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Cranial Base in Children with Lip and Palate Clefts

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The full extent of the malformation recognized as cleft lip and palate has not yet been determined. Clefts may be very localized defects, or as Wardill (*21*) concludes, they may be associated with 'widespread structural changes in other parts of the skull and, perhaps, even further afield'. Harvold (*9*) has demonstrated that the asymmetries of the facial skeleton in unilateral clefts were limited to the maxilla, with the zygomatic bones unaffected.

The cranial base is of particular interest because its growth pattern is mainly that of a cranial structure while being situated in close proximity to facial structures (*5, 7, 8, 15*). Subtelny (*19*), studying young children and infants, found no significant difference in one aspect of cranial base width between the control and the unoperated cleft group. The intra-foramina rotundum distance was the same despite a greater bihamular width in the cleft sample. He also noted that bizygomatic width was unaffected. Brader (*4*) found no difference between cleft and noncleft individuals using two angles within the cranial base. McNeill (*12*) noted that from birth to age six years the cranial base flexure and anterior cranial base length did not differ between cleft and normal groups, although the total cranial base length was less in the cleft palate series. He noted an early transient disproportion between the pre-sella and post-sella portion of the sphenoid bone which was resolved by six years of age.

Moss (*14*) claimed that there is a marked kyphosis of the sphenoid bone associated with clefts, a dysostosis sphenoidale. He considered this condition to be associated with a whole series of cephalic malformations and concluded that clefts of the lip and palate were part of this series differing only in degree, not in kind, from other cranial malformations.

The present study was designed to examine differences in the cranial base associated with clefts of the lip and palate as compared to noncleft individuals.

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Sample

The cleft sample consisted of 342 children with either unilateral cleft lip and palate, bilateral cleft lip and palate, isolated cleft palate, or isolated cleft lip. Since morphological changes in the cranial base associated with clefts might be expected to vary with the severity of the cleft, only complete clefts of each type were used. The single exception was the cleft lip group; the small number available made it necessary to include all of this type regardless of the completeness of the cleft.

The age, sex, and cleft type distribution of the sample is shown in Table 1. Since cranial base does not change appreciably after the age of 12 years, all subjects over 12 years of age were combined in one group. All had surgical repair of the clefts in infancy; none had orthodontic treatment or secondary palatal procedures such as pharyngoplasty.

Attendance at a hospital clinic tends to be from a lower socioeconomic section of the population. Assessing this factor with any degree of accuracy is difficult, although the public-private patient ratio is greater in this sample than in the hospital population as a whole.

Two hundred noncleft controls were chosen at random from the Burlington Orthodontic Research Centre in Burlington, Ontario. One source of bias in the noncleft group is a result of the slightly higher average socioeconomic level in Burlington as compared to the provincial level (*3*). Other sources of bias were investigated, but the cleft and

TABLE 1. Descriptive data for subjects for age, sex, and cleft type distribution.

Age	*Cleft Type*				*Total Cleft Group*			*Noncleft*		
	Lip Only	*Lip and Palate*		*Palate Only*	*Male*	*Female*	*Total*	*Male*	*Female*	*Total*
		Unilateral	*Bilateral*							
4	—	—	—	—	—	—	—	20	20	40
5	—	17	11	3	17	14	31	—	—	—
6	2	30	13	18	34	29	63	20	20	40
7	1	23	6	13	28	15	43	—	—	—
8	1	16	6	12	16	19	35	20	20	40
9	20	11	2	24	34	23	57	—	—	—
10	2	7	4	12	12	13	25	20	20	40
11	3	8	6	8	14	11	25	—	—	—
12	1	6	6	5	14	4	18	20	20	40
Older than 12	8	16	13	8	21	24	45	—	—	—
Male	20	90	42	38	190			100		
Female	18	44	25	65		152			100	
Total	38	134	67	103			342			200

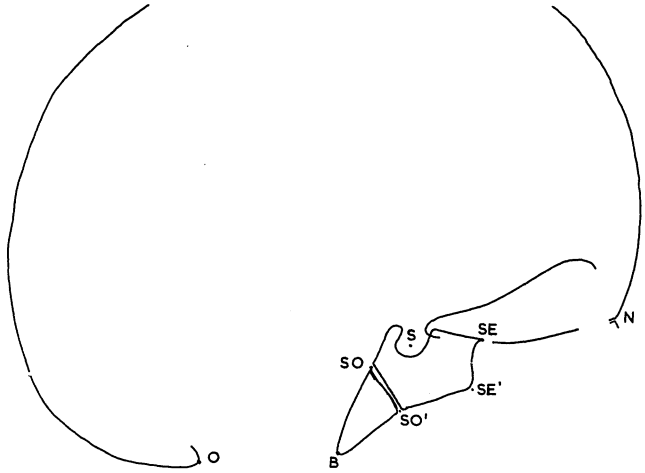

FIGURE 1. Tracing of lateral cephalometric x-ray film indicating the landmarks used for linear analysis.

noncleft samples appeared to be reasonably representative of the Ontario population from which they were drawn, with the exception of the divergent economic levels.

Method

Cephalometric x rays in the lateral view were used. Figure 1 shows the structures traced and labeled. The following points were located:

N: Nasion, the most anterior point of the naso-frontal suture.

SE: The superior point of the spheno-ethmoidal synchondrosis.

S: Sella turcica, the center of the hypophyseal fossa.

SO: The superior point of the spheno-occipital synchondrosis.

B: Basion, the most posterior and inferior point of the profile of the basi-occipital bone, forming the most anterior point of the foramen magnum.

O: Opisthion, the most posterior point of the foramen magnum.

SO′: The inferior point of the spheno-occipital synchondrosis.

SE′: A point marking the intersection of a line from *SO′* along the inferior surface of the body of the sphenoid with a line from *SE* along the anterior surface of the body of the sphenoid.

Figure 2 shows a tracing with the construction of the following planes:

Orbital Plane: A line which most closely approximates the superior surface of the orbital plates of the frontal bone, disregarding the lesser wings of the sphenoid and the anterior curved portion of the orbital plates.

Cribriform Plane: A line which most closely approximates the superior surface of the cribriform plate of the ethmoid.

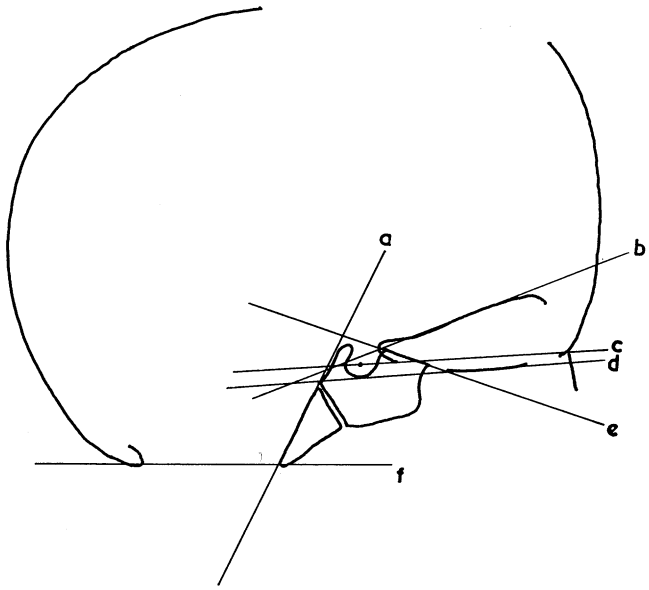

FIGURE 2. Tracing of lateral cephalometric x-ray film with the construction lines used to represent planes superimposed: a, clivus; b, orbital plane; c, S-N plane; d, cribriform plane; e, planum sphenoidale; and f, foramen magnum plane.

Planum Sphenoidale: A line which most closely approximates the superior surface of the body of the sphenoid anterior to the optic fossa.

SN: A line joining sella and nasion.

Clivus: A line which most closely approximates the cranial surface of the occipital bone anterior to the foramen magnum.

Foramen Magnum Plane: A line joining basion and opisthion representing the plane of the foramen magnum.

Seven linear measurements (Figure 1) were made to the nearest 0.5 mm: N-SE, SE-S, S-SO, SO-B, SE-SE′, SO-SO′, SO′-SE′.

These measurements were used to determine:

Anterior cranial base length: N-SE plus SE-S.

Posterior cranial base length: S-SO plus SO-B.

Cranial base length: Anterior cranial base plus posterior cranial base.

Sphenoid component of cranial base: SE-S plus S-SO.

Perimeter of sphenoid: The sum of five measurements which approximate the pheriphery of the sphenoid; namely, SE-S, S-SO, SO-SO′, SO′-SE′, and SE′-SE.

In an attempt to evaluate size differences, cranial base length was related to cranial length in a representative sample from each group consisting of 55 six-year-old children with clefts and 30 six-year-old children without clefts.

To determine the angular relationships within the cranial base, clivus was used as a base line (Figure 2), and the angles made by the inter-

section with clivus of the following lines: orbital plane, cribriform plane, planum sphenoidale, SN, and foramen magnum were measured to the nearest 0.5°.

Findings

A preliminary analysis of the data indicated that those with clefts of the lip and anterior maxilla only were more similar to the noncleft controls than to the lip-and-palate and palate-only samples, and these 38 individuals were kept separate in further analyses. When referring to the 'cleft group' therefore, reference is made to the combined lip-and-palate (unilateral and bilateral) and palate-only groups.

CRANIAL BASE-LINEAR. Table 2 presents data for the comparison on the cranial base length at each age level between the two groups. If interpolated for the ages not included, the values for the noncleft controls are consistently larger than the cleft group. The difference is approximately 3.5 mm. However, when cranial base length is expressed as a proportion of cranial length, no significant difference between the cleft and noncleft groups is found (mean proportion for the cleft group, 0.566; mean proportion for the noncleft group, 0.569; $t = 0.149$).

The contribution of the *anterior* and *posterior* segment of the cranial base to the total length is illustrated in Figure 3. It is apparent that there is no real difference in proportion between the cleft and noncleft groups, although there appears to be more variability in the cleft group. There was no sex difference in these proportions.

The *sphenoid* component of the cranial base (SE-S plus S-SO) expressed as a proportion of the total cranial base length showed no differences for age or sex, with the mean proportion of 0.344 for the cleft group and the mean proportion of 0.333 for the noncleft sample.

TABLE 2. Means (in mm) and standard deviations for cranial base length.

Age	*Males*				*Females*			
	Noncleft		*Cleft*		*Noncleft*		*Cleft*	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
4	105.7	3.62			104.0	3.34		
5			105.1	4.23			101.7	3.66
6	110.8	3.85	108.7	6.40	107.8	2.80	103.7	3.32
7			108.2	2.72			105.8	5.04
8	113.3	4.35	110.8	4.90	109.5	4.15	105.7	3.96
9			110.8	5.09			105.1	3.78
10	117.0	3.90	114.2	4.44	113.7	3.29	109.2	5.15
11			116.7	6.22			114.8	4.19
12	120.6	3.76	115.4	4.26	118.6	4.17	115.4	5.63
Older than 12			121.2	6.89			113.5	5.15

FIGURE 3. Anterior cranial base length expressed as a proportion of total cranial base length versus age of subject. The solid line represents the noncleft sample; the interrupted line represents the cleft sample.

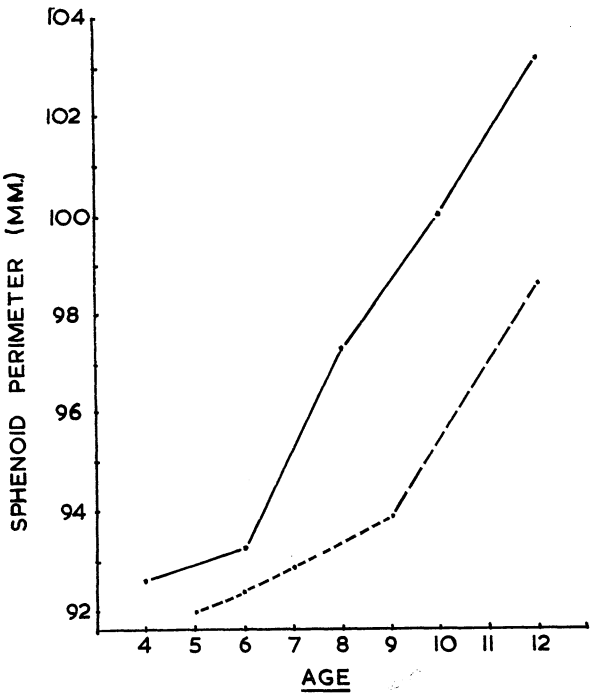

FIGURE 4. Perimeter of sphenoid bone versus age of subject. The solid line represents the noncleft sample; the interrupted line represents the cleft sample.

The data on the *perimeter* of the sphenoid bone is difficult to present and interpret. The values were extremely variable and were pooled to indicate the growth that must occur in individuals (Figure 4). There is the suggestion that pneumatization of the sphenoid bone in the group with clefts lags behind the normals.

Cranial Base-Angular. The angular measurements are presented in Table 3. The noncleft sample was subjected to a preliminary analysis of variance for age, sex, and interaction. This analysis indicated a sex

TABLE 3. Means, standard errors, and differences (in degrees) for cranial base angle. One asterisk indicates a significant difference at the 5% level; two asterisks indicate a significant difference at the 1% level.

Groups	*Clivus to Orbital Pl.*			*Clivus to Planum*		*Clivus to Cribriform*		*Clivus to For. Magnum*		*Clivus to SN*	
	N	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
Lip only	38	139.6	1.069	107.6	1.507	120.6	1.062	122.6	0.686	123.3	1.061
Palate only	103	139.4	0.641	107.4	0.840	118.7	0.689	124.9	0.602	122.3	0.575
Lip and palate											
unilateral	134	141.0	0.547	106.2	0.720	119.6	0.540	123.6	0.492	124.6	0.464
bilateral	67	141.6	0.714	106.4	0.940	119.3	0.730	124.9	0.812	125.1	0.780
Total cleft group	342	140.6	0.364	106.7	0.474	119.3	0.370	124.3	0.348	123.9	0.338
Noncleft group	200	138.5	0.424	106.2	0.591	120.9	0.425	123.8	0.383	123.0	0.368
Difference	2.1**			0.5		1.6**		0.7		0.9*	

difference in clivus-cribriform angle and clivus-SN angle (females have a larger angle), and an age difference in clivus-foramen magnum angle (a decrease with age). The combined cleft group exhibited the same tendencies. To test the difference between cleft and noncleft groups, the values for these angles were corrected for age and sex differences in the sample. In the final analysis several slight but significant differences emerged.

When the unilateral and bilateral lip and palate and the palate only values were pooled and tested against the noncleft (Table 3), highly significant differences were noted in the clivus-orbital plane angle and the clivus-cribriform plane angle. A significant difference was noted in the clivus-SN angle. It is apparent, however, that the angles varied between cleft types. This is especially marked when the sex differences are considered since the lip and palate group are predominantly male and the palate only group predominantly female.

Considering only the highly significant differences, those individuals with palate only possessed a cranial base with a smaller clivus-cribriform plane angle. Those with either a unilateral or a bilateral lip and palate showed larger clivus-orbital and clivus-SN angles, and smaller clivus-cribriform plane angles. The magnitude of the pooled angular differences should be noted, the greatest being 2.1°, and three of the five angular differences being less than 1°. The large sample and a sensitive statistical analysis were necessary to substantiate the differences.

Discussion

The cranial base in the cleft group was smaller in size than in the control group, although the proportions of the component areas were similar.

This does not necessarily indicate a generalized underdevelopment of structures forming the cranial base.

Johnson (*11*) found that children with clefts were smaller on the average than normal children. Meredith (*13*) and several other investigators have established that children from lower social and economic backgrounds are smaller on the average than children from higher socioeconomic levels. Since the Burlington sample consisted of normal children from a higher economic level than the cleft sample, both factors are involved in this study. It is probable that the observed difference in cranial base size is merely the reflection of a generalized difference in body size. This contention is substantiated by the finding that the cranial base length was equally proportional to the overall cranial length in both groups.

The minor angular differences found in this study are of no practical significance. Their presence, nevertheless, appears to confirm to some extent the theory that alterations in the configuration of the cranial base are a primary part of the cleft anomaly.

It should be remembered, however, that there are many abnormal environmental influences acting in an individual with a cleft lip or palate which tend to affect the configuration of the face and even the cranial base. Initially, there is loss of continuity in the palatopharyngeal ring of musculature and also of the lip musculature. The essentially normal tongue acts in this altered environment tending to produce further distortions. Lip surgery and palate surgery introduce new forces. The interaction of all these influences is so complex that it would require more knowledge than is currently available to predict the end result.

Suffice it to say that there is as much reason to believe that the minute differences in cranial base morphology are caused by secondary environmental factors as there is to believe that they are caused by primary developmental factors.

Avery and associates (*1*), in their examination of several embryos with clefts, found aberrations in the nasal cartilage which they felt might be a causative factor in abnormal palatal development. However, there are examples of severe disturbances in the nasal capsule which do not interfere with palate formation. In the congenital defect known as anencephaly, there is a grossly defective brain and absence of the calvarium. The nasal septum in these cases is deficient, resulting in a deep central depression running the length of the palate. Cleft palate, however, is rarely found (*2, 16*). An even more severe facial and anterior cranial anomaly, cyclopia, often shows absence of the ethmoid, vomer, nasal septum and premaxilla, but clefts of the lip or palate are not usually exhibited (*2, 22*). Caution must be exercised in drawing conclusions from findings in human embryos with clefts. The reason for

their failure to survive to term is usually unknown but it would seem probable that the cleft is not the only abnormality.

When speaking of a defect associated with clefts, it should be remembered that clefts of the lip (with or without clefts of the palate) are quite different from clefts of the palate. The major underlying factor in cleft lip and palate is heredity; in cleft palate alone it is environment (*6*).

The timing is also different. A general principle of teratology is that most developing organs pass through a critical period of increased susceptibility to teratological interference, corresponding approximately to the period of rapid growth and cell differentiation within the particular organ (*23*). Since the primary palate forms three to four weeks before the secondary palate, the 'critical' period is probably also much earlier. Animal experiments (*10, 17*) have shown this to be true: cleft lip is induced by a teratological agent acting an appreciable period of time prior to that required for the production of cleft palate.

The defect associated with cleft of the lip and alveolus seems to be failure of mesodermal penetration of the epithelial wall due to insufficiency of mesoderm (*18*) or failure of the epithelial wall (*20*). Cleft palate, however, seems more apt to be related to failure of the shelves to change their vertical orientation to a horizontal one at the proper time. Thus there are different developmental mechanisms in operation.

The great dissimilarities in the etiology, timing, and developmental mechanisms between cleft palate and cleft lip with or without cleft palate make it clear that these are two very different anomalies. It is difficult to conceive of both being associated with exactly the same cranial base anomaly.

Summary

A study of the morphology of the cranial base in 342 children with clefts of the lip and palate and 200 noncleft children revealed the following: a) The cranial base is smaller in children with clefts than in normals. This is probably due to the smaller size of the children and is not a reflection of an abnormality in the cranial base. b) The component parts of the cranial base of cleft children are equally proportional to those of noncleft children. c) The spatial relationships between the components of the cranial base are essentially the same in cleft and noncleft children. No evidence of *dysostosis sphenoidale* could be detected. There appears to be no evidence to support the contention that clefts of the lip and palate are related to other cranial malformations which have an abnormality of the sphenoid bone.

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