24.4.68. c) patient 23. 10.8.64–18.3.74. d) patient 9. M. 9.9.64–18.3.68.

REFERENCES

Bjørk, A. 1955. Facial growth in man studied with the aid of metallic implants, Acta Odont. Scand. 13, 9–34

Bjørk, A. 1966. Sutural growth of the upper face studied by implant method. Acta Odont. Scand. 24, 109–127

Bjørk, A. & Skieller, V. 1972. Facial development and tooth eruption. An implant study at the age of puberty. Am. J. Orthod. 62, 339–383

Droschl, H. 1973. The effects of heavy orthopedic forces on the maxilla in the growing Saimiri Sciureus (squirrel monkey). Am. J. Orthod. 63, 449–461

Elder, J. R. & Tuenge, R. H. 1974. Cephalometric and histologic changes produced by extra-oral high-pull traction to the maxilla in Macaca Mulatta. Am. J. Orthod. 66, 599–617

Flaaten, R. 1974. Anwendung der extraoralen Kraft bei der Behandlung des offenen und geschlossenen Bisses der Klasse II sowie der Klasse III Okklusionanomalien. Inf. Orthod. Kieferortho, 3, 4

Hasund, A. 1974. Klinische Kephalometrie für die Bergen Technik, Bergen

Lavergne, J. & Gasson, N. 1976. Variation in the degree of mandibular rotation in man. A metal implant study. Angle Orthod. 46, 144–150

Riolo, M. L., Moyers, R. E., Mc Namara, J. A. & Hunter, W. S. 1974. An atlas of craniofacial growth. Center for human growth and development. Ann Arbor. Michigan

Ødegaard, J. 1970. Mandibular rotation studied with the aid of metal implants. Am. J. Orthod. 58, 448–454