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THE SAGITTAL GROWTH OF THE UPPER FACE DURING FOETAL LIFE

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The nasal septum seems to be stable in its angular relationship with the anterior cranial base The Nasal Line NL despite an initial small increase seems to follow the same trend as the anterior cranial base and nasal septum in their angular behaviour to the posterior cranial base. There is an increase in the prognathic development of the upper jaw in relationship to NSL. The correlation analysis tends to show that a posterior rotation of the Nasal Line (NL) and the Septal Line (SL) in relation to the cranial base will lead to a reduction in upper jaw prognathism whereas an anterior rotation of NL and SL to the anterior cranial base will be followed by an increase in upper jaw prognathism. Upper facial prognathism is associated with the length and also with the relative forward position of the upper jaw and nasal septum. Increased upper facial prognathism seems to be associated with a distal basal relationship between the two jaws. There seems to be an anterior shift of the transverse maxillo-palatine suture during foetal life. In all foetal stages the lower septal point (lsp) was found anterior to the anterior nasal spine (ans). The correlation analysis tends to show that the length factor of the upper jaw and its relative forward position contributes equally in the prognathic relationship of the upper face.

The upper face is defined as the anatomical area lying between the Nasion Sella Line (NSL) and the Nasal Line (NL). The upper facial skeleton contains the nasal cavities and the greater part of the orbital cavities.

Brodie (1941) and *Ortiz* and *Brodie* (1944) in roentgenographic studies of children from three months to eight year, and from birth to 3 months of age, found that the morphogenetic pattern of the head was established by the third month of post-natal life or perhaps earlier, and once attained did not change. They also found that the incremental pattern of growth of the various areas, cranial, nasal, maxillary and mandibular, revealed a marked parallelism in geometric form and increments. This stability of the growth

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pattern was found in »normals» and in those with extreme facial growth patterns.

Scammon and *Calkins* (1929) who examined and measured externally a large number of human foetuses, determined that growth was proportional and that the pattern was set in the third month of foetal life. They noted an acceleration in the growth rate in the second half of the prenatal period.

Ford (1955) demonstrated changes in form of width, height and depth during foetal life as a result of differential growth rates of the skull and face. *Levihn* (1967) found moderate changes in the angles used in his investigation of the upper face, whereas *Burdi* (1965) found that the angular relationships between contiguous areas of the nasomaxillary region showed no significant changes with increasing Crown Rump Length (CRL).

The present investigation is a metric anthropological and roentgen-anatomical study of the upper facial skeleton in its sagittal growth process. Cephalometric landmarks, angles and reference line have been used to a large extent, this has been made possible by the dissection technique used, and by the application of contrast medium for the roentgenographic technique.

MATERIALS AND METHODS

The present study relates to 159 human foetuses, 87 from the Institute of Anatomy, University of Bergen (Bergen material) and 72 from the Anatomy Department, Queens University of Belfast, Northern Ireland (Belfast material). Chronologically the foetal material (Bergen and Belfast) corresponds to approximate foetal ages of 10 to 33 weeks.

The material and methods have been previously described in detail (*Kvinnsland,* 1971).

RESULTS

Developmental changes

All variables have been correlated to the Occipito Frontal diameter (HL) and expressed in terms of the correlation index (r_m). For all measurements a polynomic regression equation has been used varying from 1st to 4th degree depending on which value of r_m gives the best possible description of association between the variables in cases where this is an improvement on a linear regression equation. The regression equation used is stated for each individual variable in the scatter diagrams, as is the correlation index

(r_m). A correlation index value (r_m) of 0.50 has been selected as the lowest value to express a significant association.

Where $r_m \geq 0.50$ a regression line has been drawn in the scatter diagrams. The abscissa always denotes the Occipito Frontal diameter (HL).

For reference points, reference lines, angles and linear measurements used in the investigation the reader is referred to Fig. 1.

Angular measurements

Nasal Line — Nasion Sella Line (NL—NSL) (20) (Fig. 2). The angle indicating the relationship between the anterior and posterior height of the upper face. This angle shows moderate changes with the various developmental stages, first an initial increase of the angle from 3.6° (Bergen material) and 4.7° (Belfast material) at 20.0 mm HL to 12.2° at 40.0 mm HL (Bergen material) and 11.1° at 50.0 mm HL (Belfast material) thereafter a gradual reduction in the angle to 8.5° at 70.0 mm HL, and 4.6° at 89.5 mm HL (Bergen material). The corresponding values for the Belfast material are 8.7° at 70.0 mm HL and 4.9° at 82.0 mm HL.

Septal Line — Anterior Cranial Base Line (SL—ACBL) (21) (Fig. 3). The angular relationship between the lower margin of the nasal septum and the anterior cranial base. This angle shows no significant changes in the foetal period under investigation.

Septal Line — Posterior Cranial Base Line (SL—PCBL) (22) (Fig. 4). The angular relationship between the lower margin of the nasal septum and the posterior cranial base. This angle shows an increase between 20.0 mm and 50.0 mm HL, from 103.1° to 113.6° (Bergen material) and between 20.0 mm and 40.0 mm HL, from 102.7° to 120.4° (Belfast material). Stability between 50.0 mm and 70.0 mm HL, and 40.0 mm and 70.0 mm HL, for the Bergen and the Belfast materials respectively, and then finally an increase to 117.3° at 89.5 mm HL (Bergen material) and to 123.1° at 82.0 mm HL (Belfast material).

Subspinale — Nasion — Sella (ss—n—s) (23) (Fig. 5). The facial angle expressing the relationship between the maxillary apical base and NSL, commonly used to express the prognathic development of the upper jaw.

This angle shows somewhat different behaviour in the early period in the Bergen and Belfast materials. In the Bergen material there is an initial reduction in the angle 84.4° at 20.0 mm HL and 77.7° at 30.0 mm HL

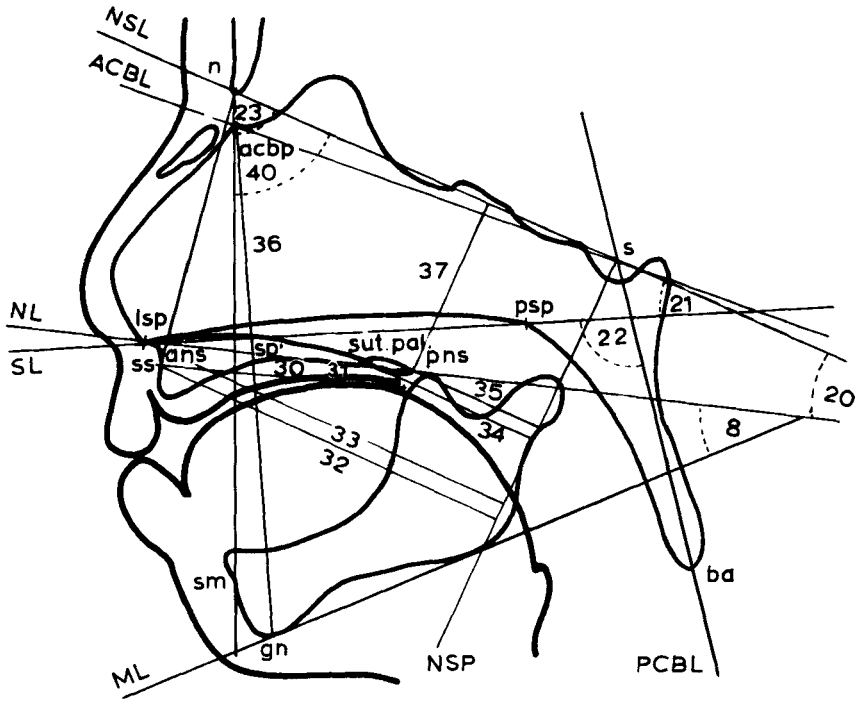

Fig. 1. Reference points, reference lines, angles and linear measurements.
acbp - anterior cranial base point: The point of intersection between the most anterior part of the horizontal cribriform plate, the more vertical uppermost part of the nasal septum and the midsagittal plane (M.S.P. n — nasion: point of intersection of the lowest point on the frontal bone and the M.S.P. lsp — lower septal point: point of intersection between the anterior vertical and lower horizontal margins of the nasal septum and the M.S.P.
psp — posterior septal point; point in the M.S.P. on the deepest concavity of the curvature between the most posterior part of the horizontal lower margin of the nasal septum and the more vertical pharyngeal part of the cranial base. ans — anterior nasal spine. pns — posterior nasal spine. ss — subspinale: point in the M.S.P. where the anteroinferior contour of the anterior nasal spine merges with the alveolar process. sp' — point of intersection between the Nasal Line, and a line between n and gn in the M.S.P. ba— basion: point of intersection between the M.S.P. and the anterior border of the foramen magnum. sut-pal — the transverse maxillopalatine suture: a point midway between the nasal and oral surface of the transverse maxillo-palatine suture in the M.S.P. sm — supramentale: point in the M.S.P. where the anterosuperior contour of the mandibular symphysis merges with the mandibular alveolar process. gn — gnathion: the lowest point on the mandibular symphysis in the M.S.P. NSL — Nasion Sella Line: a line through n and s. ACBL — Anterior Cranial Base Line: a line through acbp and s. PCBL — Posterior Cranial Base Line: a line through s and ba. NL — Nasal Line: a line through lsp and psp. NSP — Nasion Sella Perpendicular: a line through s perpendicular on NSL.
NL — NSL (20): the angle between NL and NSL.
SL — ACBL (21): the angle between SL and ACBL.
SL — PCBL (22): the angle between SL and PCBL.
ss — n — s (23): the facial angle expressing the prognathic development of the upper jaw.
ss — PNS (30): the length of the maxillary apical base.
ss — sut — pal (31): the length of the maxillary part of the hard palate.
ss — NSP (32): the anteroposterior relationship of the most anterior part of the maxillary apical base to Sella.

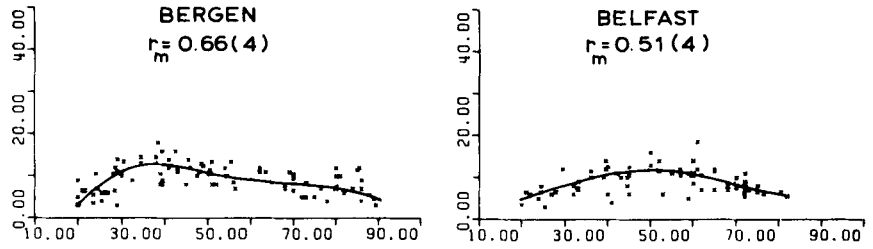

Fig. 2. Developmental changes in the angle LNL — SNL.

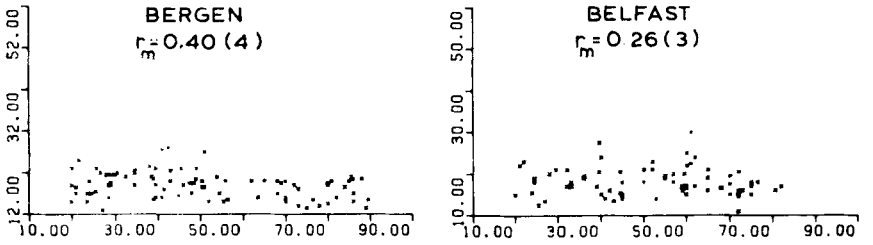

Fig. 3. The relationship between the angle SL — ACB and HL.

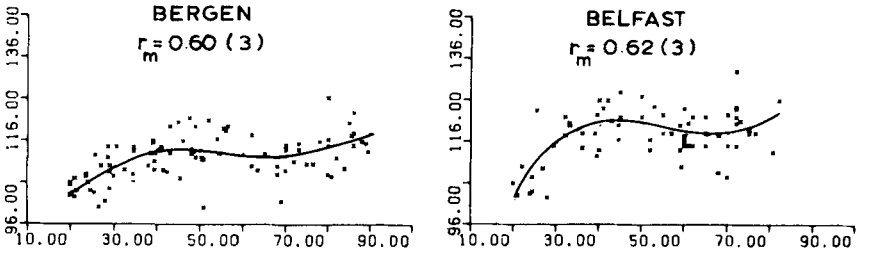

Fig. 4. Developmental changes in the angle SL — PCBL.

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lsp — NSP (33): the anteroposterior relationship of the most anteroinferior point in the nasal septum to Sella.
sut.pal. — NSP (34): the antero-posterior relationship of the transverse maxillo-palatine suture to Sella.
pns — NSP (35): the anteroposterior relationship of the most posterior part of the upper jaw to Sella.
n — sp' (36): the anterior height of the upper face measured along the n — gn line.
pns — NSL (37): the posterior height of the upper face measured along a perpendicular to NSL through pns.

followed by an increase 86.0° at 50.0 mm HL, 89.5° at 70.0 mm HL and 91.2° at 89.5 mm HL. In the Belfast material the initial reduction in the angle was not found, but a steady increase from 77.0° at 20.0 mm HL, 81.8° at 50.0 mm HL, 86.5° at 70.0 mm HL and 91.8° at 82.0 mm HL.

Linear measurements

Subspinale — Posterior Nasal Spine (*ss—PNS*) (*30*) (*Fig. 6*). The approximate length of the maxillary apical base increased from 3.5 mm (Bergen material) and 4.0 mm (Belfast material) at 20.0 mm HL to 20.1 mm at 89.5 mm HL (Bergen material) and 19.1 mm at 82.0 mm HL (Belfast material).

Subspinale — Transverse Maxillo Palatine Suture (*ss—sut.pal.*) (*31*) (*Fig. 7*). The length of the anterior part of the hard palate shows an increase from 2.6 mm (Bergen material) and 3.1 mm (Belfast material) at 20.0 mm HL to 15.2 mm at 89.5 mm HL (Bergen material) and to 15.3 mm at 82.0 mm HL (Belfast material).

Subspinale — Nasion Sella Perpendicular (*ss—NSP*) (*32*) (*Fig. 8*). The antero-posterior relationship of the most anterior part of the maxillary apical base to Sella. This measurement increases from 5.7 mm (Bergen material) and 6.6 mm (Belfast material) at 20.0 mm HL to 30.2 mm at 89.5 mm HL (Bergen material) and to 28.8 mm at 82.0 mm HL (Belfast material).

Lower septal point — Nasion Sella Perpendicular (*lsp—NSP*) (*33*) (*Fig. 9*). The antero-posterior relationship of the most antero-inferior point on the nasal septum to Sella. This measurement shows an increase from 6.8 mm (Bergen material) and 7.1 mm (Belfast material) at 20.0 mm HL, to 33.0 mm at 89.5 mm HL (Bergen material) and 32.1 mm at 82.0 mm HL (Belfast material).

Transverse Maxillo — Palatine Suture -- Nasion Sella Perpendicular (*sut.pal.—NSP*) (*34*) (*Fig. 10*). The antero-posterior relationship of the transverse maxillo-palatine suture to Sella increases from 3.4 mm (Bergen material) and 3.7 mm (Belfast material) at 20.0 mm HL, to 15.5 mm at 89.5 mm HL (Bergen material) and to 13.7 mm at 82.0 mm HL (Belfast material).

Posterior nasal spine — Nasion Sella Perpendicular (*pns—NSP*) (*35*) (*Fig. 11*). The approximate antero-posterior relationship of the most posterior

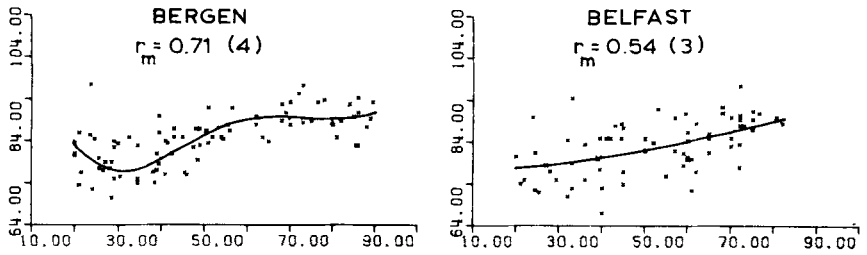

Fig. 5. Developmental changes in the angle ss — n — s.

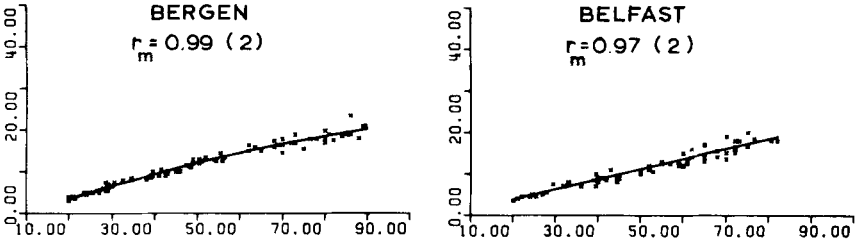

Figure 6. Linear increase in the ss — pns length.

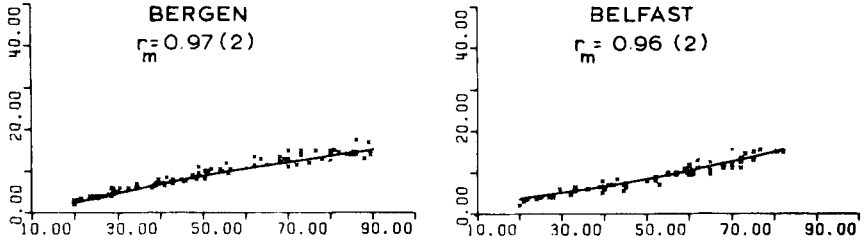

Fig. 7. Linear increase in the ss — sut.pal. length.

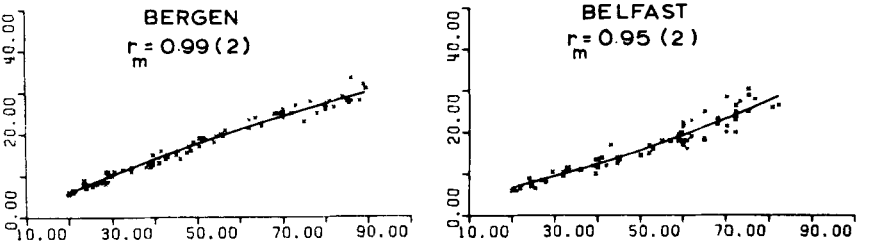

Fig. 8. Linear increase in the ss — NSP distance.

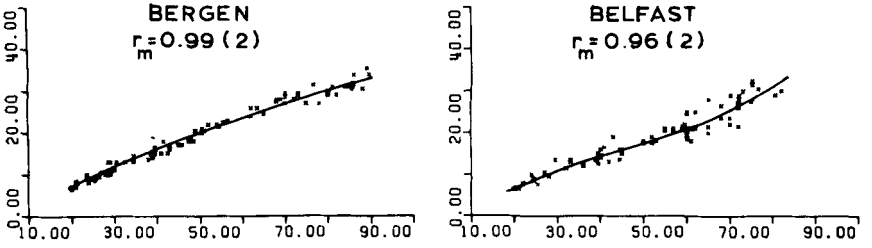

Fig. 9. Linear increase in the lsp — NSP distance.

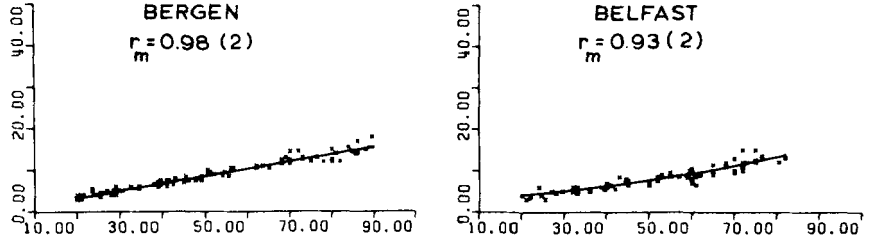

Fig. 10. Linear increase in the sut.pal. — NSP distance.

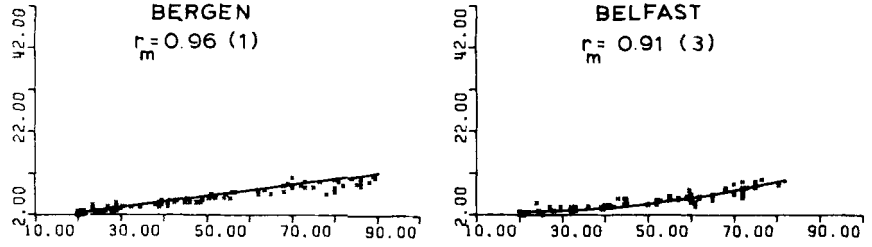

Fig. 11. Linear increase in the pns — NSP distance.

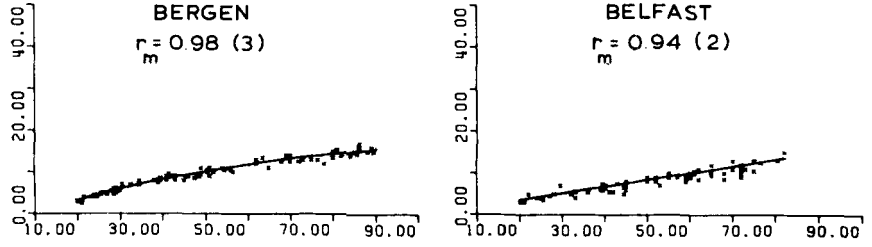

Fig. 12. Linear increase in the upper anterior facial height. (N — sp').

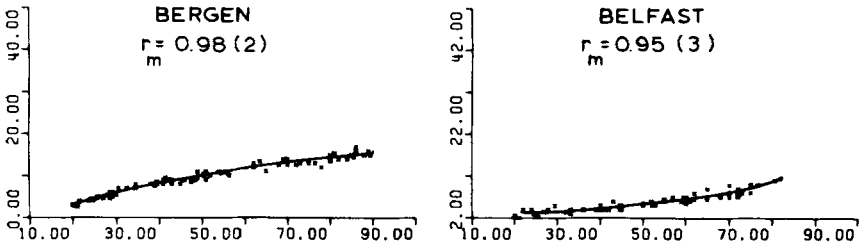

Fig. 13. Linear increase in upper posterior facial height (pns — NSL).

part of the upper jaw to Sella. This measurement increases from 2.5 mm (Bergen material) and 2.6 mm (Belfast material) at 20.0 mm HL to 10.6 mm at 89.5 mm HL (Bergen material) and to 10.3 mm at 82.0 mm HL (Belfast material).

Nasion — Nasal Line (*n—sp'*) (*36*) (*Fig. 12*). The anterior height of the upper face measured along the n—gn line. This measurement increases from 2.9 mm (Bergen material) and 3.6 mm (Belfast material) at 20.0 mm HL, to 15.7 mm at 89.5 mm HL (Bergen material) and to 13.3 mm at 82.0 mm HL (Belfast material).

Posterior nasal spine — Nasion Sella Line (*pns—NSL*) (*37*) (*Fig. 13*). The posterior height of the upper face measured along a perpendicular to NSL through pns. This measurement increases from 2.6 mm (Bergen material) and 2.7 mm (Belfast material) at 20.0 mm HL to 12.5 mm at 89.5 mm HL (Bergen material) and 11.0 mm at 82.0 mm HL (Belfast material).

Correlations. The correlation coefficient (r) has been used to express the relationship between the examined pairs of variables in both the Bergen and Belfast materials, see Tables I and II.

DISCUSSION

In this study four angular and light linear measurements have been used to examine differential direction of growth of the upper face.

The angular relationship between the Septal Line and the Anterior Cranial Base Line (SL—ACBL) did not reveal any significant changes during the foetal period investigated. The angle SL—PCBL however showed rather

Table I.

Correlations between the variables in the upper face

	Group	n	lsp-NSP	NL-NSL	ss-n-s	n-sp'	ss-pns	ss-sut. pal.	pns-NSP	ss-NSP
lsp-NSP	Bergen Belfast	87 72					0.99 0.99			
ss-n-s	Bergen Belfast	87 72	0.69 0.50	-0.39			0.68 0.47	0.67 0.47	0.70 0.56	0.70 0.51
pns-NSL	Bergen Belfast	87 72				0.98 0.96				
ss-sut. pal.	Bergen Belfast	87 72					0.99 0.99			
pns-NSP	Bergen Belfast	87 72					0.94 0.91			
sut. pal. -NSP	Bergen Belfast	87 72					0.96 0.95			
SL-ACBL	Bergen Belfast	87 72		0.50 0.65	-0.41		-0.30			-0.31
SL-acbp	Bergen Belfast	87 72				0.98 0.98				
SL-pr	Bergen Belfast	87 72				0.97 0.93				
ss-NSP	Bergen Belfast	87 72					0.99 0.99			

similar behaviour to the angle ACBL—PCBL namely an initial increase in the angle, followed by a decrease and finally a gradual increase toward the end of the period. The overall increase in the angle in the period investigated were 14.2 (Bergen material) and 20.4° (Belfast material). These findings seem to indicate that the septal plane is stable in its angular relationship to

Table II.

Correlations between the variables in the upper face and the lower face

	Group	n	lsp-NSP	n	NL-NSL	n	ss-n-s	n	n-sp'	n	ss-pns	n	ss-sut. pal.	n	SL-ACBP	n	ss-NSP
sp'-gn	Bergen Belfast					87 72	0.62 0.41	87 72	0.95 0.92								
sm-n-s	Bergen Belfast			87 72	-0.58 -0.44									87 72	-0.33		
ss-n-sm	Bergen Belfast	87 72	0.65 0.54	87 72		87 72	0.60 0.49			87 72	0.67 0.57	87 72	0.66 0.54			87 72	0.65 0.53
ML-NL	Bergen	80	0.32					80	0.32	80	0.30	80	0.36			80	0.31

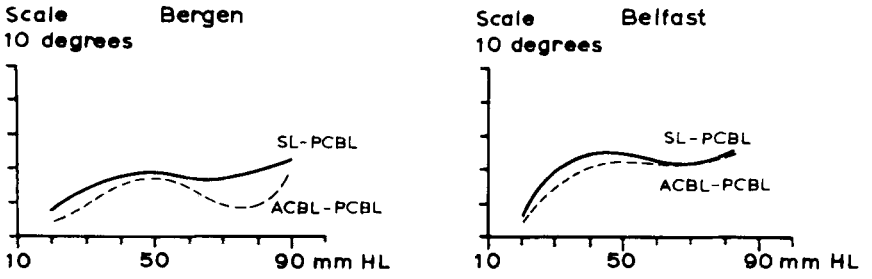

Fig. 14. Curves comparing the angular changes that take place between the anterior and posterior cranial base (ACBL — PCBL) and between the Septal Line and the posterior cranial base (SL — PCBL).

the anterior cranial base (ACBL) and changes its angular relationship with the posterior cranial base in conjunction with the anterior cranial segment (Fig. 14).

The angle between the Nasal Line and the Nasion Sella Line (NL—NSL) i.e. the angle indicating the relationship between the anterior and posterior height of the upper face, showed certain characteristic changes in the foetal period under investigation. Initially the angle increased (between 20.0 mm and 40.0 mm HL in the Bergen material and between 20.0 mm and 50.0 mm HL in the Belfast material), this was then followed by a decrease in the angle towards the end of the period. The overall increase in the angle between 20.0 mm and 89.5 mm HL (Bergen material) and between 20.0 mm and 82.0 mm HL (Belfast material) was only 1.0° and 0.2° respectively.

It would seem from these findings that the Nasal Line (NL) ultimately follows the same trend as the anterior cranial base and nasal septum in their angular behaviour to the posterior cranial base.

The initial increase in the angle NL—NSL could possibly be explained by the restraining action of the circummaxillary bony components, especially the zygomatic bone, which could account for the lagging behind of the maxilla and palatine bones in following suit with the anterior cranial base and nasal septum in their angular relationship to the posterior cranial base.

The angle (ss—n—s) expressing the prognathic development of the upper jaw in relationship to the Nasion Sella Line (NSL) showed an overall increase in the period, 6.8° for Bergen and 14.8° for Belfast. In the Bergen material there was an initial reduction of the angle between 20.0 mm and 30.0 mm HL from 84.4° to 77.7°. This reduction seems to correspond with the early period when the angle NL—NSL is showing an increase. This could explain the reduction in the angle ss—n—s between 20.0 mm and 30.0

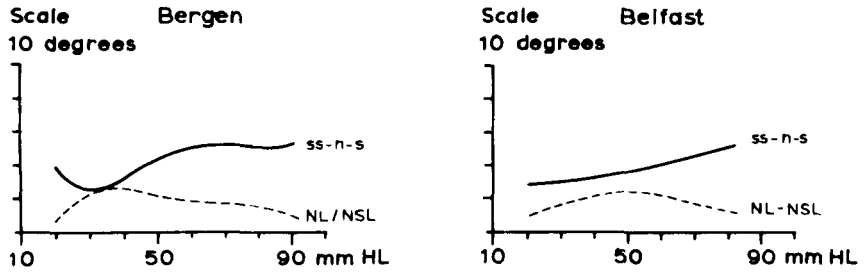

Fig. 15. Curves comparing the developmental relationship between the angles Subspinale Nasion Sella (ss — n — s) and the Nasal Line to the Nasion Sella Line (NL — NSL).

mm HL in the Bergen material, namely by a relative posterior rotation of the upper jaw (Fig. 15).

In the Belfast material, however, this initial reduction of the angle ss—n—s was not found. The reason for this is not obvious, but it could possibly be explained by the sources of error inflicted upon the Belfast material in the preparation of histological sections.

A positive correlation was found between NL—NSL and SL—ACBL and a negative correlation between ss—n—s and SL—ACBL and between ss—n—s and NL—NSL in the Bergen material (Table I) suggesting that NL and SL are showing relatively equal behaviour to the anterior cranial base and both are probably associated with the prognathic development of the upper face in that a posterior rotation of NL and SL in relation to the anterior cranial base will lead to a reduction in the ss—n—s angle, whereas an anterior rotation with a corresponding reduction in the angles NL—NSL and SL—ACBL will lead to an increase in the ss—n—s angle.

This is in agreement with previous findings on juvenile and adult material, *Björk* (1947), *Lindegård* (1953), *Hasund* (1966) who all found association between the degree of maxillary prognathism and the angle NL—NSL, a large ss—n—s angle was found in association with a small NL—NSL angle. Furthermore, the angle ss—n—s is positively correlated to ss—pns, ss—NSP, ss—sut.pal. and lsp—NSP (Table I), showing that upper facial prognathism is also associated with the length and also with the relative forward position of the upper jaw and nasal septum in relationship to Sella (s).

In the Bergen material there is a small negative correlation between SL—ACBL and ss—pns and between SL—ACBL and ss—NSP suggesting the possibility of an association between a large SL—ACBL angle and a short and relatively posteriorly positioned upper jaw.

ss—n—s is positively correlated to ss—n—sm (Table II), suggesting as

would be expected that increased upper facial prognathism is often associated with distal basal relationship between the two jaws.

The ss—n—sm angle is furthermore positively correlated to ss—pns, ss—sut.pal., ss—NSP and lsp—NSP (Table I) indicating that the basal relationship between the upper and lower jaws (described by the ss—n—sm angle) is among other factors dependent on the length and the antero-posterior position of the upper jaw.

The length of the maxillary base ss—pns increased by 16.6 mm (Bergen material) and 15.1 mm (Belfast material) in the period under investigation. The distance ss to the maxillary transverse suture, ss—sut.pal. increased by 12.6 mm and 12.2 mm in the Bergen and Belfast material, indicating that the maxillary part of the bony palate increases more in length than the horizontal process of the palatine bone during foetal life.

To measure the relative forward growth of the facial complex in relationship to Sella (s) several of the facial points were measured from the Nasion Sella Perpendicular (NSP). The antero-posterior relationship of the most posterior point of the bony palate to Sella, pns—NSP showed an increase of 8.1 mm (Bergen material) and 7.7 mm (Belfast material) while sut.pal.—NSP in the same period showed an increase of 12.1 mm (Bergen material) and 10.0 mm (Belfast material). From this it would seem as if the transverse maxillo-palatine suture is shifted forward in relationship to Sella during foetal life from a relatively more posterior position in early embryonic life to a relatively more anterior position in later embryonic life. Similar findings have been reported in the decidions dentition (*Aitchison,* 1950). The antero-posterior relationship of the most anterior part of the maxillary base, ss—NSP showed an increase of 24.5 mm (Bergen material) and 22.2 mm (Belfast material). These findings suggest that appositional growth on the anterior surface of the maxilla is probably as important in the forward growth of the upper jaw as the growth at the suture between the horizontal process of the maxilla and palatine bones, unless growth in this suture is primarily in a maxillary direction, an assumption which is rather unlikely since this suture is shifted forward during foetal development.

It furthermore shows that the maxilla is carried forward in relation to Sella to a degree which cannot be accounted for by growth of the maxilla alone. The anterior growth of the nasal septum has been measured by the dimension lsp—NSP. This measurement showed an increase of 26.2 mm (Bergen material) and 25.0 mm (Belfast material) in the period under investigation. In all foetal stages the lower septal point (lsp) was found to be anterior to the Anterior Nasal Spine (ans).

Although the present study seems to exhibit parallelism between angular

behaviour of the nasal septum and the hard palate, and between the forward growth of the nasal septum and the upper jaw, recognition of the cartilagenous nasal septum as the absolute causal agent in this growth process is beyond the scope of this study.

Regarding the vertical growth of the upper face *Brodie* (1941), *Herzberg* and *Holic* (1943) and *Wylie* (1944) have all stated that the upper facial height, is quite constant from birth to maturity, 43 per cent of the total facial height.

Levihn (1961) found that upper facial height was reduced from 47 per cent of total facial height in early prenatal life, to 41—42 per cent in the later periods. *Burdi* (1965) measuring the perpendicular height from ans and pns to NSL found the anterior height to increase more than posterior height during foetal life. *Ford* (1955) stated that septum height had the same growth rate as the prechordal part of the cranial base, it increased six to sevenfold between 10—40 weeks of intrauterine life.

In the present study the anterior height of the upper face n—sp increased by 12.8 mm (Bergen material) and 9.7 mm (Belfast material) while the posterior height of the upper face, pns—NSL increased by 9.9 mm and 8.3 mm in the Bergen and Belfast materials respectively. This is in agreement with Burdi's findings.

The correlation analysis shows a strong association between the various horizontal linear measurements within the upper face and the same is the case with the vertical linear measurements (Table I).

Furthermore, the horizontal linear measurements ss—pns, ss—NSP, ss—sut.pal., lsp—NSP and pns—NSP all show positive correlation to the ss—n—s angle (Table I) indicating that an increase in length of the upper jaw and nasal septum and a relative forward position of the upper jaw seems to contribute nearly equally in the relative prognathic relationship of the upper face.

The same horizontal linear measurement also show positive correlation to ss—n—sm and a small positive correlation to ML—NL (Bergen material) (Table II). This suggests a relationship between the relative length and antero-posterior position of the upper jaw and the basal relationship between the upper and lower jaws. It furthermore indicates that a long upper jaw is associated with an increased maxillary mandibular plane angle, ML—NL.

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