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THE SAGITTAL GROWTH OF THE FOETAL CRANIAL BASE

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There is an increase in the angular relationship between the anterior and posterior cranial components in foetal life. The angular changes taking place seem to occur in the region of the sphenoethmoidal junction. The spheno-occipital element of the cranial base showed stability during foetal life, whereas the spheno-ethmoidal part of the cranial base angles increased in the corresponding period. A large angle in any one of the cranial base angles is followed by large angles in the rest of the cranial angles. A large cranial base angle is followed by a large anterior total facial height and a relatively posterior rotation of the upper jaw, retrognathic lower face and a relatively posterior rotation of the lower jaw. The growth of the anterior cranial base is more active than the growth of the posterior cranial base. The ethmoidal and sphenoidal parts of the anterior cranial base contribute equally to the increase in length. A long anterior cranial base is followed by a large spheno-ethmoidal angle and relatively long upper and lower jaws, upper jaw prognathism, large anterior facial height and a posterior rotation of the lower jaw.

The cranial base from foramen magnum to the region of the foramen coecum is preformed in cartilage which is continuous with the cartilage of the nasal capsule, the latter including the cartilage of the nasal septum. In man the cranial base shows a higher degree of flexure than in any other animal and it has been stated that the gradual decrease in the size of the angle between the prechordal and chordal parts of the cranial base from lower mammals to man gives a good indication of the gradual increase in the development of the frontal lobes of the brain (*Duckworth,* 1904). *Dabelow,* (1931), *Stadtmüller* (1943) and *Kummer* (1952) have expressed the view that the increasing sagittal flection of the cranial base with age is mainly due to growth of the hemispheres. Various areas of the cranial base have been proposed as the site of this flexure in the past, for instance the sphenooccipital synchondrosis

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(*Björk*, 1955), the sphenoethmoidal suture (*Huxley*, 1867), the region of the pituitary fossa (*Cameren*, 1924) or the synchondrosis between the pre- and post-sphenoid elements of the body of the sphenoid bone (*Ashton*, 1957, *Scott*, 1958). *Björk* (1947) and *Lindegård* (1953) found in young and adult material association between the flexion of the cranial base and facial prognathism, a large cranial base angle was found in retrognathic face. Furthermore *Björk* (1947), *Lindegård* (1953), *Solow* (1966) and *Hasund* (1966) showed that the prognathic face has a relatively small anterior facial height and the facial planes are nearly parallel, while retrognathic faces have a large anterior facial height, and the facial planes converge posteriorly. *Ford* (1955), *Levihn* (1967) and *Kvinnsland* (1967, 1969) described an opening out (flattening) of the cranial base during human foetal life. *Ortiz* and *Brodie* (1949) examining a small number of infants from birth to three months of age found that at birth and up to the third month postnatally the anterior segment of the cranial base was larger than the posterior segment, and grew at a slightly greater rate. In the same infants they found that the posterior cranial segment increased at such a slow rate that it did not lend support to the generally accepted idea that the spheno-occipital junction is an important growth centre. *Brodie* (1941) studied the growth of the human head from the third month to the eight year in 21 children and he found that the anterior segment of the cranial base was longer than the posterior segment at six months, the rate of increase thereafter being practically equal. *Ford* (1958) stated that the dimension Sella to foramen coecum did not increase after the eruption of the first permanent molars, and the increase in the distance after this age should be wholly accounted for by increase in thickness of the frontal bone. Previous studies on human foetal material have revealed a progressive increase in length of the anterior cranial base over the posterior cranial base (*Ford*, 1955, *Burdie*, 1965; *Levihn*, 1967).

The present investigation is a metric anthropological and roentgen-anatomical study of the cranial base in its sagittal growth process. Cephalometric landmarks, angles and reference lines 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.

MATERIAL AND METHODS

The present study relates to foetuses belonging to the Institute of Anatomy, University of Bergen (the Bergen material) and the Anatomy Department, Queen's University of Belfast, Northern Ireland (Belfast material). The distinction Bergen material and Belfast material does not primarily refer to nationality or different ethnic groups, but to different techniques used in preparation of the materials for measurements.

The Bergen material includes 87 human foetuses. The material was selected for this study according to the following criteria.

1) Only specimens showing very satisfactory fixation (Streeter's grade 1) (*Streeter*, 1920) were accepted. Accordingly specimens showing any degree of wrinkling, shrinkage or unsatisfactory fixation (Streeter's grade 2 or 3) were discarded.
2) Specimens with any signs of serious face laceration, either due to obstetrical instrumentation or otherwise were discarded.
3) All specimens had to have contact between the upper and lower lips (closed mouth) and contact or near contact between the dorsum of the tongue and the hard palate, thus ensuring the nearest possible normal individual relationship between the upper and lower jaws in each specimen.

Foetal material reaching the Institute of Anatomy, University of Bergen had already been preserved in fixative by the sender, Most of the material was preserved in Bouin's fluid, the remaining few in 4 % formalin. *Scammon* and *Calkins* (1929) found the dimensional changes due to formalin fixation to be variable in human foetuses but generally noticed a 1 % increase in size using 10 % formalin. The dimensional changes due to Bouin fixation are stated to be even less than that of formalin (*Baker*, 1958). Preserving fluids generally swell the soft tissues slightly. In this study the error can be considered to have an insignificant influence upon proportions, especially the cartilagenous and osseus portions studied here. The foetuses selected for this study were decapitated and sectioned parasagittally immediately lateral to the nasal septum in order to demonstrate the mid-line anatomical relationships of the cranial base, nasal septum, upper and lower jaws (Fig. 1). Under a stereomicroscope the various reference points were defined accurately by micro-dissection. All linear and angular measurements were made by placing transparent processed Kodalith Ortho Safety film (guaranteed to be moisture and temperature stable) on the cut surface of the sagittally sectioned skull and tracing the points required for each linear measurements or angle on to the film under the stereomicroscope with a sharp tracing pen. The centre of the dots were used for measurements. The results of the angular measurements are given in degrees, of the linear measurements in mm. Linear dimensions were measured to the nearest 0.5 mm and angles to the nearest 0.5°. For landmarks lateral to the midsagittal plane a roentgenographic method with contrast medium was used as follows: the various

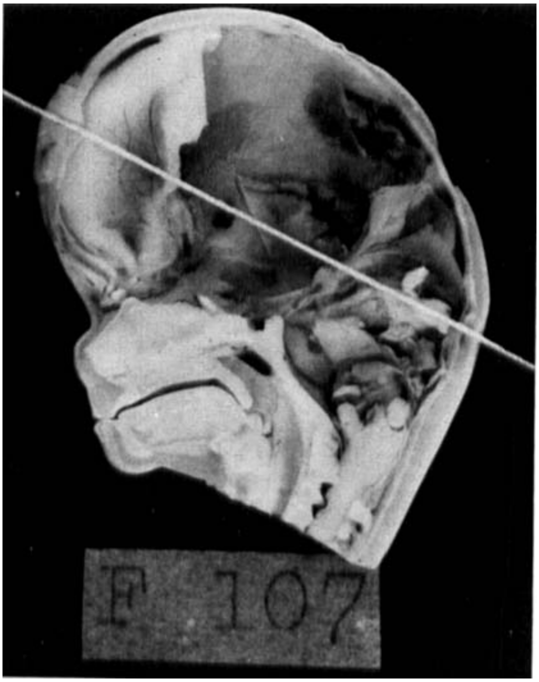

Fig. 1. Sagittal section of human foetal head. Occipito Frontal diameter (HL) is 21.0 mm.

reference points were defined by dissection under a stereomicroscope and a thin mixture of Barium Sulphate was applied to the reference points as a small dot with a sharp dental probe. The contrast points were made as small as possible and were applied under a stereomicroscope. The sagittally sectioned head was then radiographed with the sagittal plane lying directly on to the surface of the film (Fig. 2).

The Belfast material includes sagittally sectioned histological slides 15 μ in thickness of 72 human foetal heads. Most of the sections were stained with Heamatoxylin and Eosin and a few with Masson's trichzome, the total material had previously been preserved in 4 % formalin. From each foetal series of sections the slide nearest the midline sagittal plane was selected, the criterion here being that the whole of the nasal septum and cranial base should be clearly distinguishable (Fig. 3). Under a stereomicroscope the various reference points were defined and traced on to processed Kodalith Ortho safety film which was placed on the sagittal section.

In this study the Occipito Frontal diameter (Head length) (HL) has been used in assigning the developmental stage. The Occipito Frontal diameter

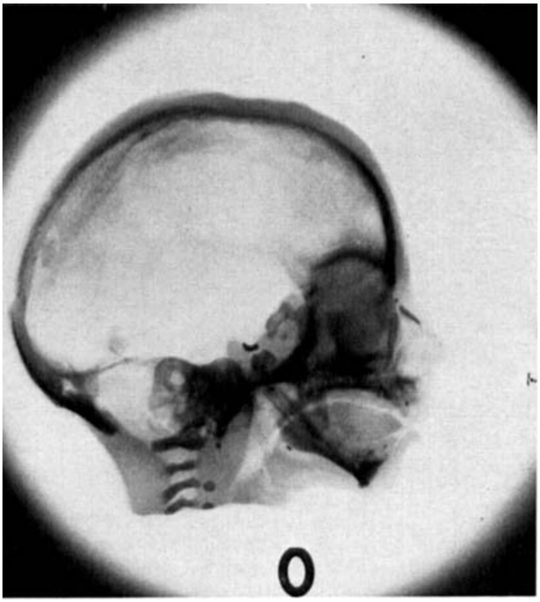

Fig. 2. Radiograph of sagittally sectioned head. Occipito Frontal diameter (HL) 63.0 mm. Contrast medium Barium sulphate.

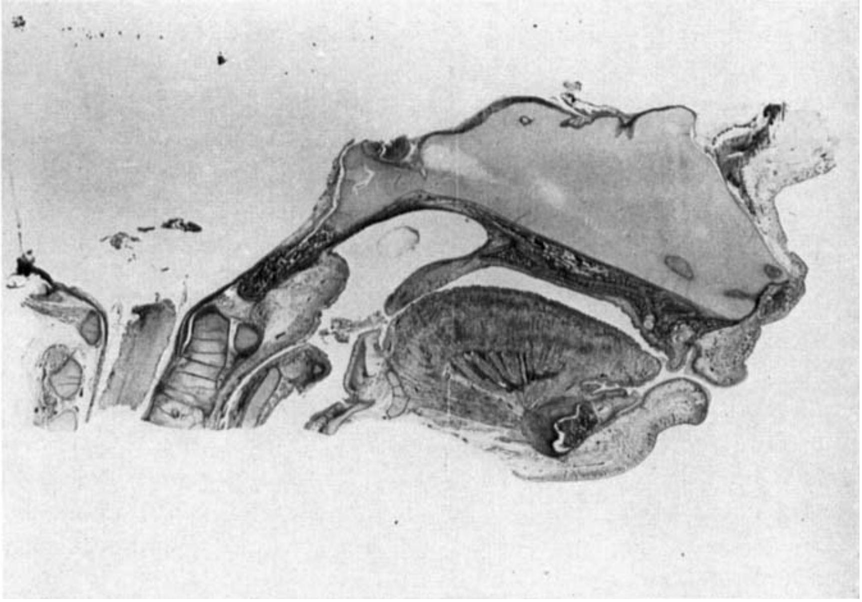

Fig. 3. Sagittal section 15 μ in thickness, of foetal face and cranial base. Occipito Frontal diameter (HL) is 52.5 mm.

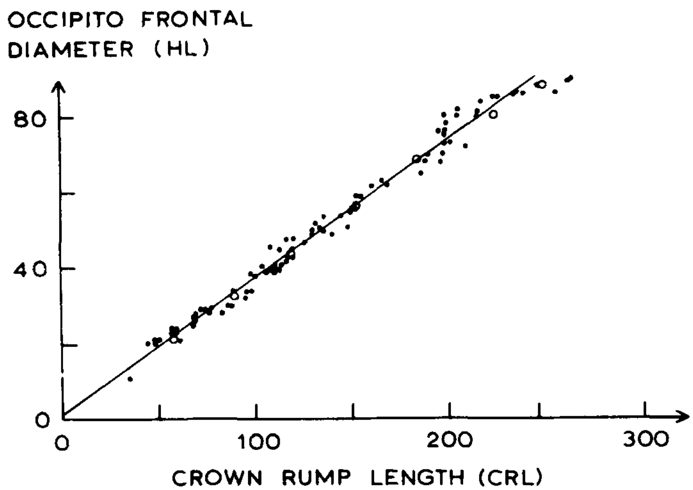

Fig. 4. Comparison between CRL (crown rump length) and HL (Occipito Frontal diameter) in Scammon and Calkins material (1929) and the Bergen material (1969).
○ Scammon and Calkins material (369 specimens)
· Bergen material (87 specimens)
The correlation index (rm) between HL and CRL in the Bergen material was 0.99.

(HL) represents the distance in a straight line from the glabella to the inion or external occipital protruberance, soft tissue included. *Scammon* and *Calkins* (1929) related the Occipito Frontal diameter to both Crown Heel length and to the Crown Rump Length in 369 foetuses and found good association between these body measurements (see Fig. 4). For the purpose of this study therefore the Occipito Frontal diameter (HL) has been considered as a simple function of the developmental stage rather than the actual age of the specimen. Chronologically the total material (Bergen and Belfast) of 159 foetuses represents Occipito Frontal diameters from 20 mm to 89.5 mm. This corresponds to Crown Rump lengths of approximately 43 mm to 263 mm which again corresponds to approximate foetal ages of 10 to 32—33 weeks.

This study was performed in order to clarify certain quantitative and qualitative changes occurring in the cranial base and face in the midsagitta-plane during foetal life. With this in mind all the variables have been correlated to the Occipito Frontal diameter (HL). A polynomic regression equation has been used varying from second to fourth degree (*Kendall & Buckland* 1960). Where the different variables have been correlated toward each other, a linear regression equation has been used.

The error of method in the present investigation seems to adhere fairly closely to corresponding studies previously done on adult and juvenile

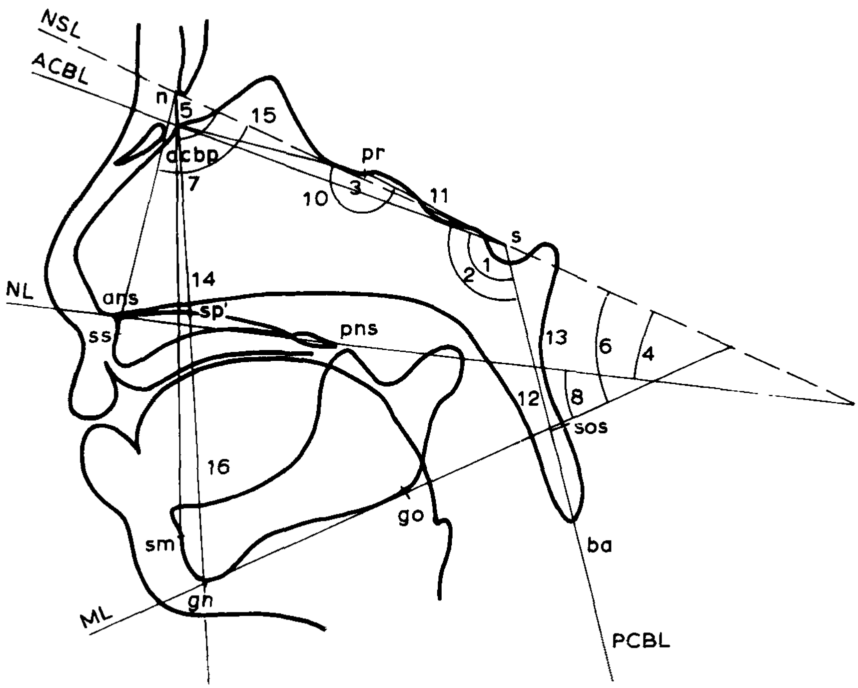

Fig. 5. Reference points, reference lines, angular and linear measurements.

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 mid-sagittal plane (M.S.P.) n — Nasion: point of intersection of the most caudal point on the frontal bone and the M.S.P. pr — Prosphenion: the intersection between the M.S.P. and the junction between the ethmoid and sphenoid elements of the cranial surface of the anterior cranial fossa. s — Sella: the center of the sella turcica in the M.S.P. ba — Basion: Intersection of the M.S.P. and the anterior border of the foramen magnum. ans — Anterior nasal spine. pns — Posterior nasal spine. ss — Subspinale: point on the M.S.P. where the antero-inferior contour of the anterior nasal spine merges with the maxillary alveolar process. sos — Spheno-occipital synchondrosis. Point of intersection between the M.S.P. and the most cranial point on the ossified part of the basi-occipital bone. sm — Supramentale: point in the M.S.P. where the antero-superior contour of the mandibular symphysis merges with the mandibular alveolar process. gn — Gnathion: the lowest point in the mandibular symphysis in the M.S.P. go — Gonion. The point on the contour of the mandibular angle decided by halving the tangent angle. sp' — point of intersection between the Nasal line (NL) and a line between n and gn 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 ans and pns. ML — Mandibular Line: a line through gn and go. ACBL—PCBL (1) the angle between the anterior and posterior cranial base lines. pr-s-ba (2) the angular relationship of the spheno-occipital element of the cranial base. acbp-pr-s (3): the angular relationship of the spheno-ethmoidal elements of the anterior cranial base. acbp-s (10): the pre-Sellar length of the anterior cranial base. pr-s (11): the pre-Sellar length of the Sphenoid part of the anterior cranial base. s-ba (12): the length of the posterior cranial base. s-sos (13): the post-Sellar length of the sphenoid element of the posterior cranial base.

material (*Björk*, 1947; *Bergland*, 1963; *Hasund*, 1969). For reference points, reference lines, angles and linear measurements used in this investigation the reader is referred to Fig. 5.

RESULTS

Developmental changes

All variables have been correlated to the Occipito Frontal diameter (HL). The relationship between the Occipito Frontal diameter (HL) and the various variables have been expressed in terms of the correlation index (r_m). For all the measurements a polynomic regression equation has been used varying from 1st. to 4th. degree depending on which value of rm gives the best possible description of association between the variables in cases where this is an improvement on linear regression equation. The regression equation used is stated for each individual variable in the scatter diagrams. A correlation index value (r_m) of 0.50 has been selected as the lowest value to express a significant association. Where $r \geqq 0.50$ a regression line has been drawn on the scatter diagrams. The abscissa always denotes the Occipito Frontal diameter (HL).

Angular measurements

Anterior Cranial base — Posterior cranial base (*ACBL—PCBL*) (*1*) (Fig. 6). This angle shows a general tendency to open out in the period under investigation starting off with an estimated value of 124.1° at 20.0 mm HL in the Bergen material and 121.7° in the Belfast material. The angle shows an increase up to about 50 mm HL, 134.7° for the Bergen material and 139.7° for the Belfast material followed by a gradual decrease to about 70 mm HL, again followed by an increase to 138.2° at 89.5 mm HL for the Bergen material and 138.7° at 82.0 mm HL for the Belfast material.

Prosphenion-Sella-Basion (*pr-s-ba*) (*2*) (*Fig. 7*). The angular relationship of the spheno-occipital element of the cranial base. The characteristic feature of this angle is great individual variation but no apparent significant correlation to the developmental stage of the foetus.

Anterior cranial base point-Prosphenion-Sella (*acbp-pr-s*) (*3*) (*Fig. 8*). The angular relationship of the spheno-ethmoidal element of the anterior cranial base. The angle shows a well marked increase in the period, from an estimated value of 148.8° (Bergen material) and 149.5 (Belfast material) at 20.0

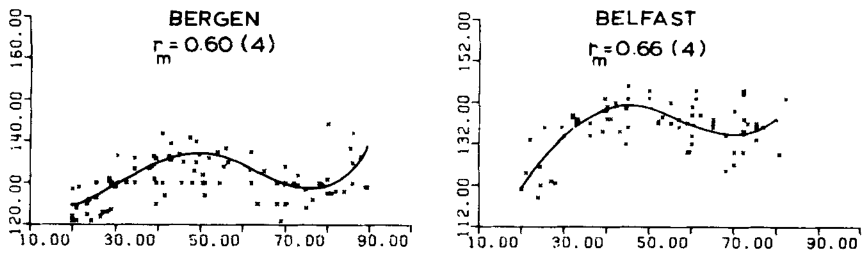

Fig. 6. Development changes in the angle ACBL—PCBL.

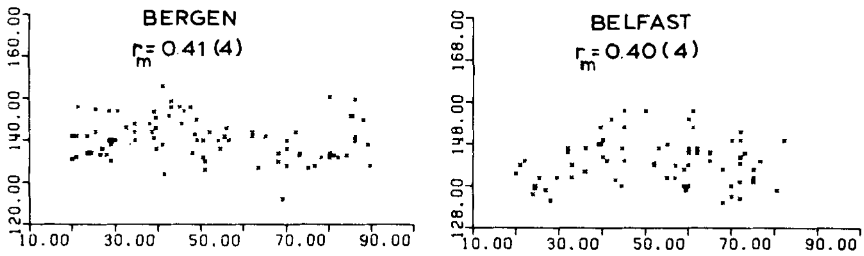

Fig. 7. The relationship between the angle pr-s-ba and HL.

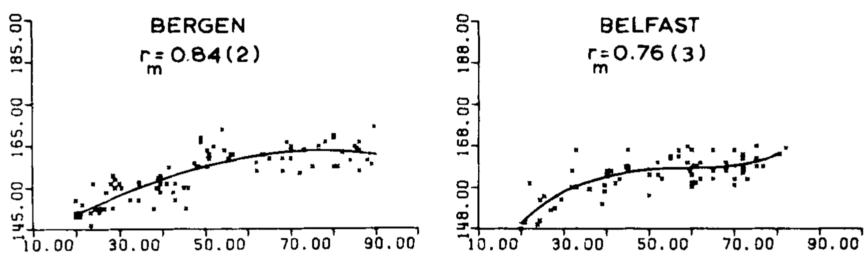

Fig. 8. Developmental changes in the angle acbp-pr-s.

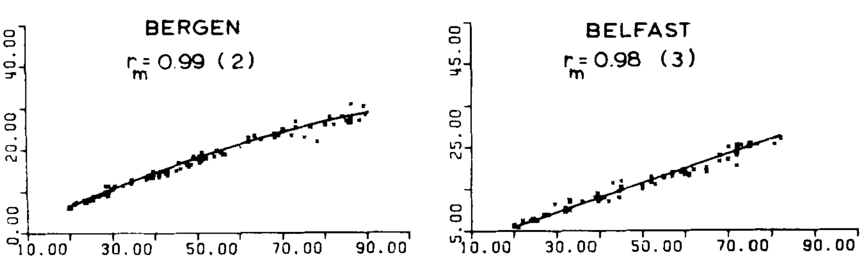

Fig. 9. Linear increase in the acbp-s length.

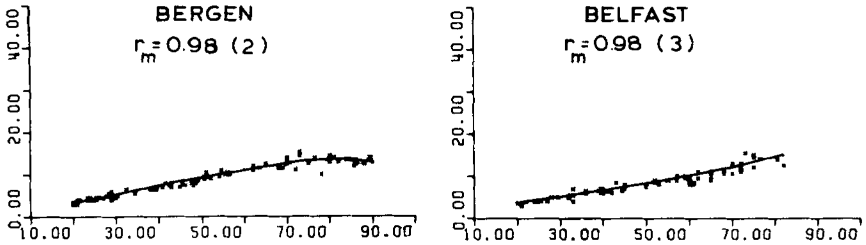

Fig. 10. Linear increase in the pr-s length.

mm HL to 163.2 at 89.5 mm HL (Bergen material) and 166.0° at 82.0 mm (Belfast material).

Linear measurements

Anterior cranial base point-Sella (*acbp-s*) (*10*) (*Fig. 9*). The pre-sellar part of the cranial base increases in length from an estimated value of 6.3 mm (Bergen material) and 6.1 mm (Belfast material) at 20.0 mm HL to 28.6 mm at 89.5 mm HL (Bergen material) and 27.8 mm at 82.0 mm HL (Belfast material).

Prosphenion-Sella (*pr-s*) (*11*) (*Fig. 10*). The pre-Sellar part of the sphenoid element of the cranial base shows an increase from 3.0 mm (Bergen material) and 3.3 mm (Belfast material) at 20.0 mm HL to 13.0 mm at 89.5 mm HL (Bergen material) and 14.8 mm at 82.0 mm HL (Belfast material).

Sella-Basion (*s-ba*) (*12*) (*Fig. 11*). The posterior cranial base increases from 6.2 mm (Bergen and Belfast materials) at 20.0 mm HL to 18.7 mm (Bergen and Belfast materials) at 89.5 mm HL and 82.0 mm HL respectively.

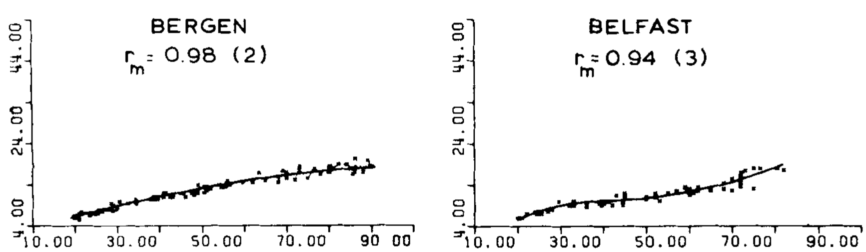

Fig. 11. Linear increase in the s-ba length.

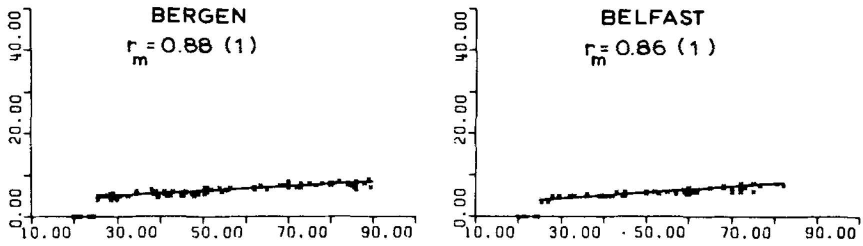

Fig. 12. Linear increase in the s-sos length.

Sella-Spheno-occipital-synchondrosis (*s-sos*) (*13*) (*Fig. 12*). The post-Sellar part of the sphenoid element of the cranial base shows a small increase in the foetal period investigated, from 4.7 mm and 4.2 at 25.5 mm HL (Bergen and Belfast materials respectively) to 8.2 mm at 89.5 mm HL (Bergen material) and 7.5 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

Table I.
Correlations between the variables in the cranial base

	Group	n	ACBL-PCBL	acbp-pr-s	acbp-s	n-s
NSL-PCBL	Bergen Belfast	87 72	0.97 0.99	0.32 0.46		
pr-s-ba	Bergen Belfast	87 72	0.75 0.82			
acbp-pr-s	Bergen Belfast	87 72	0.37 0.48		0.80 0.69	0.80 0.69
acbp-pr-ba	Bergen Belfast	87 72	0.71 0.78	0.85 0.88	0.75 0.61	0.75 0.61
acbp-s	Bergen Belfast	87 72		0.80 0.69		
n-s	Bergen Belfast	87 72		0.80 0.69	0.99 0.99	
pr-s	Bergen Belfast	87 72			0.98 0.97	0.97 0.97
s-ba	Bergen Belfast	87 72			0.98 0.96	0.98 0.96
s-sos	Bergen Belfast	87 72			0.87 0.87	0.87 0.87

Table II.

Correlations between the variables in the cranial base and the upper face

	Group	n	ACBL-PCBL	NSL-PCBL	pr-s-ba	acbp-pr-s	n-s
lsp-NSP	Bergen Belfast	87 72				0.82 0.70	0.99 0.97
NL-NSL	Bergen Belfast	87 72	0.44 0.48	0.49 0.46			
ss-n-s	Bergen Belfast	87 72			-0.33 -0.22	0.53 0.44	0.64 0.53
n-sp'	Bergen Belfast	87 72	0.34 0.31	0.32 0.30			0.99 0.94
ss-pns	Bergen Belfast	87 72				0.82 0.70	0.99 0.97
ss-sut. pal.	Bergen Belfast	87 72				0.83 0.68	0.98 0.97
pns-NSP	Bergen Belfast	87 72				0.73 0.64	0.97 0.92
SL-PCBL	Bergen Belfast	87 72	0.83 0.84	0.83 0.84	0.53 0.61	0.51 0.55	
ss-NSP	Bergen Belfast	87 72				0.80 0.69	0.99 0.97

Table III.

Correlations between the variables in the cranial base and the lower face

	Group	n	ACBL-PCBL	n	NSL-PCBL	n	pr-s-ba	n	acbp-pr-ba	n	n-s
sp'-gn	Bergen Belfast									87 72	0.96 0.91
sm-NSP	Bergen Belfast									87 72	0.94 0.91
sm-n-s	Bergen Belfast	87 72	-0.58 -0.62	87 72	-0.66 -0.63	87 72	-0.47 -0.55	87 72	-0.32 -0.47		
ss-n-sm	Bergen Belfast	87 72	0.48 0.51	87 72	0.48 0.49			87 72	0.61 0.52		0.65 0.59
ML-NL	Bergen									80	0.31
po-co	Bergen									80	0.98
po-go	Bergen									80	0.96

Table IV.
Correlations between the variables in the total face, and between the variables in the total face and cranial base, upper face and lower face

	Group	n	acbp-pr-s	n	n-s	n	n-sp'	n	ss-pns	n	sp'-gn	n	ss-n-sm	n	ML-NSL
ACBL-PCBL	Bergen													80	0.30
NSL-PCBL	Bergen													80	0.37
n-sp'	Bergen													80	0.33
n-gn	Bergen Belfast	87 72	0.77 0.69	87 72	0.98 0.94	87 72	0.98 0.97	87 72	0.97 0.96	87 72	0.99 0.99	87 72	0.65 0.47	80	0.39
sp'-gn	Bergen													80	0.42
sm-n-s	Bergen													80	-0.57
ss-n-sm	Bergen													80	0.54
ML-NL	Bergen				0.31									80	0.91

materials. Owing to the fact that in this part of the investigation interest was concentrated on the smallest possible association between variables a correlation coefficient (r) of 0.30 was selected as the lowest limit, see Tables I—IV.

DISCUSSION

The present study demonstrated a gradual initial increase in the angular relationship between the anterior and posterior cranial components ACBL-PCBL. This initial increase of the angle (between 20.0 mm and 50.0 mm HL) was followed by a decrease in the angle between 50.0 mm and 70.0 mm HL followed again by an increase between 70.0 mm and 89.5 mm HL for the Bergen material and between 70.0 mm and 82.0 mm HL for the Belfast material. The total increase for the angle ACBL-PCBL in the period was 14.1° for the Bergen material and 17.0° for the Belfast material. The angular relationship of the spheno-occipital element of the cranial base pr-s-ba in the present investigation exhibited no significant correlation to the developmental stage of the foetus in either the Bergen or the Belfast material. This would indicate that the spheno-occipital element of the cranial base seems to be rather stable during foetal life. This finding agree with an earlier investigation (*Kvinnsland,* 1967). The spheno-ethmoidal part of the anterior cranial base acbp-pr-s was found to show an increase in the period under investigation opening out 14.4° between 20.0 mm and 89.5 mm HL in the Bergen material and 16.5° between 20.0 mm and 82.0 mm HL in the Belfast material. The angles pr-s-ba and acbp-pr-s have not been used by anthropologists on human foetuses in the past, and the present findings suggest that the angular changes that take place in the cranial base during foetal life occur in or near the region of the sphenoethmoidal junction (pr). *Augier* (1931) stated that the angular changes of the cranial base during foetal life were in all probability brought about mechanically by the expansion of the cranial contents. He further stated that if the mechanical force of brain expansion was absent or reduced as in anencephalus or microcephalus the angle between the prechordal and chordal parts of the cranial base often remained acute as in early foetal life. There is positive correlation between the cranial base angle ACBL-PCBL and pr-s-ba and ACBL-PCBL and acbp-pr-s (Table I). This would suggest that a large basicranial angle, ACBL-PCBL is followed by relatively large values in the rest of the cranial base angles. The basicranial angle ACBL-PCBL is positively correlated to NL-NSL and to n-sp' (Table II) in both materials indicating that a large cranial base angle is followed by a large anterior upper facial height and a relative posterior rotation of the upper jaw. This is in agreement with the general growth pattern preciously found in young and adult material (*Björk*, 1947; *Lindegård*, 1957; *Hasund*, 1966; *Solow*, 1966). Furthermore the cranial base angles ACBL-PCBL and pr-s-ba are negatively correlated to sm-n-s (Table III) in both materials and ACBL-PCBL is positively correlated to ML-NSL (Table IV) in the Bergen material, which indicates that an abtuse cranial base angle is associated with a retrognathic lower face and a relatively posterior rotation of the lower jaw. This is in agreement with *Lindegård* (1953) who found a strong positive association between the angle n-s-ba and the angle ML-NSL in adult material. No correlation was found between the angles ACBL-PCBL and ss-n-s (Table II). A positive correlation was found, however, between acbp-pr-s and ss-n-s and between acbp-pr-s and the horizontal dimensions of the upper face, and a negative correlation between pr-s-ba and ss-n-s in the Bergen material (Table II). This suggests that an angular increase in the anterior part of the cranial base acbp-pr-s is followed by an increase in the prognathic development of the upper jaw whereas an angular increase in the posterior part of the cranial base pr-s-ba is associated with reduced upper jaw prognathism. The anterior cranial base acbp-s was found to increase by 22.3 mm between 20.0 mm and 89.5 mm HL (Bergen material) and by 21.7 mm between 20.0 mm and 82.0 mm HL (Belfast material). The posterior cranial base s-ba was found to increase by 12.5 mm (Bergen and Belfast materials) in the same period, showing that the growth of the anterior cranial base is more active than the growth of the posterior cranial segment during foetal life. In considering the anterior cranial base as an ethmoidal and a sphenoidal part it was found that the sphenoid part of the anterior cranial base pr-s increased by 10.0 mm in the Bergen material (between 20.0 mm and 89.5 mm HL) and 11.5 mm in the Belfast material (between 20.0 and 82.0 mm HL). It would seem from these findings that the ethmoidal and sphenoidal parts contribute nearly equally to the increase in length of the anterior cranial base. The posterior cranial base, s-ba can also be considered to consist of two parts, a sphenoidal and an occipital part. In measuring the distance s-sos it was found that it increased only by 3.5 mm in the Bergen material and by 3.3 mm in the Belfast material in the period under investigation. This finding seems to agree with *Ortiz* and *Brodie* (1949) who found that the posterior cranial base increased at such a slow rate between birth and three months of age that it did not lend much support to the idea that the spheno-occipital junction is an important growth centre.

Koski (1968) giving a review of the literature is himself doubtful over the role of the spheno-occipital synchondrosis as an important growth centre in post-natal life, although hitherto this has been more or less universally accepted (*Baer*, 1954; *Baume*, 1961; *Björk*, 1955; *Salzman*, 1966; *Scott*, 1954). From the present findings it seems as if surface apposition is equally important, if not more so, than the spheno-occipital synchondrosis in the dimensional increase of the posterior cranial segment during foetal life. Further research, however, both in pre- and postnatal material is necessary before an ultimate answer to the importance of the spheno-occipital synchondrosis as a growth centre can be given. The linear dimensions of the cranial base are positively correlated to one another which reveals that an increase in one diameter is, as expected, followed by a corresponding increase in the others (Table I). Furthermore there is positive correlation between acbp-s and acbp-pr-s suggesting that a long anterior cranial base is followed by a large sphenoehtmoidal angle (Table I). The anterior cranial base length, acbp-s is also positively correlated to the horizontal dimensions of the upper and lower face indicating that increased anterior cranial base length is followed by long upper and lower jaws (Tables II and III). Furthermore n-s is correlated to ss-n-s (Table II) and to n-gn (Table III) in both materials and to ML-NL (Table III) in the Bergen material, indicating that a long anterior cranial base is also associated with a relative upper jaw prognathism, a large anterior facial height, posterior rotation of the lower jaw, and distal basal relationship between the upper and lower jaws.

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