ADOLESCENT AGE CHANGES IN SAGITTAL JAW RELATION, ALVEOLAR PROGNATHY, AND INCISAL INCLINATION

by

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MOGENS PALLING

In a preceding article, *Björk* 1953 a, attention has been drawn to those significant changes which may occur in the occlusion of the teeth during the growth and development of the individual. Occlusal changes of this kind are symptomatic of the combined effect of all the factors which influence the structure of the jaw and the bite. An understanding of the complexity of causes which determine the occlusal development is of the utmost importance to the diagnosis and treatment planning in cases of malocclusion, and the object of the present article is to examine the mechanism behind the age changes in sagittal occlusion.

MATERIAL

The material for this article is derived from measurements made on lateral head x-ray exposures of a group of 243 Swedish boys, examined at the age of 12 and re-examined by the same method at the age of 20. The study thus covers the adolescent developmental period.

MODE OF ANALYSIS

The problem at hand is to determine the manner in which age changes in overjet arise. A sub-division of the factors which determine the variation in sagittal incisal occlusion may be drawn up as shown in Fig. 1. (*Björk* 1947 & 1953 b). The sub-divisions thus obtained have been given the heading, "Variation

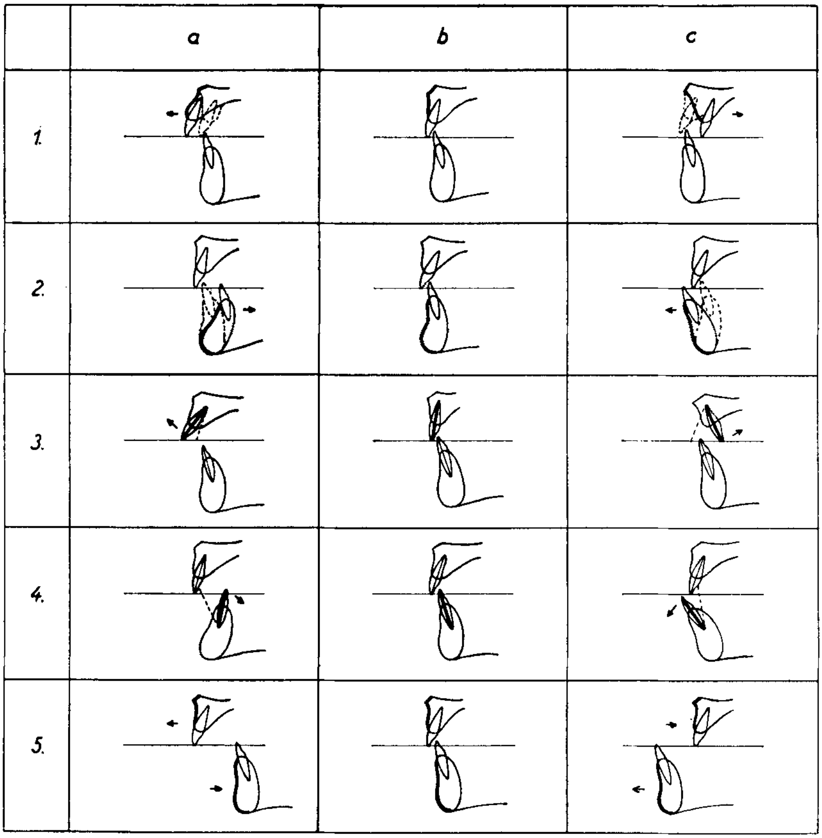

Fig. 1. Variations of second order in sagittal occlusion (overjet). A subdivision is made into four dento-alveolar components (1—4), and one facial (5). The first and second component are related to the alveolar prognathy, the third and fourth to incisal inclination in both jaws. The fifth component represents the sagittal jaw relation. The effect of all components in the first column (a) is towards increased maxillary overjet, in the third (c) towards mandibular overjet, while the centre column (b) indicates an unchanged condition. (From Björk 1953 b).

in Sagittal Occlusion of the Second Order". Factors 1 to 4 represent variations, confined to the dental and alveolar arches, while the fifth factor denotes the facial component. The first and second factors refer to the development in alveolar prognathy, and the third and fourth factors concern the incisal inclination in both jaws. The fifth factor denotes the difference in prognathic development between the jaws, referred to as the sagittal jaw relation.

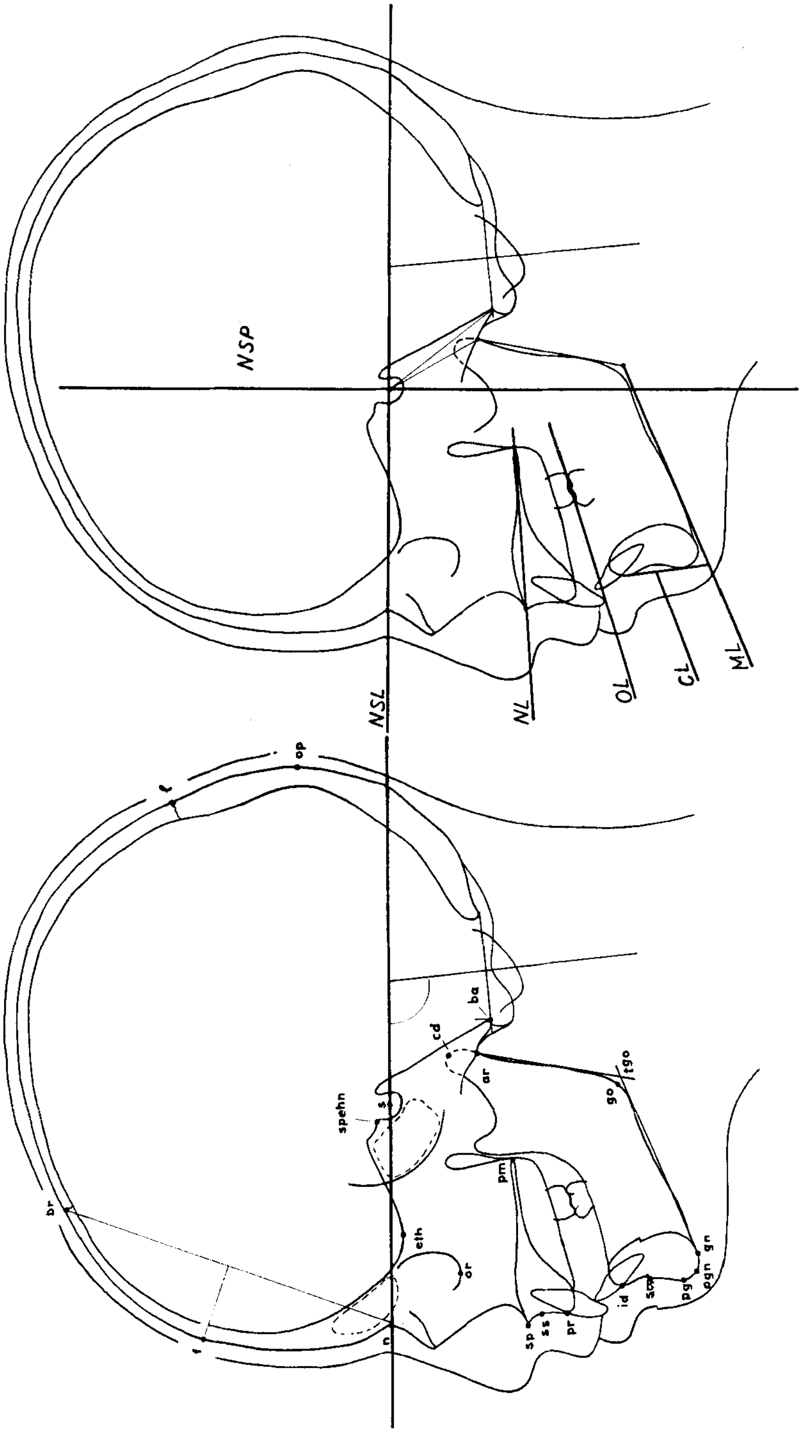

Fig. 2. Reference points and lines within cranial base and face.

A further sub-division has been made in accordance with the direction of the variations, as illustrated in Fig. 1. In the first column, the divergencies for all the factors are towards increased maxillary overjet, in the third column towards mandibular overjet, while the centre column represents unchanged condition.

It is naturally possible to express the various components metrically in a number of different ways and some of the alternative methods have been analysed in the following, cf. Table VI.

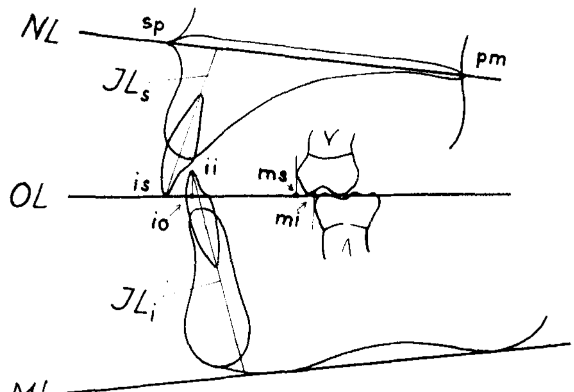

Fig. 3. Reference points and lines within the bite.

The reference points and reference lines used for the x-ray exposures of the facial build are denoted in Fig. 2, and those related to the bite in Fig. 3. The measurements are made in accordance with the method described by *Björk* 1947 with some alterations of the definitions. Measuring points and lines within the cranial base and brain case are described in a recent article (*Björk* 1954), and those related to the facial structure and the bite are described as follows. In case of double projection the midpoints are used.

Measuring points:

ARTICULARE (ar): point at the junction of the contour of the external cranial base and the dorsal contour of the condylar processes.

BASION (ba): the perpendicular projection of the anterior border of foramen magnum (endobasion) on a tangent through the lower margin of the foramen.

CONDYLION (cd): the top of the condylar head.

GNATHION (gn): the lowest point on the symphysis of the mandible.

GONIAL TANGENT POINT (tgo): the junction of the basal tangent and the ramal tangent of the mandible.

GONION (go): a point on the bony contour of the gonial angle located by bisection of the angle formed by the mandibular base line and the ramal line.

INCISION INFERIUS (ii): the midpoint of the incisal edge of the more prominent lower central incisor.

INCISION SUPERIUS (is): the midpoint of the incisal edge of the more prominent upper central incisor.

— (io): normal projection of incision inferius on the occlusal line.

INFRADENTALE (id): the highest and most forward projecting point on the mandibular alveolar process.

MOLARE INFERIUS (mi): the perdendicular projection of the mesial contact point of the lower first permanent molar onto the occlusal line, determined as the midpoint between right and left molars. The position may be transferred to the roentgenogram as the projected arch length, measured from the dental cast from incision inferius to the corresponding bimolar point.

MOLARE INFERIUS (mi): the perpendicular projection of the mesial contact point of the upper first molar onto the occlusal line, determined as the midpoint between right and left molars. The position may be transferred to the roentgenogram as projected arch length, measured from dental cast from incision superius to the corresponding bimolar point.

NASION (n): the most anterior point of the naso-frontal suture.

ORBITALE (or): the lowest point on the infraorbital margin.

POGONION (pg): the most anterior projecting point on the chin.

PROGNATHION (pgn): a point on the bony contour of the chin, located by the bisection of the angle formed by the chin line and the mandibular base line.

PROSTHION (pr): the lowest and foremost projecting point of the maxillary alveolar process.

PTERYGOMAXILLARE (pm): a point representing the dorsal margin of the maxilla at the nasal floor level. The point is located on the dorsal contour of the maxilla, upwards forming the anterior border of the pterygopalatine fossa, where it intersects the contour of the hard and soft palates.

SELLA (s): the centre of the bony crypt forming the sella turcica. The surface of the sella turcica is determined regardless of the contours of the clinoid processes, and is limited upwards by a line from tuberculum sellae to dorsum sellae. The centre is defined as the midpoint of the greatest diameter from tuberculum sellae.

SPINAL POINT (sp): (Acanthion), the apex of the anterior nasal spine.

SUBSPINALE (ss): the most posterior point on the outer contour of the maxillary alveolar process.

SUPRAMENTALE (sm): the most posterior point on the outer contour of the mandibular alveolar process.

Reference lines:

NSL: the nasion-sella line.

NSP: the nasion-sella perpendicular.

NL: the nasal line, through the spinal point and pterygomaxillare.

OL: the occlusal line, through incision superius and the distal cusp summit of the first upper molar, or, when this tooth is missing, the mesial cusp summit of the second upper molar.

ML: the mandibular line, tangential to the mandibular base.

CL: the chin line, from infradentale through pogonion.

IL_s: upper incisor axis from is through apex.

IL_i: lower incisor axis from ii through apex.

STATISTICAL METHODS

Analysis of age changes necessitates a relatively comprehensive statistical treatment, and an account of the methods employed is therefore given below.

The mean values of the various determinations for the ages 12 and 20 years (M_{12} and M_{20}), the average age changes (M_D), and the standard deviation of these values (s) will all be found in Table I.

The quotient s_D/s_{12} given in column 4 denotes the distribution of the age changes in relation to the distribution of the characteristics in question at the age of 12 and appears to provide a reliable indication of the variation in shape with age in relation to the variation at a given stage of development.

An expression for the individual age development has been obtained by calculating the values of the determinations for the 20-year old material as the regression of the values at 12 years, $b_{20/12}$ in column 5.

In those cases where the adolescent development is similar, irrespective of the value of the determination at 12 years. the coefficient of regression is 1.0. A coefficient greater than 1.0 denotes that a value which is high for the determination at 12 years increases with age more in proportion than a low value. If the coefficient is less than 1.0, this means that a value which is high for the determination at 12 years will generally increase less up to adult age in proportion to a low 12-year value.

The amount by which the regression coefficient $b_{20/21}$ deviates from unity can be checked by comparison with the correlation coefficient, $r_{D/12}$ in column 7. The latter coefficient refers to the correlation between the determination at 12 years and the age change (D) for the same determination. If the correlation is significant, then the regression coefficient may be safely assumed to deviate from unity.

The correlation coefficient $r_{20/12}$, column 6, expresses the correlation between the values at 12 and 20 years.

The correlation between age changes is denoted r_D. Correlation between determination at 12 years is denoted r_{12} and at 20 years r_{20}.

When the probability of a coefficient of correlation differing from zero is more than 99 per cent, the correlation is considered significant (**). When the probability is less than 99 per cent but greater than 95 per cent, the correlation is considered probable (*).

The average proportion between two properties is often expressed in terms of an index and such an index may be computed irrespective of whether the properties in question are correlated. For estimating proportions in an individual in relation to a population the index method, however, is misleading if the proportions in question are correlated. (*Gavan* 1952, *Hjortsjö & Lindegård* 1953). The reason for this is that the proportions are not independent of absolute size. Instead the use of orthogonal regression is proposed, as a more accurate method of analysing the proportionality of properties which, although correlated, are independent variables. With this method the proportionality is expressed by the orthogonal regression line, which is the major axis of the ellipsoidal area of distribution. The slope of the major axis is given by the coefficient of orthogonal regression b^1, obtained from the formula.

$$\tan 2\alpha = \frac{2 \cdot r \cdot s_x \cdot s_y}{s_x^2 - s_y^2} \text{ where } b^1 = \tan \alpha \text{ (\textit{Hald} 1952).}$$

This method appears to be particularly suitable for the purpose of analysing the proportionality of linear dimensions, as illustrated in Fig. 7. It may also be used in the analysis of shape, as shown in Fig. 6.

Table Ia

The five components.

Variable	1		2		3		4	5	6	7
	M_{12}	s_{12}	M_{20}	s_{20}	$M_D \pm \varepsilon(M)$	s_D	s_D/s_{12}	$b_{20/12}$	$r_{20/12}$	$r_{D/12}$
I *Alveolar prognathy, upper:*										
1. pr-n-ss	2.3	0.9	2.3	1.0	0.0 ± 0.05	0.8	0.88	0.71	0.65**	0.34
II *Alveolar prognathy, lower:*										
2. id-n-pg	1.2	1.4	0.9	1.7	-0.3 ± 0.06	1.0	0.71	0.98	0.83**	−0.02
3. CL/ML	68.2	5.4	65.4	6.4	-2.8 ± 0.21	3.2	0.59	1.00	0.86**	0.01
III *Incisal inclination, upper:*										
4. IL_s/OL	57.8	4.6	60.3	4.7	2.5 ± 0.25	3.8	0.83	0.68	0.66**	0.38
5. IL_s/NL	110.5	6.0	111.2	6.4	0.7 ± 0.27	4.3	0.72	0.80	0.76**	−0.28
IV *Incisal inclination, lower:*										
6. IL_i/OL	70.3	6.3	69.8	6.6	-0.5 ± 0.33	5.2	0.83	0.71	0.68**	−0.35
7. IL_i/ML	92.1	6.7	90.5	7.2	-1.7 ± 0.29	4.6	0.69	0.89	0.83**	−0.16
V *Sagittal jaw relation:*										
8. ss-n-pg	2.5	2.6	1.3	3.0	-1.2 ± 0.09	1.5	0.58	1.00	0.87**	0.01
9. (ar-pgn)-(ar-ss)[1]	19.9	4.0	27.8	4.9	7.9 ± 0.15	2.4	0.60	1.06	0.87**	0.10
Sagittal apical base relation:										
10. ss-n-sm	3.4	2.3	2.7	2.6	-0.7 ± 0.08	1.3	0.57	0.77	0.86**	−0.08
11. OL/ss-sm[2]	92.6	4.5	91.5	4.6	-1.1 ± 0.16	2.4	0.53	0.89	0.86**	−0.20
12. (ar-sm)-(ar-ss)[1]	8.0	3.2	12.5	4.0	4.5 ± 0.13	2.0	0.63	1.09	0.87**	0.15

[1] difference in length of facial radii.
[2] inferior-posterior angle between occlusal line (OL) and a profile line through ss and sm.

AGE CHANGES OF THE SINGLE COMPONENTS

(Table I)

Sagittal jaw relation: In the following analysis of the age changes which occur in the various components of the bite the obvious starting point appears to be the variations in the skeletal development. The first aspect to be dealt with is therefore the sagittal jaw relation and the age changes it suffers during adolescence.

The average age changes in the facial profile and the individual variations in this development have previously been dealt with. (*Björk* 1947, 1951 & 1953 b; *Lande* 1952). Age changes in the facial profile during adolescence, such as they generally appear, are illustrated in Figs. 4 a and 5 a. Mandibular prognathism on

Table Ib

Other measurements related to the profile.

Variable	1 M_{12}	s_{12}	2 M_{20}	s_{20}	3 $M_D \pm \varepsilon(M)$	s_D	4 s_D/s_{12}	5 $b_{20/12}$	6 $r_{20/12}$	7 $r_{D/12}$
Profile angle:										
13. n-ss-pg	173.8	5.3	177.7	6.1	3.9 ± 0.18	2.9	0.55	1.00	0.88**	0.00
Prognathic angles:										
14. s-n-ss	81.3	3.3	82.0	3.7	0.8 ± 0.10	1.5	0.45	1.00	0.91**	0.05
15. s-n-sm	77.8	3.3	79.3	3.7	1.5 ± 0.10	1.6	0.48	1.00	0.90**	0.03
16. s-n-pg	78.8	3.3	80.7	3.9	2.0 ± 0.11	1.7	0.52	1.00	0.89**	0.07
Inclination of upper to lower incisors:										
17. IL_s/IL_i	128.1	8.3	130.1	9.0	2.0 ± 0.42	6.6	0.80	0.77	0.72**	−0.29**
Facial radii:										
18. ar-ss	83.4	4.0	91.4	4.6	7.9 ± 0.13	2.0	0.50	1.00	0.91**	0.00
19. ar-sm	91.4	4.5	103.9	5.4	12.5 ± 0.17	2.6	0.58	1.00	0.87**	0.00
20. ar-pgn	103.3	5.1	119.2	6.0	15.8 ± 0.20	3.0	0.59	1.00	0.86**	0.00
Jaws:										
21. pm-ss	48.1	2.6	52.7	2.9	4.6 ± 0.11	1.7	0.65	0.92	0.81**	−0.11
22. pm to NSP	13.9	2.7	13.8	3.3	0.1 ± 0.11	1.7	0.63	1.05	0.86**	0.05
23. pgn-cd	110.4	4.9	127.6	5.9	17.2 ± 0.24	3.8	0.78	0.93	0.77**	0.09

Table I.

Mean values of measurements from 243 cases at the 12 years (M_{12}) and at the 20 years of age level (M_{20}), the mean of the age changes (M_D), and the standard deviations (s). Determinations no: 9, 11, 18, 19, 20 are expressed in millimeters, all others in degrees.

an average increases somewhat in relation to the upper jaw, causing the profile to straighten and the lower jaw to become more protrudent.

Because the age changes in facial prognathy vary considerably from individual to individual and as the differential displacement of the jaws may occur in either direction, individual deviations from the general growth pattern may be considerable.

If the angle ss-n-pg is taken as expression for the sagittal jaw relation (row 8, Table I) it will be seen that the standard deviation for the age changes in this angle is 1.5°, with a range of variation of 10°.

Figs. 4 b and 5 b illustrate one of the cases from the sample in which the mandibular prognathy has increased relative to the maxillary prognathy, whereas Figs. 4 c and 5 c show a case in which the age development has been in the opposite direction, i.e. towards retrognathy of the mandible relative to the maxilla.

The age variation in sagittal jaw relation thus occurs in both directions. The distribution of the age changes, expressed by the quotient s_D/s_{12}, has been computed to be 0.58 and thus amounts to roughly 60 per cent of the variation in shape at the age of 12. This age variation is proportional to the variation which occurs in the facial structure and cranial base as a whole and which may be designated the general skeletal growth variation.

As has already been shown, the difference in the degree of maxillary and mandibular prognathy varies widely with the development of the individual. It is not possible, however, to forecast the magnitude and direction from a determination of the sagittal jaw relation at the pre-pubescent stage of development. The regression of the sagittal jaw relation at the age of 20 in relation to the corresponding value at 12 is expressed by the coefficient $b_{20/12}$ which has been computed to be 1.0. This value implies that the age change in sagittal jaw relation remains on an average the same, irrespective of the value at the age of 12.

An analysis of the age changes in the facial angles of prognathy reveals a similar development. For none of these angles does the value of the regression coefficient $b_{20/12}$ depart significantly from unity, from which it may be concluded that the degree of prognathy of either jaw cannot, in itself, provide any indication of the age development.

The same facts may be proved by calculating the correlation between the age changes in prognathy and the degree of prognathy at 12 years, $(r_D/_{12})$. Correlation calculations of that kind for the maxilla (s-n-ss) as well as for the mandible (s-n-pg) give insignificant values (Table I). The correlation between age changes in sagittal jaw relation (ss-n-pg) and the values for the same determination at 12 years is also insignificant. It should

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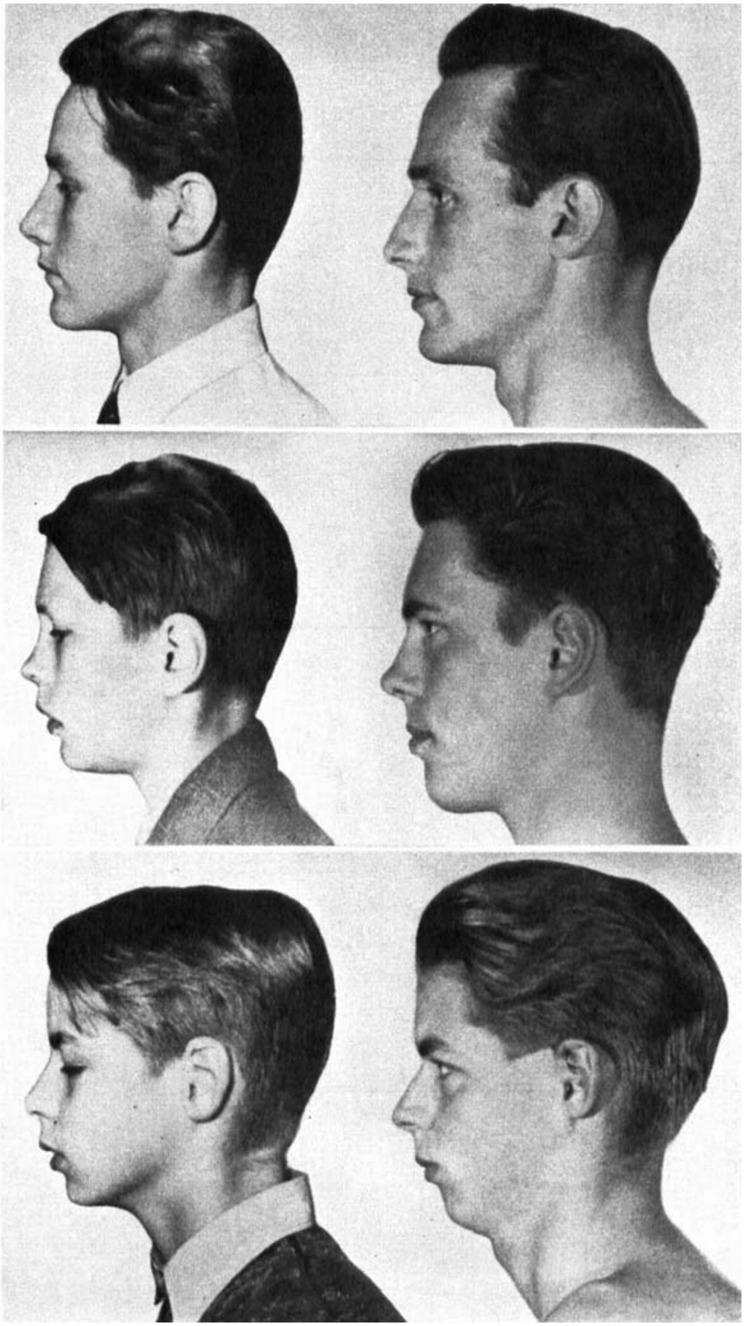
Fig. 4. Photographs of three cases from the sample studied, illustrating varying growth changes of the face during adolescence.

a) Case V 77 representing an average growth pattern.

b) Case V 301 showing marked protrusion with age of the lower jaw in relation to the upper.

c) Case V 177 showing marked retrusion of the lower jaw with age in relation to the upper.



a

b

c

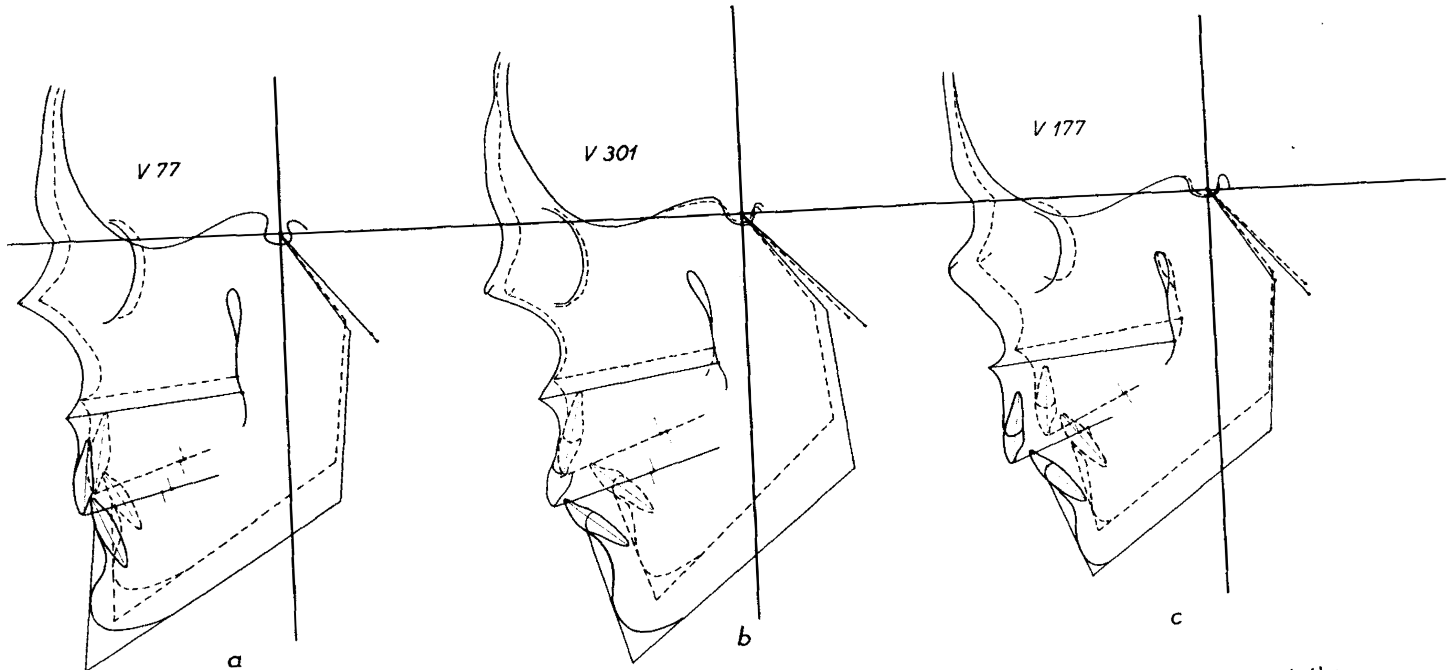


Fig. 5. Growth analysis of the three cases, whose photographs are shown in Fig. 4. The dotted lines represent the facial pattern at 12 years, the heavy lines at 20 years of age.

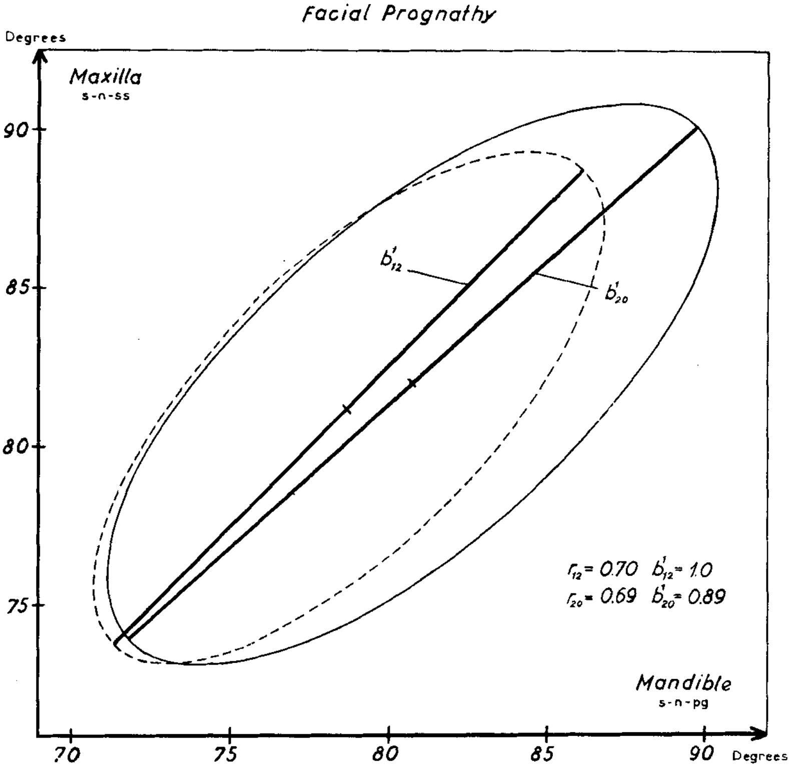


Fig. 6. Age development of facial prognathy, illustrated by the ellipsoid distribution of maxillary prognathism in relation to mandibular at the two age levels, 12 and 20 years. The orthogonal regression is denoted by b^1_{12} and b^1_{20}.

be noted in this connection that neither the age changes in the various facial angles of prognathy nor the sagittal jaw relation show any statistical evidence of a significant relation with the type of sagittal occlusion present at the 12-year stage, neither when the sagittal occlusion is expressed in terms of overjet or molar occlusion ($r = 0.0$ in both cases).

The development of the facial prognathy and the sagittal jaw relation during adolescense therefore appears to be independent of the sagittal occlusal type found at the 12-year stage.

It is interesting, however, to analyse the proportionality between maxillary and mandibular facial prognathy for the two ages (Fig. 6). This relation is expressed for each age in terms of the ellipsoidal areas of distribution. In the case of the 12-year stage the orthogonal coefficient of regression b^{1}_{12} is found to be 1.0, which means that the slope of the major axis of the ellipse is 45°. Hence the sagittal jaw relation is on the whole the same, irrespective of the degree of facial prognathy.

Because the standard deviation of the mandibular prognathy increases with age in relation to that of the maxillary prognathy, the distribution ellipse for the 20-year stage will be rotated in relation to the ellipse for the 12-year stage. The orthogonal coefficient of regression b^{1}_{20} in the latter case is 0.89, and significantly less than unity. This implies that the sagittal jaw relation in 12-year olds is independent of the facial prognathy, whereas in adults it varies with the degree of facial prognathy. In adults, therefore, the protrudence of the mandible becomes proportionately greater in relation to the maxilla with increased total facial prognathy. In other words, the sagittal jaw relation alters with age in this respect.

However, the facial angles of prognathy express only the shape of the facial profile in relation to the brain case. In order to fully appreciate the developmental sagittal variations in the upper facial structure and in the mandible, it is necessary to analyse the internal age changes which occur in the facial structure. (*Lindegård* 1953; *Björk* 1954).

The variation in the sagittal jaw relation being of particular interest, both from a clinical point of view and for the purpose of understanding the manner in which malocclusion arises, an alternative method of registration is given, which is based on linear measurements and hence on absolute size. In rows 18 and 20 in Table I are entered the lengths of the facial radii, measured from articulare to the maxilla (ar-ss) and to the chin point (ar-pgn).

The age variation of the radii provides the same information as the angles of prognathy referred to above. Regression calculations for $b_{20/12}$ show that the size at 12 years does not give any information of the magnitude of the linear growth increment that occurs up to adult age. The same also applies to the length of the maxilla, row 21, and its protrusion as measured from its dorsal contour, normal to NSP (pm to NSP), row 22.

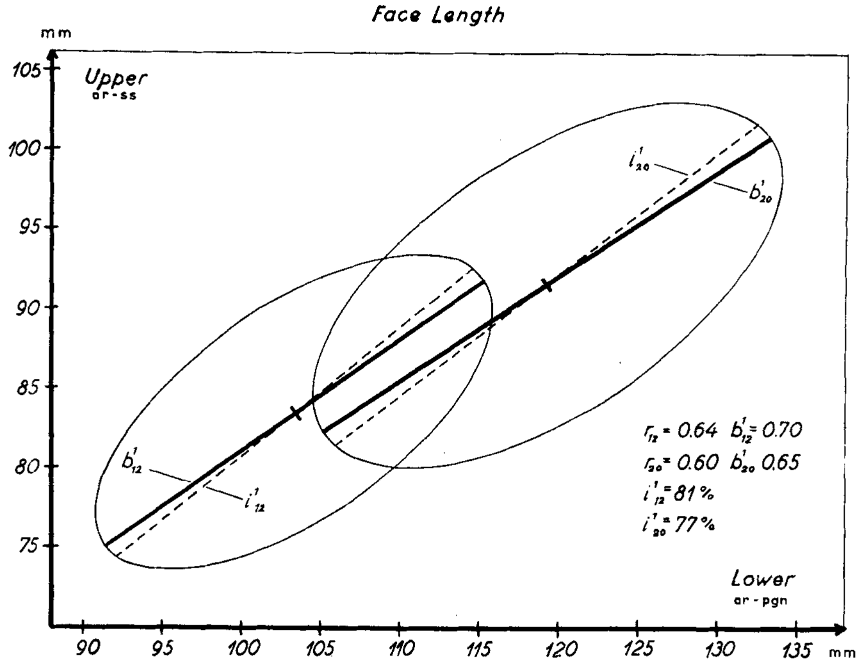


Fig. 7. Age development of facial length, illustrated by the ellipsoid distribution of the upper facial length in relation to the lower at 12 and at 20 years. The orthogonal regression is indicated by b^1_{12} and b^1_{20}. The average proportion is expressed by the index of the upper facial length in per cent of the lower and denoted by i_{12} and i_{20}.

The proportions of the upper and lower facial length are illustrated in Fig. 7, which shows the ellipsoidal areas of distribution for the two age levels.

Calculations based on linear measurements do provide a certain amount of information additional to that deducted from the analysis of the shape. It will be seen from Fig. 7 that the orthogonal regression (b^1_{12} and b^1_{20}) do not coincide with the index lines (i_{12} and i_{20}) which express the average proportionality. This illustrates the fact that the proportion depends on the absolute size. This condition applies to both age groups.

As regards development in length of the face it is appropriate to point out here that it does not appear to be related to the occlusion type either. No interconnection has been found between age changes in the sagittal jaw relation, expressed in terms of linear differential facial length (row 9 in Table I) and the sagittal occlusion type at the age of 12, whether the latter is expressed as overjet or as molar occlusion ($r = 0.0$).

Alternative methods of registering the sagittal jaw relation are found to give the same result, whether they are based on variations in shape or variations in absolute size. Thus the age change in the sagittal jaw relation, expressed by the quotient s_D/s_{12}, amounts to the same for both methods. The correlation between maxillary and mandibular prognathy is also the same as the correlation between the lengths of the upper and lower jaws (Figs. 6 and 7). Both methods have been employed in the following analysis of the relation between the five components.

Alveolar prognathy: In the upper jaw the alveolar prognathy is measured in terms of the angle pr-n-ss, while in the lower jaw it is expressed partly by the angle id-n-pg and partly by the chin angle CL/ML.

The average age change in the alveolar prognathy of the maxilla is insignificant, whereas in the mandible it shows a tendency to diminish, which is in agreement with the conclusion arrived at earlier. The variation found for the ages of 12 as well as of 20 is bigger in the mandible than in the maxilla. Individual age changes are found to occur in either direction and these are also greater in the mandible (s_D). Hence the alveolar prognathy varies more in the lower jaw, in all respects.

Age changes in alveolar prognathy, expressed by the quotient s_D/s_{12} are extremely great. In the case of the angle pr-n-ss it is found to be 0.88 and for the angle id-n-pg 0.71. This means that the age changes amount to between 70 and 90 per cent of the variation in shape at the age of 12, and indicates that the development of the alveolar arches does not depend merely on the general variation in growth which characterises the cranial development as a whole, but in addition exhibits a pronounced modification of the shape during the growth period in question, affected by the formative influence exerted by the muscular function of the lips and tongue or by some extraneous factor.

The coefficient of regression for the maxillary alveolar prognathy at the age of 20 in relation to the corresponding value at the age of 12 deviates significantly from unity ($b_{20/12} = 0.71$).

Pronounced alveolar prognathy in the upper jaw at the age

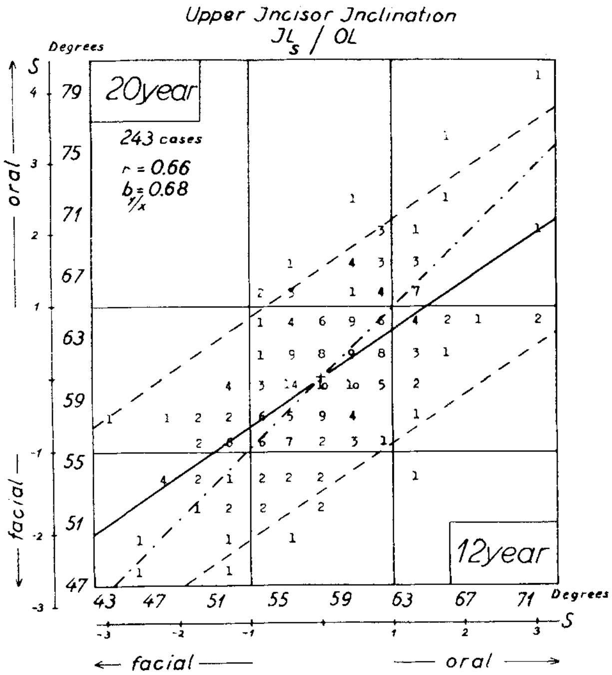


Fig. a

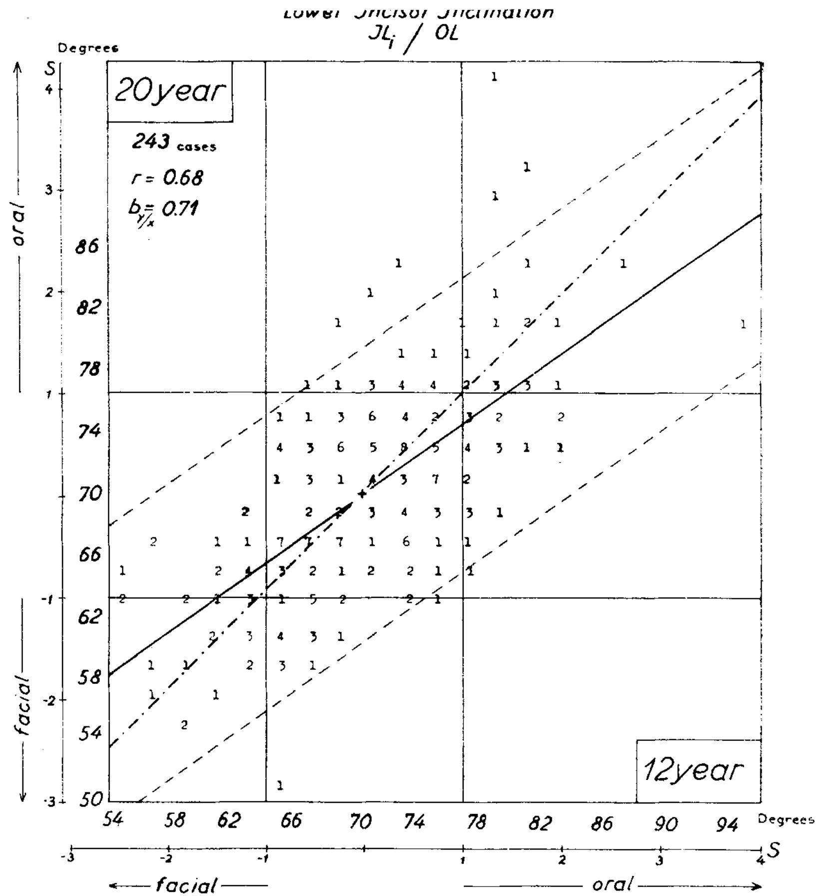


Fig. b.

Fig. 8. Individual development of incisal inclination from 12 to 20 years: a) upper and b) lower jaw. The heavy line denotes the actual regression line ($b_{20/12}$), the dotted line the individual age variation within the limits plus or minus two standard deviations around the regression line ($s_{y/x}$). The dotted and pointed line represents the expected slope of the regression line in case of $b_{20/12} = 1.0$.

of 12 will therefore be found, on an average, to diminish in time, whereas if the degree of alveolar prognathy is small an increase will occur. It will be seen from this that the general tendency in the case of wide deviations in either direction is towards a compensating development. This modification in shape during the developmental period, which shows great individual variations, shall be discussed later on.

Incisal inclination: The inclination of the incisors has been determined both in relation to the occlusal line and to the base of each jaw. The variation in inclination for both age groups (s_{12} and s_{20}) is found to be wider than for any other components of the bite studied. As both the occlusal line and the lines representing the jaw bases alter position with age it has been found practical to employ both methods of registration. The variations show a definite but slight tendency to increase with age.

The average age change in the inclination of the incisors (M_D) in the material dealt with in the present investigation was found to be comparatively insignificant, with a tendency for the angle formed by longitudinal axes of the upper and lower incisors to widen with age (row 17).

Individual age changes are known to occur in either direction (*Schaeffer* 1949; *Björk* 1951). The range of variation for these individual age changes (s_D) is remarkably wide and, expressed in terms of the quotient s_D/s_{12}, amounts to about 80 per cent of the variation range at the age of 12.

The shape of the dental arches, in similarity with that of the alveolar arches, is intimately dependent on the formative influence of functional forces active during the growth period, the effect of which is a more or less strongly pronounced modification in shape occurring with age. This is a circumstance which is reflected in the distribution of the age changes (see Fig. 8). The coefficients of regression b_{20}/b_{12} for the age changes of both upper and lower incisors deviate significantly from unity. This means, in other words, that incisors with a pronounced inclination, facial or oral, show a marked tendency to straighten during the developmental period, and individual age changes in the inclination of the incisors occur in both a compensatory and a dysplastic direction.

CO-VARIATION OF THE COMPONENTS

(Tables II and III)

Compensatory and dysplastic variations: Age changes in the sagittal jaw relation are accompanied by secondary changes of a compensatory nature in the alveolar and dental arches. This appears to be the result of pressure exerted by the lips and tongue, which tends to maintain the bite form, while development is causing a sagittal displacement between the upper and lower jaw. By correlative calculations between the age changes of the five components it is possible to obtain some indication of the average effectiveness of this compensatory influence. In certain cases, however, the dysfunction of the lips and tongue have the effect of inhibiting the compensatory changes, wholly or partially. This is therefore one of the factors which reduces the correlation.

Table II

Intercorrelations of age changes from 12 to 20 years of the five components (r_D).

Components	II	III	IV	V
	CL/ML	IL_s/OL	IL_i/OL	ss-n-pg
I pr-n-ss	0.10	0.10	−0.11	−0.34**
II CL/ML	—	−0.08	−0.32**	0.39**
III IL_s/OL	—	—	0.04	0.11
IL_s/NL	—	—	—	−0.23**
IV IL_i/OL	—	—	—	−0.34**
IL_i/ML	—	—	—	0.34**

Table III

Intercorrelations between the five components at 20 years of age (r_{20}).

Components	II	III	IV	V
	CL/ML	IL_s/OL	IL_i/OL	ss-n-pg
I pr-n-ss	0.10	−0.34**	−0.15*	−0.28**
II CL/ML	—	−0.23**	−0.53**	0.61**
III IL_s/OL	—	—	0.23**	0.0
IV IL_i/OL	—	—	—	−0.53**

The dysfunction of the lips and tongue in various functional connections, special habits such as lip biting, thumb sucking, etc., have long been considered as modifying factors in influencing the shape of the bite (*Rix* 1947—48; *Strang* 1950). Dysplastic modifications of this kind may on the whole be expected to appear independently of skeletal age changes and not to affect the development of the basal jaw arches appreciably. Here the intercorrelation between the various components of the bite would also serve to indicate the extent of the modifications provided that the compensatory variation could be excluded.

Intercorrelation: Compensatory and dysplastic variations tend, more or less, to cancel each other out with age, which greatly complicates any study of the development of the bite. A significant correlation between the age changes of two bite components may be interpreted as a preponderance of either the compensatory or dysplastic changes, according to the direction indicated by the correlation. Absence of any correlation implies approximate equality of the compensatory and dysplastic factors and that hence, on an average, they have cancelled out. The intercorrelations of age changes of the five components (r_D) are given in Table II. Taking the age changes in the sagittal jaw relation, the fifth component, as a starting point it will be found that compensatory changes in the bite occur in the alveolar and dental arches in both jaws. The more the mandible becomes retruded with age in relation to the maxilla, the lesser becomes the alveolar prognathy in the upper jaw ($r_D = -0.34^{**}$) and the greater the alveolar prognathy in the mandible ($r_D = 0.39^{**}$). This is accompanied by a deviation in oral direction of the upper incisors ($r_D = -0.23^{**}$) and by a facial inclination of the lower incisors ($r_D = 0.34^{**}$) as measured to the jaw bases. Any change of the sagittal jaw relation in the opposite direction, i.e. towards increased protrusion of the mandible relative to the upper jaw, results in compensatory changes opposite to those described here.

It will be seen from the above that the compensatory modifications within the alveolar and dental arches are more pronounced than the dysplastic changes and that they are somewhat greater in the mandible.

It is evident therefore, that the compensatory dento-alveolar changes predominate during adolescence. The variations in the dento-alveolar components which occur at adult age (r_{20}, Table III) are thus found to be mainly of a compensatory nature. Retruded position of the mandible in relation to the maxilla in adults is accompanied by pronounced alveolar prognathy of the mandible and facial inclined mandibular incisors, whereas the maxillary alveolar prognathy is somewhat reduced. The variation found in the inclination of the maxillary incisors depends about equally on compensatory and dysplastic factors at this age. This is in accordance with a previous report from this study.

The combination of compensatory and dysplastic modifications of the bite varies with the individual, and a study of the individual growth pattern will provide the desired information about which factors are predominant in any given case, cf. Fig. 9. It is also evident from what has been said above that any analysis of the effect on the tooth position of the dysfunction of lips and tongue, and the influence of individual habits such as thumb sucking, etc., must be carried with due regard to the concurrent changes of a compensatory nature, resulting from the growth changes of the jaw structure.

RELATION TO OVERJET
(Table IV)

Age changes in the sagittal jaw relation, the fifth component, is of great importance in the development of the sagittal occlusion (*Björk* 1947, 1953 a). However, the displacement in occlusion that results from this is not proportional to the displacement of the jaws, it is considerably smaller. This is explained by the compensatory changes in incisal inclination or alveolar prognathy in either or both jaws with age, as discussed above.

The compensatory mechanism is thus to reduce the correlation between the age changes in sagittal jaw relation and the age changes in overjet ($r_D = 0.25^{**}$, row 8, Table IV). The importance of the compensatory effect in this connection may be demonstrated by calculating the partial correlation, eliminating the age changes in the incisal inclinations in both jaws, by which calculation the correlation increases ($r_D = 0.38^{**}$).

The mutual correlation between the age changes in overjet and the age changes in incisal inclination is lower but nevertheless significant. The calculations are for the upper incisors

$r_D = -0.18^{**}$, row 4, and for the lower $r_D = 0.20^{**}$, row 6, as measured to the occlusal line. If the variation with age in sagittal jaw relation and inclination of the incisors in the opposite jaw is eliminated by partial correlation calculation the figures increase ($r_D = -0.28^{**}$ and $r_D = 0.35^{**}$, respectively). These calculations also serve to illustrate the importance of the compensatory changes for the development of the occlusion.

In a quantitative sense, therefore, the changes in sagittal jaw relation, which occur during adolescence, exercise greater influence on the development of overjet than do the dysplastic changes within the alveolar and dental arches. The development of the four bite components, with reference to the effect of overjet, during the growth period 12 to 20 years is readily discernable from the correlation calculations, which will be found in Table IV.

Table IV

Correlations between overjet and alternative determinations of the five components, calculated on the 12 years of age level (r_{12}), at 20 years (r_{20}), and between age changes in overjet in relation to age changes of the components (r_D).

Components	1	2	3
	r_{12}	r_{20}	r_D
I *Alveolar prognathy, upper:*			
1. pr-n-ss	0.07	0.09	0 0
II *Alveolar prognathy, lower:*			
2. CL/ML	0.03	0.17**	−0.04
3. id-n-pg	−0.09	0.03	−0.09
III *Incisal inclination, upper:*			
4. IL_s/OL	−0.19**	−0.05	−0.18**
5. IL_s/NL	0.07	−0.05	0.06
IV *Incisal inclination, lower:*			
6. IL_i/OL	−0.03	−0.16*	0.20**
7. IL_i/ML	0.06	0.21**	−0.15*
V *Sagittal jaw relation:*			
8. ss-n-pg	0.46**	0.47**	0.25**
9. (ar-pgn)−(ar-ss)	−0.45**	−0.53**	−0.38**
Sagittal apical base relation:			
10. ss-n-sm	0.58**	0.59**	0.35**
11. OL/ss-sm	−0.56**	−0.61**	−0.22**
12. (ar-sm)−(ar-ss)	−0.62**	−0.62**	−0.42**

Extreme maxillary overjet in the 12-year old boys is generally accompanied by a facial (dysplastic) inclination of the upper incisors ($r_{12} = -0.19$**, row 4, as measured to OL).

The variation in the inclination of the maxillary incisors at this age is thus determined mainly by dysplastic factors. In the case of the other dento-alveolar components, the effects of dysplastic and compensatory factors counter-balance each other.

During the remaining growth period, up to adult age, the situation undergoes a change. At the age of 20 the compensatory and dysplastic variations cancel out within the maxillary alveolar and dental arches (Table IV). In the mandible, on the other hand, the alveolar prognathy, expressed in terms of the chin angle, increases in the case of extreme maxillary overjet ($r_{20} = 0.17$**) as a result of compensatory influence, while the incisors of the same jaw suffer a forward inclination, ($r_{20} = 0.21$, as measured to ML). The dental and alveolar arches are thus at adult stage generally of a compensatory shape. These findings are in agreement with the results of an earlier investigation (*Björk* 1947).

It should be noted, however, that the correlation calculations quoted in the above should be regarded only as indicative of the quantitative relationship. As far as the individual is concerned, however, all the components are of importance in the development of overjet.

RELATION TO DENTAL ARCH FORM

(Table V)

The functional modification in the frontal parts of the dento-alveolar arches in relation to age changes in sagittal jaw relation has been discussed above. The question of the extent to which the frontal modelling may be transferred to the side segments of the dental arches, affecting the dental arch shape as a whole, can not be answered clearly from this study. In the individuals the reaction seems to be very different. The significance of the frontal modelling on the development of dental arch length and frontal spacing of the teeth is at least in some cases apparent, as illustrated in Fig. 9. It seems fairly evident that the effect of extracting teeth at an early stage of development, deciduous

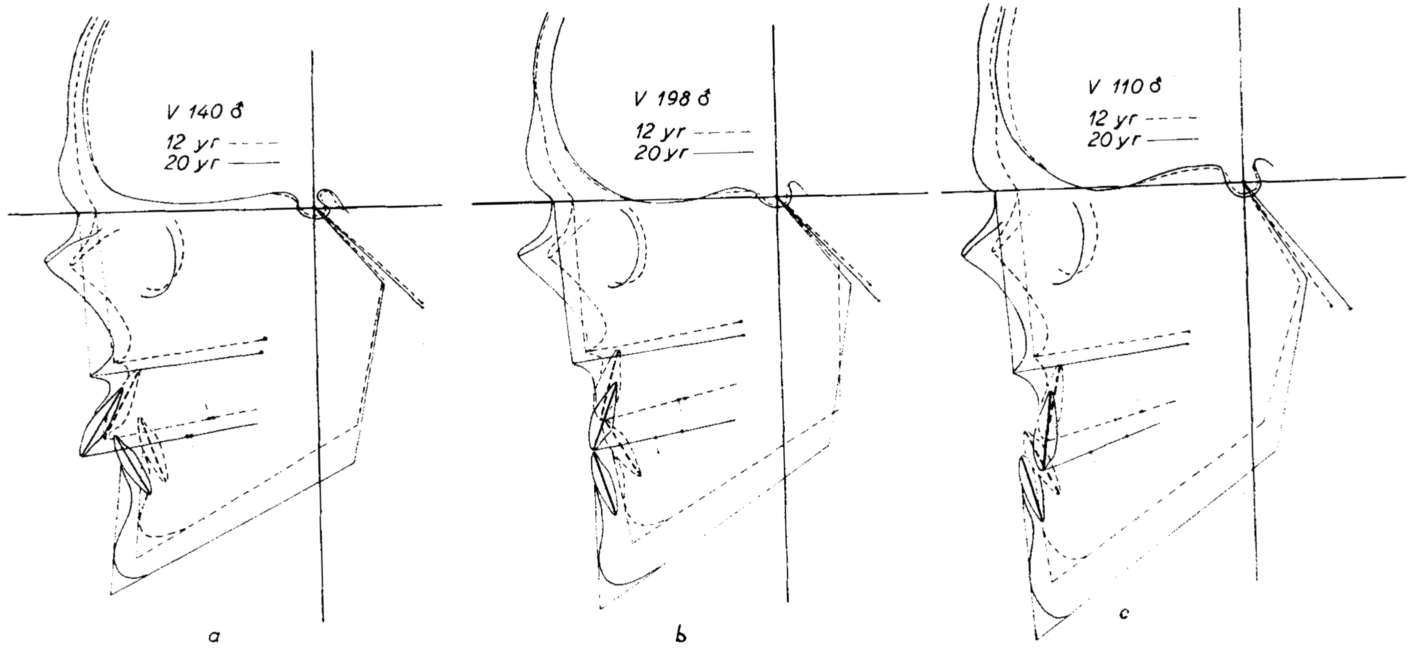


Fig. 9. Growth analysis of three cases showing varying dento-alveolar compensatory modifications with age. (From Björk 1953 b).

canines or first premolars, must be judged in the light of these facts. Early extraction, for instance of a deciduous canine, may at least in some cases result in a reduction of the alveolar prognathy and consequently impair the change of normal development of the alveolar arches, especially in the lower jaw. For this reason the extraction of deciduous teeth as a method of correcting crowding does not appear to be very well justified, if not considered in relation to the individual growth pattern.

Table V

Correlations between dental cast measurements and sagittal jaw relation (column 1) and overjet (column 2) at 20 years in 142 cases without loss of teeth. (ms and mi represent the mesial contact point of the upper first molars).

Variable	1 (ss-n-pg) r_{20}	2 (is-io) r_{20}
Upper dental arch:		
1. projected length: is-ms (L_1)	0.13	0.31**
2. width: ms-ms (B_1)	—0.04	—0.05
3. spacing of the teeth (D_1)	—0.09	—0.07
Lower dental arch:		
4. projected length: ii-mi (L_1)	0.24**	0.10
5. width: mi-mi (B_1)	—0.08	—0.01
6. spacing of the teeth (D_1)	—0.06	—0.29**
Molar occlusion:		
7. mi-ms (mean of right and left side)	0.11	0.70**

As discussed above, correlative studies of dental arch development are of limited value due to the interaction of dysplastic and compensatory modelling of the dento-alveolar arches in all dimensions. In Table V a correlation table is given of the association between sagittal jaw relation and dental arch form on one hand, (column 1), and between overjet and dental arch form on the other, (column 2). Significant relations are as can be seen nearly absent.

The interpretation of these findings may be, as discussed above, that compensatory and dysplastic development are equal, reducing the correlation to zero. A better understanding of this problem should naturally require an analysis of the individual development as related to the actual skeletal growth pattern and the function of the soft tissues.

CLINICAL DIAGNOSIS

(Table VI)

According to the classification used, the variation in overjet is analysed as related to five factors, four dento-alveolar and one facial, each of which can be expressed in terms of a three-point scale (Fig. 1). This makes a total of $3^5 = 243$ combinations in the development of the overjet, all theoretically possible. This system is termed the combination method of analysis, and the section discussed here the variation in sagittal occlusion of the second order. It may be concluded that the fifth factor, the sagittal jaw relation, varies with age irrespective of the individual combination of the dento-alveolar components. The development of the four dento-alveolar components, however, is strongly dependent on the development of the sagittal jaw relation.

Table VI

Correlations between alternative determinations of the components at 20 years of age.

Components	r_{20}
I *Alveolar prognathy, upper:*	
pr-n-ss and spacing	0.05
II *Alveolar prognathy, lower:*	
id-n-pg and CL/ML	0.84**
id-n-pg and spacing	0.07
III *Incisal inclination, upper:*	
IL_s/OL and IL_s/NL	—0.84**
IV *Incisal inclination, lower:*	
IL_i/OL and IL_i/ML	— 0.76**
V *Sagittal jaw relation:*	
ss-n-pg and (ar-pgn)-(ar-ss)	—0.65**
Sagittal apical base relation:	
ss-n-sm and OL/ss-sm	—0.75**
ss-n-sm and (ar-sm)-(ar-ss)	—0.71**

The method serves a dual purpose: it is used for describing the shape of the bite, *morphological analysis,* and for describing the growth changes in the bite or changes brought about by orthodontic treatment, *growth analysis.*

For purposes of clinical use the five components may be expressed in terms of several alternative determinations and the values obtained will depend upon factors such as stage of development, anomalous position of individual teeth, jaw deformities, etc.

In order to get an idea of the reliability of the alternative expressions used for the components the different methods have been intercorrelated, Table VI. It appears from this table that all the different methods discussed above serve the purpose equally well.

In the same table is included an analysis of the registration of the degree of tooth spacing as an alternative registration to alveolar prognathy. However, no association was found. For clinical analysis of the bite form at a certain age, i.e. from a purely morphological point of view, the degree of spacing of the teeth may be used alternative to the registration of the alveolar prognathy despite the fact of lack of association. The degree of spacing provides a direct clinical indication of the extent to which the alveolar prognathy may be expected to change due to frontal expansion of the dental arch or retrusion with or without extraction of teeth.

From a clinical point of view the registration of the apical base relation has come into widespread use in recent years. Owing to dysplastic and compensatory modifications in alveolar arch form, the apical base section will follow a different pattern of development than the sagittal jaw relation. This differential development is of importance in growth analysis. The functional influence on the apical base zone is clearly visible in many of the statistical data. In two of the three methods which have been used for determining apical base relation (Nr: 10—12, Table I) the regression of the value at 20 for a given value at 12 years shows a coefficient ($b_{20/12}$), which differs notably from 1.0. As discussed above, this will be taken as an expression of a functional modelling.

The value of biometrical methods in clinical diagnosis depends entirely on the user's appreciation of the limitations inherent in the method. Cephalometric methods of analysis, especially growth analysis, can be extremely valuable, but presuppose a thorough knowledge of normal and anomalous growth and development and how to interpret biometrical methods. Failing this, such methods may prove difficult to understand and may even be misleading.

SUMMARY

Growth and development brings with it appreciable changes in the occlusion of the teeth. In order to obtain some insight into the mechanism underlying the developments of the overjet, the quantitative effect of the various factors and their developmental interaction have been analysed by statistical methods. The material studied for this investigation comprised cephalometric x-ray measurements made on a random sample of 243 Swedish boys, followed from the age of 12 to 20.

The conclusions may be summarized briefly as follows:

1. The development of the overjet may be analysed in respect of four dento-alveolar components and one facial component. The dento-alveolar components are (1 and 2) the development of the alveolar prognathy in each jaw, and (3 and 4) the age changes in the incisal inclination in each jaw. The facial component (5) is represented by age changes in the sagittal jaw relation (cf. Fig. 1).

2. Individual variations occurring with age in the facial component is proportional to the individual age variation in the facial structure and cranial base as a whole and is denoted the general age variation. As a result of the formative influence of the functional factors, the dento-alveolar components exhibit an individual age variation considerably in excess of the general age variation and which is denoted a modification in shape. This variation is both of a dysplastic and compensatory nature.

3. The development of the facial component appears to be independent of the development of the dento-alveolar components. The latter are in their turn intimately dependent on the development of the facial component, the sagittal jaw relation.

4. The modification occurring in the dento-alveolar components owing to adolescent development is mainly of a compensatory nature.

5. Intercorrelation of the alternative registrations of different components indicates that biometrical methods may be expected

to reveal to a large extent, although not fully, the interdependence in development or to serve as a morphological description of a specific case.

6. The use of orthogonal regression has been demonstrated as a complement to the index method in the study of proportionality.

ZUSAMMENFASSUNG

ADOLESCENTE ALTERSVERÄNDERUNGEN DER SAGITTALEN KIEFER RELATION, DER ALVEOLÄRE PROGNATHIE UND DER INKLINATION DER INCISIVEN

Wachstum und Entwicklung führen ganz bedeutende Veränderungen der Okklusion der Zähne mit. Um ein gewisses Verständnis des Entwicklungsmechanismus des horizontalen Überbisses zu erreichen, ist die quantitative Wirkung der verschiedenen Faktoren und ihre Wechselwirkung während der Entwicklung bei Hilfe statistischer Methoden analysiert worden.

Das Material dieser Untersuchung umfasst Messungen cephalometrischer Profilroentgenaufnahmen von einer wilkürlichen Auswahl 243 schwedischer Knaben, deren Untersuchungen im Alter von 12 Jahren begonnen und bei 20 Jahren abgeschlossen werden.

Die Konklusionen können folgenderweise kurz ausgedrückt werden:

1. Die Entwicklung des horisontalen Überbisses kann bezüglich vier dento-alveoläre Komponenten und eines facialen Komponentes analysiert werden. Die dento-alveolären Komponenten sind (1—2) die Entwicklung der alveolären Prognathie der beiden Kiefer und (3—4) die Altersveränderungen der Inklination der Incisiven, auch der beiden Kiefer. Die Altersveränderungen der sagittalen Relation der Kiefer ist der faciale Komponent (5) (siehe Fig. 1).

2. Individuelle Variationen des facialen Komponentes, die mit dem Alter eintreten, sind mit der individuellen Altersvariationen der facialen Struktur und der den basis cranii im grossen und ganzen proportional und werden "die allgemeine Altersvariation" genannt. Wegen des formgestaltenden Einflusses der funktionellen Faktoren zeigen die dento-alveolären Komponenten eine individuelle Altersvariation, die bedeutend mehr ausge-

sprochen ist als die generelle Altersvariation. Diese Variation wird "Modifikation der Form" genannt. Diese Variation ist sowohl von einer dysplastischen als auch von einer kompensatorischen Art.

3. Die Entwicklung des facialen Komponentes scheint von der Entwicklung der dento-alveolären Komponenten unabhängig zu sein. Ihrerseits sind diese Komponenten von dem facialen Komponent, der sagittalen Relation der Kiefer, abhängig.

4. Die Modifikation der dento-alveolären Komponenten, die wegen der adolescenten Entwicklung eintreten, ist hauptsächlich von kompensatorischer Art.

5. Die Interkorrelation der alternativen Registrierungen der verschiedenen Komponente zeigen, dass es möglich ist, die Entwicklung obwohl nicht vollständig, so doch im weiten Umfang, mit Hilfe biometrischer Methoden klarzulegen, und dass die Methode zu morphologischer Beschreibung eines speziellen Falles angewannt werden kann.

6. Der Gebrauch orthogonaler Regression ist als Komplement zur Index-Methode im Studium der Proportionalität demonstriert worden.

RÉSUMÉ

CHANGEMENT ADOLESCENT SUIVANT L'ÂGE DES RELATIONS SAGITTALES DES MAXILLES DE LA PROGNATHIE ALVEOLAIRE ET DE L'INCLINATION INCISALLE

La croissance et le développement, aménent des modifications assez prononcées dans l'occlusion des dents.

Dans le but d'obtenir une idée exacte du mécanisme du développement d'overjet, les effets quantitatifs des différents facteurs et leur interaction évolution ont été analysée par des méthodes statistiques.

Le matériel de cette analyse comprend: des mensurations de téléradios céphalometriques de 243 Suédois mâle, non choisis, depuis l'âge de 12 ans jusqu'à 20 ans.

Les conclusions peuvent être résumées de cette maniére:

1. Le développement d'overjet peut-être analysé en considerant 4 constituants alvéolo-dentaires et un constituant facial. Les constituants alvéolo-dentaires (1—2) indiquent le développement d'une prognathie alvéolarie des deux maxillaires, et (3—4)

les modifications suivant l'âge de l'inclination des incisives dans les deux maxillaires. Le constituant facial est représenté par les modifications suivant l'âge de la relation sagittale des deux maxillaires.

2. Les variations individuelles suivant l'âge dans le constituant facial, sont proportionelles aux modifications suivant l'âge des structures faciales et de la base cranienne, et sont appelées la variation générale suivant l'âge.

Comme résultat de l'influence formatrice des facteurs fonctionnels, les constituants alvéolo-dentaires montrent une variation individuelle suivant l'âge, beaucoup plus prononcée que la variation générale suivant l'âge. Cette variation est appelée la modification de forme et est d'une nature dysplastique et compensatrice.

3. Le développement du constituant facial paraît être indépendant du développement des constituants alvéolo-dentaires, tandis que les constituants alvéolo-dentaires sont de leur coté intimement dépendants au développement du constituant facial, la relation sagittale des maxillaires.

4. La modification qui se présenté dans les constituants alvéolo-dentaires dû au développement de l'adolescence est en général d'une nature compensatrice.

5. L'intercorrélation des enregistrements alternatifs des constituants differents indiquent que la méthode biométrique peut être appliquée, jusqu'à en certain point, à révéler l'interdépendance du développement et servir à la description morphologique d'un cas spécial.

6. L'emploi de la régression orthogonale a étè démontré comme un moyen complémentaire à la méthode d'index dans l'étude de la proportionalité.

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