**SUMMARY**

652 P-A X-ray headfilms of 51 unilateral cleft lip and palate, UCLP; 27 bilateral cleft lip and palate, BCLP; and 62 isolated cleft palate, CP were studied longitudinally at 0–3 months, 4–6 months, and annually from 1:0–6:0 years. Breadth change, height change, and growth direction of nine paired landmarks were investigated by means of the rectangular coordinate system with right to left zygomatico-frontal suture (Zf) point line as the X-axis and the perpendicular line to this X-axis at the mid-point between the right and left Zf points as the X-axis. Major findings were:

(1) Study of Sphenoid body, interorbital, bizygomatico-frontal suture, and bizygomatic arch breadths showed that BCLP had a significantly broader face than either UCLP or CP. An apparent tendency to hypertelorism still remained at 6:0 in this group while UCLP and CP groups were both close to the Bolton Standards. (2) Nasal and maxillary breadths of BCLP and UCLP were significantly wider during the first year than in CP, but they showed only a slight growth change after the age of one year, compared to constant growth in CP. (3) All marked structural differences disappeared by 6:0 suggesting the effects of lip and/or palate surgery. (4) A slight cross-bite was found in UCLP and BCLP, but there was no such cross-bite in CP. (5) The effect of clefting was seen in mandibular dimensions where the bigonial notch was slightly broader than in non-cleft averages. (6) Upper facial height occlusal height, and posterior total facial height in each cleft group seemed to be larger than the Standard, though both maxillary height and gonial notch height approximated the Standard by 6:0 (7) From 0:3–6:0, there was no noteworthy difference among the cleft groups in either growth direction or facial symmetry of upper face and mandible. It was only in the mid-facial and dental areas that notable characteristics peculiar to the type of cleft were found. The landmarks of nasal aperture, maxilla, and dental arch showed a slight medial displacement on the affected side, although the degree and amount depended on the cleft-type.


# A Longitudinal Study of Morphological Craniofacial Patterns via P-A X-Ray Headfilms in Cleft Patients from Birth to Six Years of Age


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A recent study of longitudinal lateral roentgenocephalometric analysis in cleft patients showed that well-timed and conservative surgery minimizes the effect of

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surgical intervention and facilitates "normal" post-operative craniofacial growth (Krogman, et al. 1975). The purpose of this study is to investigate the abovementioned situation in more detail by means of the P-A X-ray headfilms, based on the same longitudinal samples studied via lateral headfilms.

In this study the growth changes in breadth and height and the growth direction from birth to six years (0:3–6:0) in unilateral cleft lip and palate (UCLP), bilateral cleft lip and palate (BCLP), and isolated cleft palate (CP), patients are discussed in detail. It should be noted that the 0:3 age group included a number of cases seen at 0:1 or 0:2. Hence, we refer to either birth–6:0 or 0:3–6:0.

## Procedure

MATERIAL. The material analyzed was comprised of 652 P-A X-ray headfilms of 140 cleft cases: UCLP, 51 cases; BCLP, 27 cases; CP, 62 cases; all from our longitudinal files. In view of the fact that we have established but not published that sex is not a significant factor in clefting in at least the first two postnatal years, male and female data are pooled at each age group, as summarized in Table 1.

Head position on the P-A headfilm was carefully checked. In children under three years of age, it is well known that it is difficult to hold the head steadily with the ear rods of the cephalometer. Therefore, the infant was sedated before the radiographic procedures were begun (Mazaheri and Sahni, 1969). Furthermore, according to an earlier investigation of the geometrical changes on the P-A headfilm in the various head positions, a change within 10 degrees of up-down or right-left rotation was less than the method error and was a negligible factor in breadth measurements. In height measurements, however, the effect was a little more than in the breadth. Therefore, all P-A films rotated over 10 degrees either vertically or laterally were eliminated from the study.

The age of lip repair was three (+/– ½) months and palate repair was 14 (+/–2) months. All surgical procedures were done by the same plastic surgeon, R. L. Harding, D.D.S,, M.D.

METHOD. Eighteen landmarks on the P-A X-ray headfilm, were used as shown in Figure 1. These were selected as stable reference points on the basis of a preliminary study regarding method errors.[1] After tracing, all landmarks were punched on IBM cards by OSKAR Model F and IBM 026 cardpunch.

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[1] Eighty-four P-A headfilms were selected randomly from 134 films of 27 BCLP cases in this material, and were traced twice at an interval of about two weeks. *Method Error:* $\sqrt{\Sigma(X_a - X_b)^2/2N}$ where Xa and Xb = 1st and 2nd measures and N = 84, was calculated on nine dimensions. The results were as follows:

| Dimension | Method Error |
|---|---|
| Maxillary breadth | 0.809 mm |
| Nasal breadth | 0.806 mm |
| Bizygomatic breadth | 0.631 mm |
| Sphenoid body breadth | 0.529 mm |
| Interorbital breadth | 0.469 mm |
| Bizygomatico-frontal suture breadth | 0.438 mm |
| Bigonial notch breadth | 0.409 mm |
| Lower external arch breadth | 0.322 mm |
| Upper external arch breadth | 0.223 mm |

TABLE 1: Sample Sizes

| *age (year(s) +/− 15 days)* | | *0:3* | *0:6* | *1:0* | *2:0* | *3:0* | *4:0* | *5:0* | *6:0* | *Total* |
|---|---|---|---|---|---|---|---|---|---|---|
| UCLP: | 51 cases | 32 | 35 | 31 | 30 | 34 | 32 | 28 | 26 | 248 |
| male | 29 cases | (22) | (21) | (20) | (19) | (19) | (18) | (16) | (15) | |
| female | 22 cases | (10) | (14) | (11) | (11) | (15) | (14) | (12) | (11) | |
| BCLP: | 27 cases | 17 | 20 | 16 | 20 | 18 | 15 | 15 | 11 | 132 |
| male | 18 cases | (10) | (12) | (10) | (11) | (11) | (10) | (10) | (10) | |
| female | 9 cases | (7) | (8) | (6) | (9) | (7) | (5) | (5) | (1) | |
| CP: | 62 cases | 26 | 35 | 37 | 38 | 33 | 34 | 39 | 30 | 272 |
| male | 28 cases | (13) | (15) | (16) | (21) | (18) | (16) | (17) | (11) | |
| female | 34 cases | (13) | (20) | (21) | (17) | (15) | (18) | (22) | (19) | |

Nine facial breadth measurements were taken. These are detailed in Figure 1. These breadths were measured as the distance projected via a perpendicular to the *Standard Line* (S-line in Figure 1) between the right and left zygomatico-frontal suture point (Zf).

Eight *height* measurements found in Figures 10 and 11 were also calculated as the mean distance of the right and left side from each landmark to the S-line.

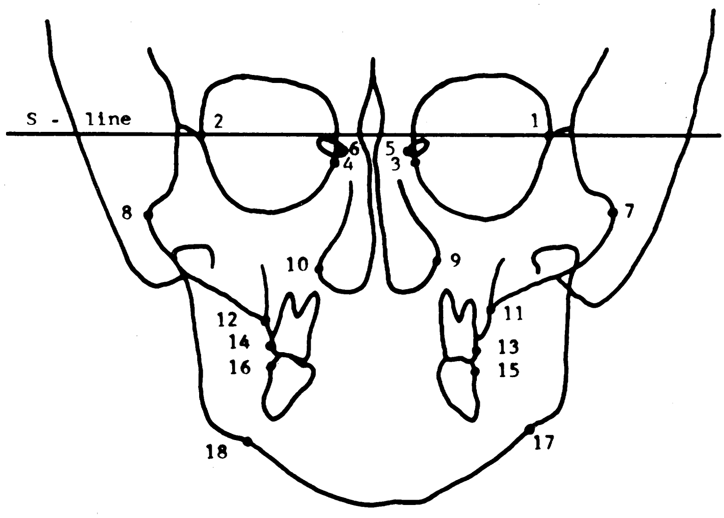
We also examined facial symmetry and growth direction by means of a co-ordinate system. The co-ordinate values of 18 landmarks were represented in the rectangular co-ordinate system with right Zf-point (#1) to left Zf-point (#2) line as the X-axis and the perpendicular line to this X-axis at the mid-point between right and left Zf-point as the Y-axis. The UCLP group was further classified in two groups: right side UCLP (1) (16 cases), and left side UCLP (35 cases).

The *Standard Line* (S-Line), drawn by connecting the right and left Zf points, was chosen after considerable thought and testing. We might have chosen the Frankfort Horizontal (FH), connecting right and left orbital (Or) points, and discussed vertical growth above it and below it. However, we wanted a reference line (or plane) that would more nearly dichotomize cranial and facial growth: Zf-Zf as a horizontal reference line satisfies this requirement because 1) it is more nearly medially in line with cranial base (occipito-sphenoethmoid complex) and 2) it is in line with the planum, which is, in turn, anteriorly and transversely, is in line with cranial base. The S-line, therefore, sets off the facial skeleton from the cranial skeleton behind at cranial base level, in front at great wing of sphenoid, ethmoid, and orbital roof levels. We are not so much implying that the face grows down from the S-Line as suggesting that what we measure below the S-Line is cranial base and facial structures while cranial vault structures are above.

## Results

### Growth Change of Facial Breadth

*Upper face: mid-line and lateral.* Bizygomatico-frontal suture, interorbital, sphenoid body, and bizygomatic breadths are included in this category. Means




| | | | | | |
|---|---|---|---|---|---|
| 1 | . | 2 | : | (Zf) | Medial point of zygomatico-frontal suture |
| 3 | . | 4 | : | (Or) | Medial point of inner orbital ridge |
| 5 | . | 6 | : | (Of) | Medial point of optic-foramen |
| 7 | . | 8 | : | (Z) | Lateral point of zygomatic bone |
| 9 | . | 10 | : | (Na) | Lateral point of nasal aperture |
| 11 | . | 12 | : | (M) | Intersection of lateral contour of maxillary alveolar process and lower contour of maxillo-zygomatic process of maxilla |
| 13 | . | 14 | : | (Um) | External point of upper 2nd deciduous molar |
| 15 | . | 16 | : | (Lm) | External point of lower 2nd deciduous molar |
| 17 | . | 18 | : | (G) | Gonial notch |
| S-line | | | : | | Standard line |

FIGURE 1. Landmarks on P-A film.

and standard deviations appear in Table 2. They are graphed in Figure 2 (with the exception of sphenoid body breadth which parallels and overlaps interorbital breadth).

Table 2 and Figure 2 show that in each of these dimensions BCLP is consistently larger than UCLP and CP. The latter two are very close in bizygomatic-frontal suture, interorbital, and sphenoid body breadths. In bizygomatic breadth, width is greatest for BCLP and least for UCLP with CP falling in the mid-position. Over-all, upper face is broadest in BCLP, in both mid-line and lateral breadths.

Bizygomatic-frontal suture and bizygomatic breadths show a difference which, in a sense, is progressive with severity of cleft: BCLP tends to stand apart from UCLP and CP while UCLP and CP do not markedly differ. In other words, facial laterality in breadth seems to be a function of type, severity, and involvement of cleft, with CP and UCLP closer to each other than either is to BCLP.

The two mid-line breadth dimensions, interorbital and sphenoid body, show a greater dimensional stability in clefting, more so when UCLP and CP are

TABLE 2: Facial breadths in mm (means and standard deviations)

| *age* | *bizyg.-frontal* | | | *interorbital* | | | *sphenoid body* | | | *bizygomatic* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *CP* | *UCLP* | *BCLP* | *CP* | *UCLP* | *BCLP* | *CP* | *UCLP* | *BCLP* | *CP* | *UCLP* | *BCLP* |
| | *M* σ | *M* σ | *M* σ | *M* σ | *M* σ | *M* σ | *M* σ | *M* σ | *M* σ | *M* σ | *M* σ | *M* σ |
| 0:3 | 64.9 (2.9) | 66.9 (3.6) | 68.8 (3.4) | .16.5 (1.1) | 17.2 (2.2) | 17.8 (2.2) | 15.7 (1.3) | 16.4 (1.8) | 17.6 (1.7) | 83.2 (4.3) | 83.7 (3.6) | 86.5 (4.7) |
| 0:6 | 70.6 (3.3) | 71.8 (4.1) | 74.1 (3.4) | 16.9 (1.7) | 17.8 (2.2) | 18.6 (2.4) | 16.5 (1.5) | 17.8 (1.8) | 18.5 (2.2) | 91.1 (4.9) | 91.3 (4.6) | 94.4 (4.8) |
| 1:0 | 74.9 (3.0) | 75.2 (3.0) | 78.0 (3.1) | 18.0 (1.7) | 18.6 (2.1) | 19.6 (2.1) | 17.4 (1.6) | 18.2 (1.6) | 19.3 (1.9) | 98.0 (3.9) | 96.7 (4.2) | 101.3 (3.7) |
| 2:0 | 77.7 (3.0) | 78.6 (3.9) | 81.1 (3.1) | 19.0 (1.4) | 19.2 (2.2) | 20.5 (2.3) | 18.1 (1.3) | 18.7 (1.6) | 20.0 (1.7) | 104.1 (3.7) | 102.4 (4.7) | 105.8 (3.6) |
| 3:0 | 79.2 (3.1) | 78.8 (3.7) | 82.5 (3.4) | 19.5 (1.6) | 19.1 (1.9) | 21.1 (2.3) | 18.6 (1.1) | 18.8 (1.4) | 20.4 (1.8) | 106.3 (4.5) | 103.8 (4.4) | 108.6 (4.7) |
| 4:0 | 81.0 (3.3) | 81.2 (4.1) | 83.8 (2.8) | 20.3 (1.7) | 20.3 (2.2) | 22.0 (2.5) | 19.0 (1.7) | 19.4 (1.7) | 21.5 (1.8) | 109.0 (4.7) | 107.0 (4.7) | 111.5 (5.2) |
| 5:0 | 82.5 (4.1) | 82.2 (4.0) | 85.5 (2.3) | 20.8 (2.1) | 20.6 (2.1) | 22.7 (2.6) | 19.5 (1.6) | 20.0 (1.7) | 21.5 (2.1) | 111.8 (4.9) | 109.1 (3.9) | 114.3 (5.3) |
| 6:0 | 83.8 (4.2) | 83.8 (4.7) | 87.1 (2.5) | 21.7 (2.3) | 21.5 (2.2) | 23.7 (2.7) | 20.1 (1.9) | 20.7 (1.9) | 21.9 (2.0) | 113.6 (4.1) | 111.4 (4.5) | 117.5 (5.5) |

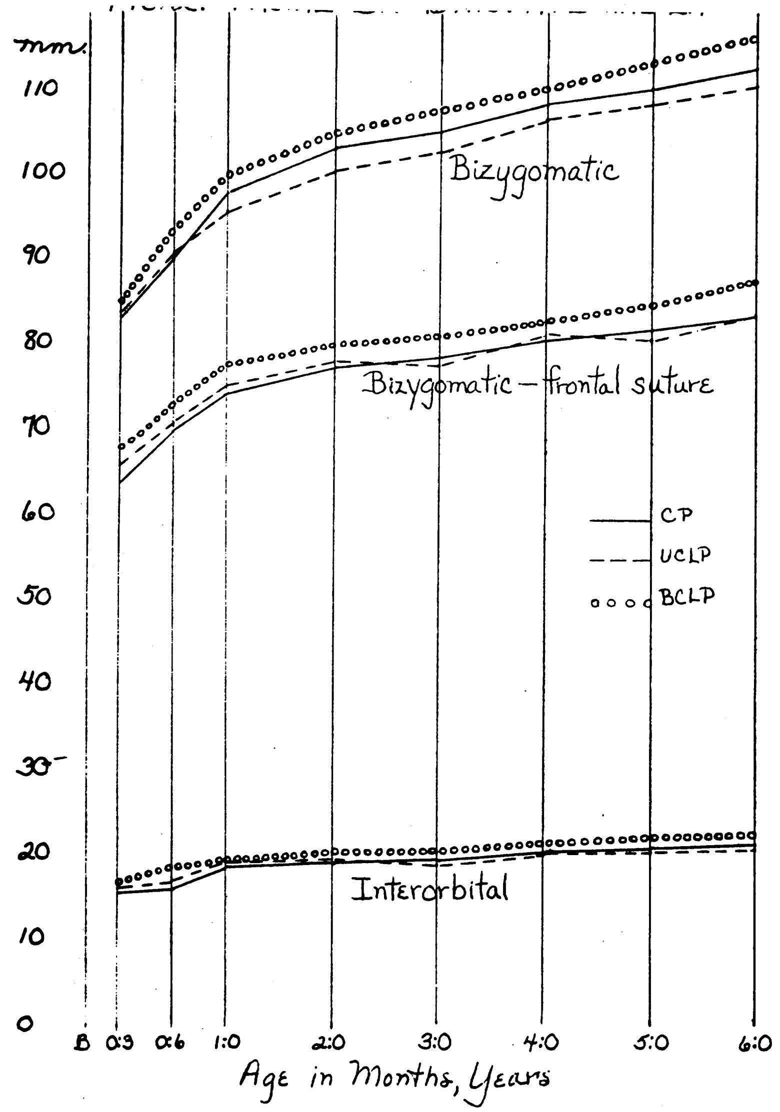



FIGURE 2. Facial breadths: mid and lateral.

contrasted, less so when UCLP and BCLP and CP are paired. In essence mid-line breadths follow a relational increment pattern of CP, UCLP, BCLP, the first two in contrast to the third.

The total dimensional increases from 0:3-6:0 (in mm. all +) are as follows:

| *Dimension* | *UCLP* | *BCLP* | *CP* |
|---|---|---|---|
| Bizygomatico-frontal suture | 16.9 | 18.3 | 18.9 |
| Interorbital | 4.3 | 5.9 | 5.2 |
| Sphenoid body | 4.4 | 4.3 | 4.4 |
| Bizygomatic | 27.7 | 31.0 | 30.4 |

In more lateral breadth growth, CP and BCLP stand together compared to UCLP; in mid-line breadth growth CP and BCLP interorbital breadth is closer, but sphenoid body breadth is a virtual constant.

*Anterior Mid-facial Structures.* Here we consider two dimensions; nasal aperture breadth and maxillary breadth. These are shown in Table 3 and in Figure 3.

An interesting picture emerges in Figure 3. From 0:3–3:0 the size order, smaller to larger, is CP, UCLP, BCLP, but from 3:0–6:0 it is CP, BCLP, UCLP. This trend is slightly more marked in maxillary than in nasal aperture breadth.

When paired, UCLP and BCLP, UCLP and CP, and UCLP and BCLP, show virtually no real differences.

Total dimensional increases from 0:3–6:0 (mm. all +) are as follows:

| *Dimension* | *UCLP* | *BCLP* | *CP* |
|---|---|---|---|
| Nasal aperture | 2.7 | 2.8 | 5.6 |
| Maxillary | 9.5 | 8.7 | 12.0 |

This is an interesting contrast to the more posterior mid-line breadths (interorbital, sphenoid body). Here BCLP stands apart from grouped UCLP and CP. The maxillary bone, *per se,* is involved in both of these anterior breadth dimensions. It is as though BCLP in its transverse effect is shaped like an inverted $\wedge$, i.e., narrower behind, broader in front. In the more extensive BCLP, involving the primary palate, we may ponder the complex yet compensatory role of a progressively separated, relatively isolated, pre-maxillary segment.

*Upper and Lower Outer Dental Arch Breadth.* In this area we have analyzed only the 3:0–6:0 period, for we assumed full outer arch dimensional growth with the completion of the deciduous dentition. These data, summarized in Table 4, are obviously so similar that it is not necessary to graph them.

For the dental arch breadths, we have had recourse to the Bolton Standard of the P-A headfilm view. This Standard gives only modal (not average) tracings

TABLE 3: Anterior mid-face breadths in mm (means and standard deviations)

| | *Nasal aperture breadth* | | | *maxillary breadth* | | |
|---|---|---|---|---|---|---|
| *age* | *CP* | *UCLP* | *BCLP* | *CP* | *UCLP* | *BCLP* |
| | *M* ($\sigma$) | *M* ($\sigma$) | *M* ($\sigma$) | *M* ($\sigma$) | *M* ($\sigma$) | *M* ($\sigma$) |
| 0:3 | 19.6 (2.0) | 20.9 (2.1) | 21.6 (2.2) | 44.3 (3.1) | 45.6 (3.9) | 47.8 (3.2) |
| 0:6 | 20.5 (1.7) | 20.9 (2.4) | 21.3 (1.8) | 44.9 (2.9) | 45.2 (3.1) | 47.4 (3.4) |
| 1:0 | 21.8 (2.0) | 21.9 (2.1) | 23.2 (2.5) | 47.3 (2.8) | 47.4 (2.9) | 49.2 (3.5) |
| 2:0 | 22.3 (1.7) | 21.9 (2.1) | 23.0 (1.9) | 51.0 (2.8) | 49.9 (3.2) | 51.2 (2.9) |
| 3:0 | 22.8 (1.8) | 22.3 (1.9) | 23.3 (2.2) | 51.8 (2.9) | 51.2 (3.0) | 52.1 (2.9) |
| 4:0 | 23.6 (1.9) | 22.9 (2.1) | 23.4 (2.3) | 53.8 (2.5) | 51.8 (2.9) | 52.1 (3.4) |
| 5:0 | 24.4 (2.0) | 23.6 (2.2) | 23.6 (2.0) | 54.9 (3.0) | 53.5 (2.8) | 53.4 (3.1) |
| 6:0 | 25.2 (2.3) | 23.6 (2.2) | 24.4 (2.4) | 56.3 (3.1) | 55.1 (3.3) | 56.5 (4.0) |

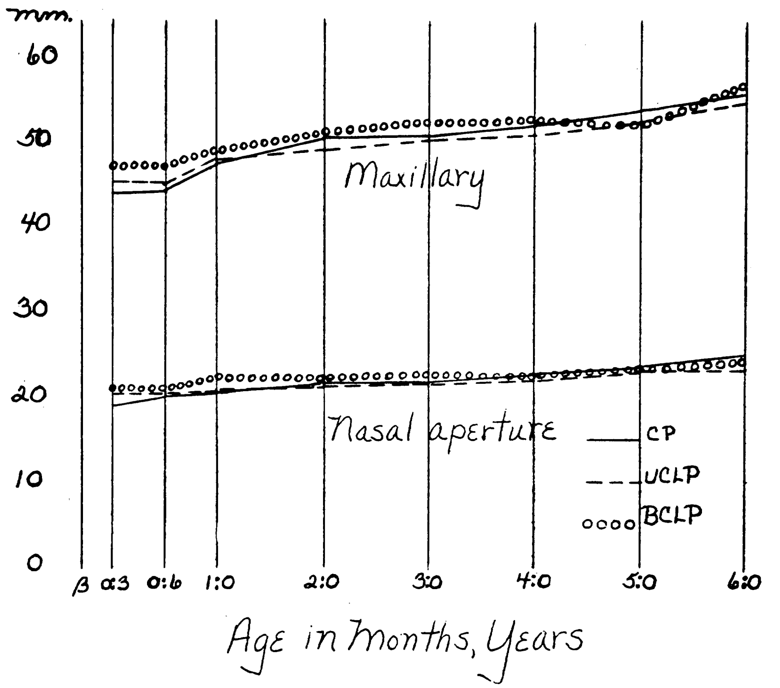



FIGURE 3. Anterior mid-face breadths.

and does not carry with it any mensurational data.[2] However, on the 3:0–6:0 P-A tracings we measured outer arch breadths, upper and lower, as defined by us. In the upper arch, outer breadth went evenly from 48.8 mm. at 3:0 to 50.3 mm. at 6:0. Correspondingly, the lower arch went from 46.3 mm. at 3:0 to 48.1 mm. at 6:0.

One fact immediately emerges. The cleft dental arches, both upper and lower, are slightly narrower than the Standard. Deviations are greater in the upper than in the lower arch. In the upper arch, the amount of divergence from the Standard is in order of BCLP, UCLP, CP. In the lower arch, a similar order holds, but UCLP and CP are close together. By 6:0 all three cleft-types are uniformly narrower than the Standard to about the same extent.

From 3:0–6:0 in both dental arches there is no noticeable difference when the pairings are UCLP and BCLP, UCLP and CP, and BCLP and CP. Since our

[2] All headfilms upon which the Bolton Standards are based have been digitized and computerized, but resulting data were not available when this study was done. Each P-A Standard, sexes pooled, was created in the following manner: for each age, at 3:0, 6:0, 9:0, 10:0, 11:0, 12:0, 13:0, 14:0, 15:0, and 18:0 there were selected 32 P-A headfilms with normal occlusion and a Dental Age consistent with Chronological Age. These 32 were randomly paired and superimposed by 2's to give 16 tracings; the 16 were paired randomly to give 8, the 8 to give 4, the 4 to give 2, the two to give a final 1. The last tracing (the 1) is the Standard and is in ultimate the tracing of greatest frequency. It is, in a sense, a final "distillate" of the original 32. While the differences between each pair of tracings was drawn in as an "average" between the two, these "averages" were not summated as the 32, 16, 8, 4, 2, 1 sequence was run through and each final single age Standard emerged.

normative data here begin at 3:0, which is palatal post-operative, it is logical to assume normal (catch-up) growth from 3:0–6:0.

The toal dimensional increases from 3:0–6:0 (mm., plus and minus) are as follows:

| *Dimension* | *UCLP* | *BCLP* | *CP* | *Standard* |
|---|---|---|---|---|
| Upper dental arch | +0.4 | −0.1 | +0.9 | +1.5 |
| Lower dental arch | +0.6 | −0.6 | +0.0 | +1.8 |

In the cleft types, the dental arch outer breadths have not changed from 3:0–6:0, once the deciduous teeth are all in place while the Standard has increased only slightly.

*Lower (Mandibular) Lateral Facial Breadth.* In this category, there is only one dimension:—bigonial notch breadth. Table 5 and Fig. 4 summarize these data.

All three cleft-types parallel one another in over-all breadth in the size order of BCLP, CP, UCLP. From 3:0–6:0. all are broader in the lower face than the Standard. This is as would be expected, for lateral upper-face (bizygomatico-frontal suture) and lateral mid-face (bizygomatic) both tend to be broader in clefting when compared to normative values. Hence, upper, mid, and lower facial lateral breadths are all somewhat greater in clefting. One might say that

TABLE 4: Upper and lower outer dental arch breadths in mm (means and s andard deviations)

| *age* | *upper arch* | | | *lower arch* | | |
|---|---|---|---|---|---|---|
| | *CP* | *UCLP* | *BCLP* | *CP* | *UCLP* | *BCLP* |
| | *M* $\sigma$ | *M* $\sigma$ | *M* $\sigma$ | *M* $\sigma$ | *M* $\sigma$ | *M* $\sigma$ |
| 3:0 | 46.1 (2.7) | 45.1 (3.3) | 45.2 (3.5) | 45.0 (2.7) | 44.8 (2.7) | 46.1 (1.9) |
| 4:0 | 47.1 (2.7) | 45.3 (3.6) | 45.0 (3.7) | 44.9 (2.3) | 44.8 (2.4) | 45.7 (2.1) |
| 5:0 | 47.0 (2.6) | 45.8 (3.6) | 44.9 (3.7) | 45.0 (2.5) | 45.5 (2.7) | 45.4 (1.9) |
| 6:0 | 47.0 (2.5) | 45.5 (3.7) | 45.1 (4.1) | 45.0 (2.5) | 45.4 (2.5) | 45.5 (2.2) |

TABLE 5: Bigonial notch breadth in mm (means and standard deviations)

| *age* | *CP* | *UCLP* | *BCLP* |
|---|---|---|---|
| | *M* $\sigma$ | *M* $\sigma$ | *M* $\sigma$ |
| 0:3 | 52.9 (4.2) | 51.8 (3.5) | 53.7 (2.9) |
| 0:6 | 56.6 (3.1) | 56.1 (3.0) | 57.8 (2.9) |
| 1:0 | 61.5 (3.0) | 60.3 (2.5) | 62.5 (3.5) |
| 2:0 | 66.1 (2.9) | 65.2 (3.2) | 66.3 (3.4) |
| 3:0 | 67.8 (3.1) | 66.5 (2.9) | 68.6 (2.9) |
| 4:0 | 70.5 (3.3) | 69.1 (3.6) | 71.1 (3.2) |
| 5:0 | 73.0 (3.6) | 71.3 (3.7) | 73.5 (2.9) |
| 6:0 | 74.4 (3.8) | 74.0 (4.1) | 75.8 (3.8) |

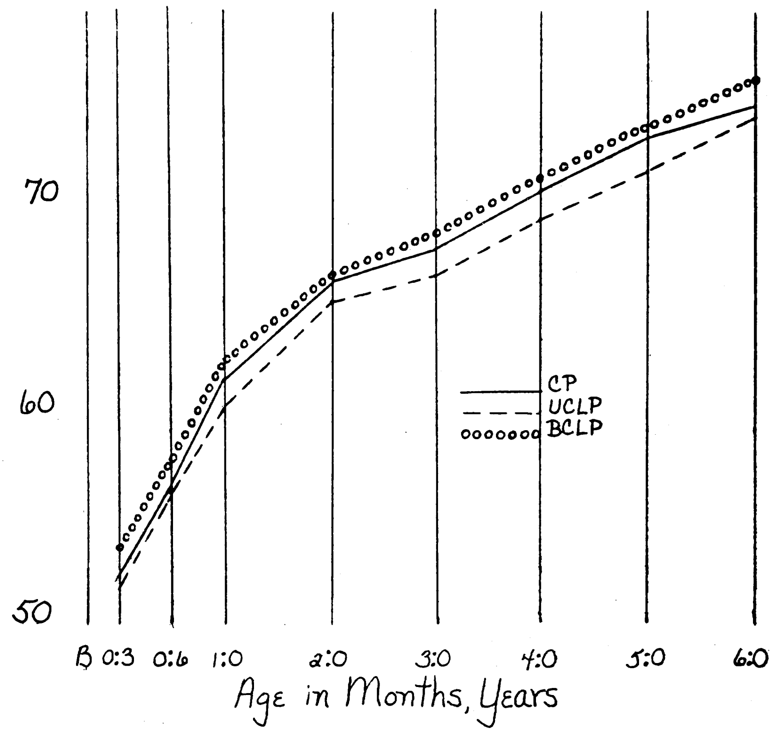



FIGURE 4. Bigonial notch breadth.

mid-line clefting "spreads" the facial skeleton laterally. In mandibular (gonial) breadth UCLP, BCLP, and CP stand together, for there are no really significant paired differences.

The total dimensional increases from 0:3–6:0 are (mm., all +) as follows:

| *Dimension* | *UCLP* | *BCLP* | *CP* |
|---|---|---|---|
| Bigonial notch breadth | 22.2 | 22.1 | 21.5 |

*Changes in Facial Height.* Here we shall pick up the same focal areas as were designated in the analysis of facial breadth, but they are (arranged slightly differently):

1. Posterior and anterior mid-face heights
   a. Inner orbital ridge
   b. Sphenoid body
   c. Nasal aperture
   d. Maxillary bone
2. Upper and lower dental arch heights
3. Lateral mid-face and lower face heights
   a. Zygomatic arch
   b. Gonial notch.

In this part of our findings, it must be pointed out that all heights were measured with reference to the Standard Line (S-Line), as seen in Fig. 1. Since the S-Line is regarded as fixed, all height "increases" really represent a "lowering" of the areal or structural height being measured. This methodological principle is a *tour de force,* and is operative in all roentgenographic cephalometry, where tracings of age-successive X-ray headfilms are superimposed upon a common base-line, an endpoint of which is the fixed "registration point." In this study, we have, as explained earlier, separated cranial growth (base and vault) from facial growth at the level of the S-Line. In the lateral headfilm S-N (anterior cranial base) is the arbiter of a craniofacial dichotomy. Looked at in this way, nasion represents, basically, a craniofacial suture, and the S-Line is only a bit above the nasion level. Moreover, face growth is relatively autonomous, for it continues *after* cranial growth has ceased (or has at least reached its 95% value). It follows, then, that face grows downward in a sort of a *contra coup* manner, abutting from the nasion area (or the S-Line area).

*Posterior and Anterior Mid-face Heights.* Posteriorly, we shall consider, as structurally related, inner orbital ridge and sphenoid body heights. Anteriorly, we shall consider nasal aperture and maxillary bone heights. The data are tabulated in Table 6 and are graphed in Figure 5. (Because inner orbital ridge and sphenoid body heights are dimensionally so close, we have graphed only the former).

For both inner orbital ridge and sphenoid body heights, increase is slight. CP has increased the most, with less change for UCLP and BCLP. These latter two types are virtually identical. When the cleft-types are paired, there are no differences with regard to inner orbital ridge. However, from 3:0–6:0 both UCLP and BCLP stand apart from CP when sphenoid body is examined.

The vertical increase in nasal aperture height is a measure of the down-ward movement of the floor of the nose (which is also the roof of the mouth, i.e., the hard palate). Hence, vertical increase in maxillary bone height, which parallels nasal aperture, suggests that both—plus upper dental arch height, as we shall note—are part of a total anterior maxillary complex.

In the anterior mid-line, we confirm what was noted in the lateral headfilm, viz., that there is increased facial verticality in clefting compared to the Standard. In nasal aperture, the dimensional increase is greater in CP, with UCLP and BCLP being of lesser magnitude and closer together. In maxillary bone, the three cleft-types cluster. Mid-face heights show little or no differences when the three cleft-types are paired. It is the mid-lint, *per se,* that is quite uniformly involved in the height changes in all three cleft-types.

The total incremental height increases from 03–6:0 (in mm., plus and minus) are as follows:

| Dimension | CP | UCLP | BCLP |
|---|---|---|---|
| Inner orbital ridge | 0.0 | −0.8 | −0.3 |
| Sphenoid body | +0.8 | +0.6 | +0.5 |
| Nasal aperture | +12.9 | +13.2 | +10.5 |
| Maxillary bond | +15.8 | +15.4 | +16.1 |

Posterior mid-face vertical dimensions are remarkably stable in the age period

TABLE 6: Posterior and anterior mid-face heights in mm (means and standard deviations)

| age | *inner orb. ridge* | | | *sphenoid body* | | | *nasal aperture* | | | *maxillary bone* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *CP* | *UCLP* | *BCLP* | *CP* | *UCLP* | *BCLP* | *CP* | *UCLP* | *BCLP* | *CP* | *UCLP* | *BCLP* |
| | *M* $\sigma$ | *M* $\sigma$ | *M* $\sigma$ | *M* $\sigma$ | *M* $\sigma$ | *M* $\sigma$ | *M* $\sigma$ | *M* $\sigma$ | *M* $\sigma$ | *M* $\sigma$ | *M* $\sigma$ | *M* $\sigma$ |
| 0:3 | 3.4 (1.5) | 3.2 (1.8) | 3.1 (2.0) | 2.1 (1.9) | 1.6 (1.3) | 1.3 (1.8) | 19.3 (2.0) | 17.9 (2.3) | 19.5 (2.4) | 26.8 (2.3) | 27.2 (2.8) | 27.1 (2.7) |
| 0:6 | 3.8 (1.8) | 3.2 (1.4) | 3.5 (2.5) | 2.6 (2.1) | 1.5 (1.5) | 1.4 (1.7) | 23.2 (2.1) | 21.6 (2.0) | 22.0 (3.3) | 32.2 (2.2) | 32.3 (3.1) | 32.5 (2.7) |
| 1:0 | 3.9 (2.1) | 3.1 (2.0) | 2.8 (2.5) | 2.5 (1.5) | 1.5 (1.9) | 1.6 (1.9) | 25.5 (1.8) | 24.2 (2.0) | 24.0 (2.4) | 35.4 (2.1) | 34.8 (1.9) | 35.3 (2.4) |
| 2:0 | 3.7 (2.1) | 2.8 (2.1) | 3.1 (2.4) | 2.6 (1.9) | 1.5 (2.0) | 1.6 (2.3) | 27.2 (2.2) | 26.6 (2.4) | 26.0 (2.8) | 37.6 (1.9) | 38.3 (3.4) | 38.3 (2.2) |
| 3:0 | 3.9 (2.4) | 2.9 (2.0) | 2.8 (1.9) | 3.0 (2.0) | 1.7 (1.8) | 1.8 (1.5) | 28.5 (2.4) | 27.7 (1.9) | 26.9 (2.3) | 39.1 (2.6) | 38.4 (2.3) | 39.3 (2.4) |
| 4:0 | 3.4 (1.8) | 2.8 (1.9) | 3.2 (2.7) | 3.2 (2.4) | 1.6 (1.5) | 2.0 (1.8) | 30.2 (2.7) | 28.3 (2.6) | 28.4 (2.4) | 40.4 (2.4) | 40.4 (3.4) | 41.7 (2.8) |
| 5:0 | 3.2 (2.0) | 3.0 (2.1) | 2.9 (2.1) | 3.0 (2.5) | 2.0 (2.2) | 1.7 (1.7) | 31.3 (2.7) | 30.1 (2.6) | 28.7 (2.4) | 42.3 (3.1) | 42.3 (3.1) | 42.3 (2.4) |
| 6:0 | 3.4 (1.8) | 2.6 (2.2) | 2.8 (2.3) | 2.9 (1.9) | 2.2 (1.5) | 1.8 (1.8) | 32.2 (2.3) | 31.1 (3.8) | 30.0 (2.1) | 42.6 (3.2) | 42.6 (4.3) | 43.2 (2.3) |

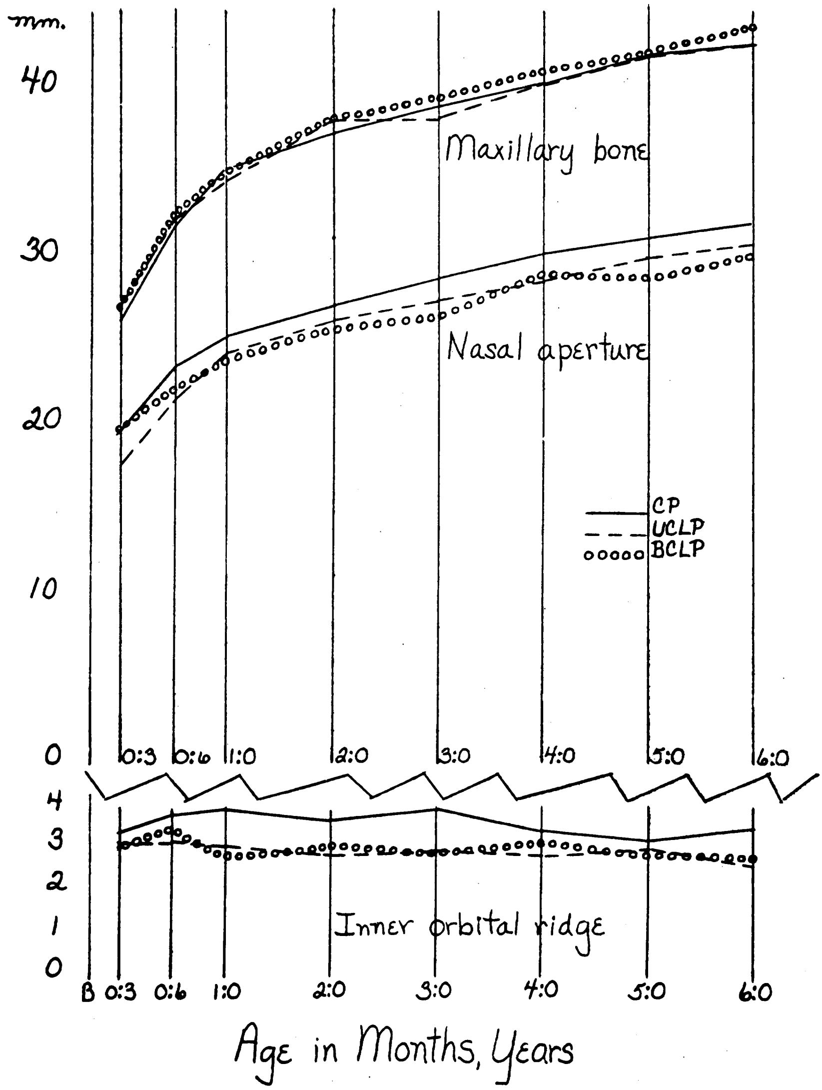



FIGURE 5. Posterior and anterior mid-face heights.

TABLE 7: Upper and lower dental arch heights in mm (means and standard deviations)

| age | upper arch | | | lower arch | | |
|---|---|---|---|---|---|---|
| | CP | UCLP | BCLP | CP | UCLP | BCLP |
| | M σ | M σ | M σ | M σ | M σ | M σ |
| 3:0 | 48.3 (2.9) | 47.0 (3.4) | 47.8 (2.8) | 55.2 (3.2) | 54.5 (3.0) | 55.9 (2.8) |
| 4:0 | 51.3 (2.9) | 50.0 (3.4) | 51.0 (2.9) | 57.9 (3.0) | 56.9 (4.3) | 58.0 (2.9) |
| 5:0 | 53.7 (3.4) | 53.0 (3.0) | 53.2 (3.1) | 60.3 (3.7) | 59.4 (3.1) | 59.7 (3.4) |
| 6:0 | 55.2 (3.4) | 55.0 (3.9) | 55.9 (3.7) | 62.0 (3.6) | 60.4 (3.7) | 62.6 (3.8) |

covered. Gain in maxillary bone is uniformly greater than in nasal aperture in all three cleft-types. Within nasal aperture itself, gain is least in BCLP and about the same in CP and UCLP.

*Upper and Lower Dental Arch Heights.* The data here are tabulated in Table 7 and graphed in Figure 6. As in arch breadths, we offer data only from 3:0–6:0, beginning with completion of the deciduous dentition.

For these two dimensions we have once more gone to the Bolton Standards for normative (non-cleft) values. They are as follows (in mm.):

| *Age* | *Upper Arch* | *Lower Arch* |
|---|---|---|
| 3:0 | 44.2 | 50.0 |
| 4:0 | 45.3 | 51.2 |
| 5:0 | 48.0 | 55.0 |
| 6:0 | 51.0 | 58.1 |

A major fact emerges, viz., that the positional change in dental arch levels, in terms of dimensional verticality below the S-Line, is quite different in cleft-types than in the Standard. The arches seem lower, positionally, which agrees well with our findings in the lateral headfilm, i.e., that upper face height is greater in

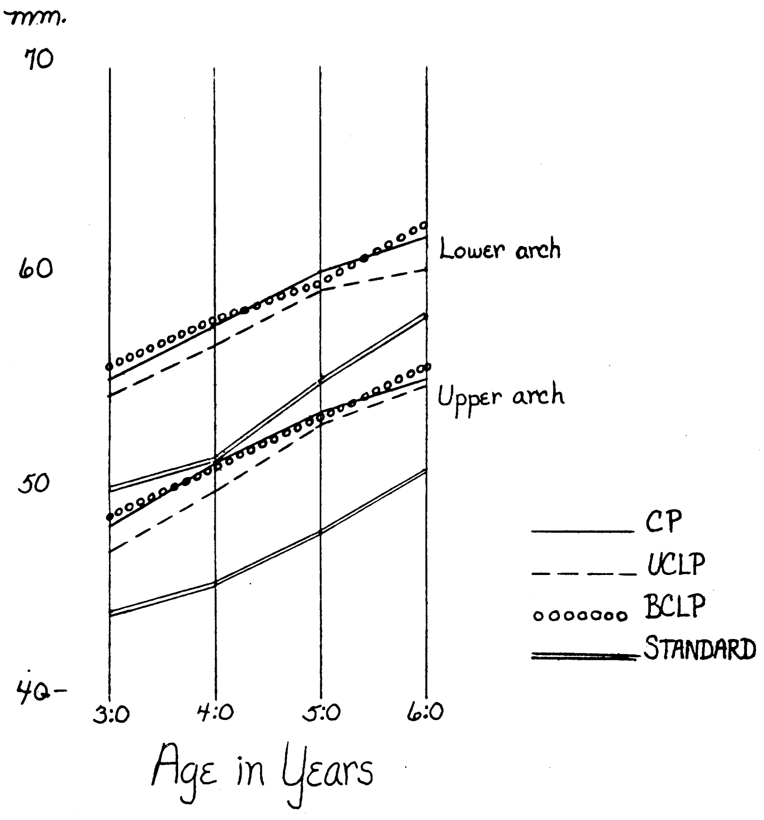



FIGURE 6. Upper and lower dental arch heights.

clefting (ANS and/or Point A to Nasion). This suggests that upper face height, as a total, is in part a function of the descent of the dental arches and is greater in cleft than in non-cleft subjects.

Figure 6 reveals another interesting fact. The CP, UCLP, and BCLP curves parallel one another over the 3:0–6:0 age period. This means that the reciprocal relation of the dental arches is quite constant during this period.

Over the 3:0–6:0 span, the total incremental height changes are as follows (in mm., all +):

| *Dimension* | *CP* | *UCLP* | *BCLP* | *Standard* |
|---|---|---|---|---|
| Upper dental arch | 6.9 | 8.0 | 8.1 | 6.8 |
| Lower dental arch | 6.8 | 5.9 | 6.7 | 8.1 |

*Lateral Mid-face and Lower Face Heights.* These dimensions embrace the zygomatic arch in the mid-face and the gonial notch in the lower face. The data are tabulated in Table 8 and graphed in Figure 7.

There is relatively little change in the level of the zygomatic arch. In addition, the three cleft-types cluster, and there are really no differences among them.

On the other hand, the gonial notch measurement, taking in the lower border of the mandible, is greater in both size and extent of change. The factor here is undoubtedly mandibular ramal height, which is independent of the position of the zygomatic arch. Again, there are no discernible difference among cleft-types.

The total incremental growth from 0:3–6:0, (mm., all +) is as follows:

| *Dimension* | *CP* | *UCLP* | *BCLP* |
|---|---|---|---|
| Zygomatic arch | 6.2 | 6.6 | 4.4 |
| Gonial Notch | 27.1 | 26.9 | 27.4 |

*Growth Directions from 0:3–6:0.* Here we have classified the data into four groups: UCLP(1), right side; UCLP(2), left side; BCLP; CP. The analysis of the growth directions was accomplished by means of the co-ordinate system described earlier.

The growth directions of the optic foramen (Of), the inner orbital ridge (Or),

TABLE 8: Lateral mid-face and lower face heights in mm (means and standard deviations)

| | *zygomatic arch* | | | *gonial notch* | | |
|---|---|---|---|---|---|---|
| *age* | *CP* | *UCLP* | *BCLP* | *CP* | *UCLP* | *BCLP* |
| | *M* $\sigma$ | *M* $\sigma$ | *M* $\sigma$ | *M* $\sigma$ | *M* $\sigma$ | *M* $\sigma$ |
| 0:3 | 10.6 (2.9) | 11.1 (3.2) | 10.9 (2.8) | 44.7 (4.1) | 45.2 (4.0) | 45.4 (3.0) |
| 0:6 | 14.1 (3.3) | 13.0 (3.4) | 12.9 (2.4) | 54.3 (3.9) | 54.4 (4.5) | 54.8 (4.8) |
| 1:0 | 13.9 (3.7) | 14.3 (2.8) | 13.1 (2.5) | 58.6 (3.7) | 59.7 (3.4) | 60.1 (4.6) |
| 2:0 | 15.2 (3.3) | 15.1 (3.6) | 14.1 (2.7) | 64.2 (3.5) | 64.0 (4.6) | 64.7 (3.8) |
| 3:0 | 16.1 (3.2) | 16.0 (2.8) | 15.0 (2.7) | 66.2 (4.0) | 65.6 (3.6) | 66.9 (3.0) |
| 4:0 | 16.1 (3.4) | 16.0 (3.6) | 13.8 (3.9) | 68.2 (3.9) | 68.4 (5.3) | 68.5 (4.0) |
| 5:0 | 17.0 (4.5) | 16.8 (3.9) | 14.5 (3.9) | 70.4 (4.8) | 70.9 (5.0) | 69.3 (5.1) |
| 6:0 | 16.8 (3.2) | 16.7 (3.8) | 15.3 (2.4) | 71.8 (4.5) | 72.1 (5.6) | 72.8 (4.2) |

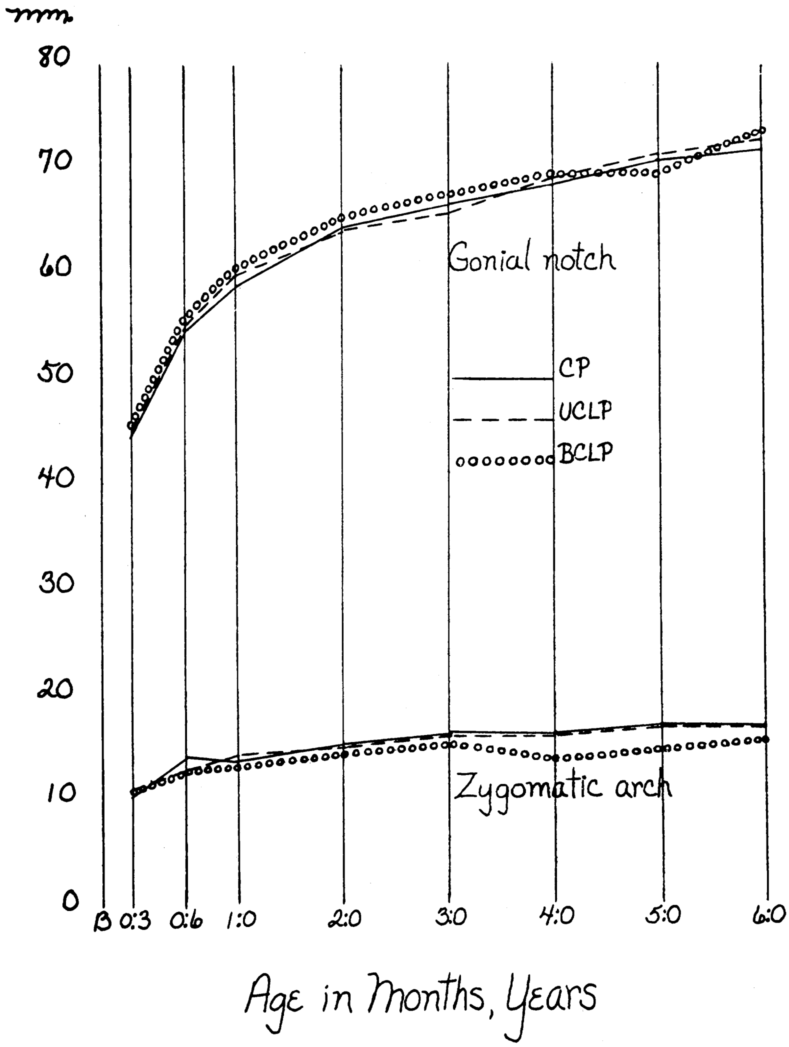



FIGURE 7. Lateral mid-face and lower face heights.

the zygomatic arch (Z), and the gonial notch (G) are almost identical in the four cleft groups. Each direction is as follows: the optic foramen has a lateral and slightly downward growth; the inner orbital ridge a lateral; the zygomatic arch lateral and slightly downward; and the gonial notch downward and slightly lateral. There are no over-all significant differences in these four measurements between right and left sides. We may also conclude that there are no noteworthy random or systematic differences in these four landmarks. These data are summarized in Figure 7.

However, in the growth direction of the other four points, i.e., nasal aperture, maxillary, upper arch, and lower arch point, each of the four groups shows its own characteristic pattern.

In the UCLP(1) as seen in Figure 8, the un-affected left side of the nasal aperture and the maxilla grow relatively downward and laterally, compared to the downward growth of the affected right side. The growth direction of the left (non-cleft) side may be considered normal. It is an interesting finding that the breadths of the nasal aperture and the maxilla on the affected right side are broader than on the left side during the first three or four years, but then they become narrower. Dental relationships show a slight cross bite on the right side and a normal bite on the left side.

The pattern of the growth of UCLP(2) (Figure 9) is in constrast to UCLP(1) (Fig. 8). There is a downward growth of both the Na and M points on the affected left side, and a slight cross bite on the same side.

The nasal aperture and maxilla of BCLP (Figure 10) show mostly downward growth symmetrically on both sides, although the maxilla has a rapid lateral growth from 5:0–6:0. A slight cross-bite is found on both the right and left sides during the period investigated (3:0–6:0). There is no noteworthy breadth difference between right and left sides in any measurements.

The CP group shows a lateral and downward growth in the region of nose and maxilla, and no cross bite in the dental arches (Figure 11). There is no noticeable asymmetry of facial or dental pattern. This latter facial growth pattern may well be the close to normal growth than any of the other cleft groups investigated.

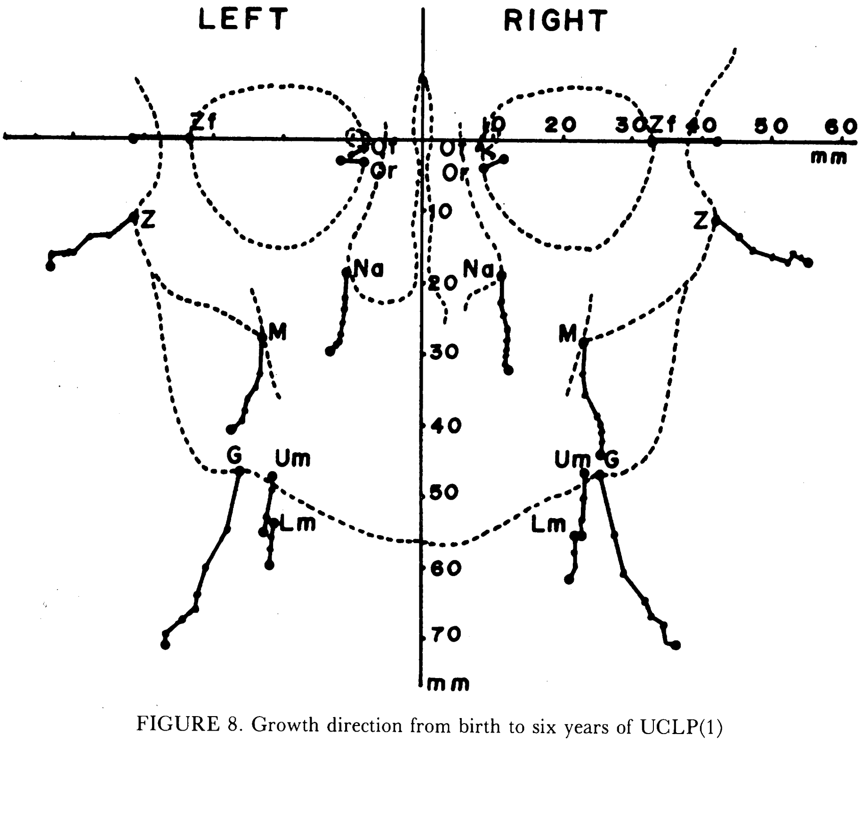



FIGURE 8. Growth direction from birth to six years of UCLP(1)

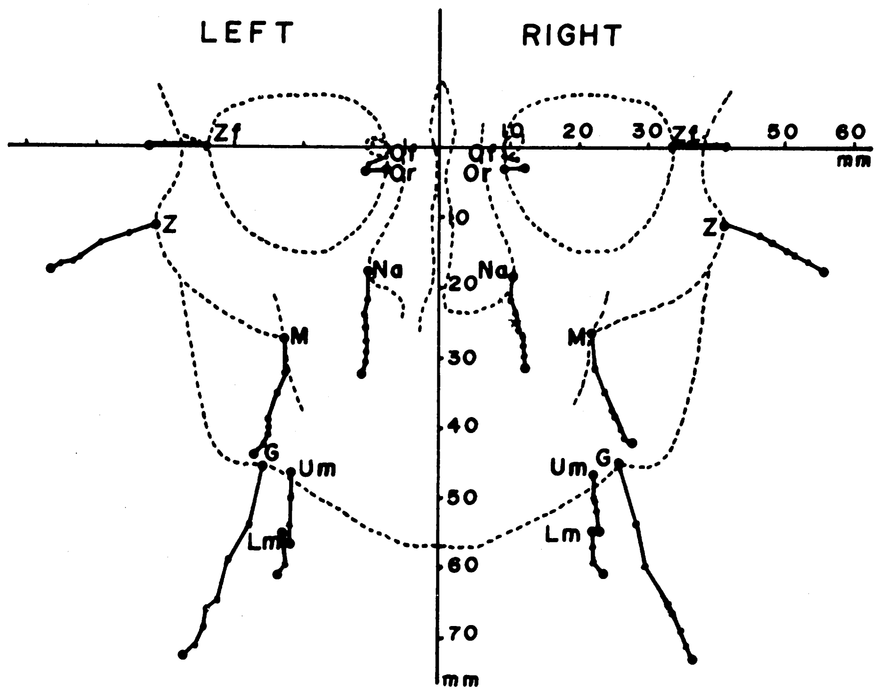



FIGURE 9. Growth direction from birth to six years of UCLP(2)

## Discussion

The study of postnatal facial breadth change is one of the most important avenues of research in the craniofacial growth and development of cleft patients. Up to the present time, the frontal (P-A) X-ray headfilm has been relatively neglected, both morphologically and clinically. Harvold (1954), Coupé and Subtelny (1960), Aduss and Pruzansky (1967, 1968), among others, have analyzed growth changes observed in frontal cephalometric radiographs.

Facial Breadth Changes in Cleft Children. Both clinicians and researchers have needed to ascertain the breadth growth of facial and dental structures in the child with a cleft. The problem centers on how cleft types differ from the normal and from each other. This has been the occasion for considerable discussion over the years.

Ortiz-Monasterio, *et al.* (1966) and Atherton (1967a, 1967b) reported on the facial growth of unrepaired cleft patients. Head breadth, interorbital breadth, and maxillary breadth appear to be wider in infancy and to remain wide in adult life. The bucco-lingual relationship of the teeth was excellent. Finally, they suggest that there is at least a normal growth potential in the width of the face in unrepaired cleft children. On the other hand, regarding growth change of repaired cleft patients, it has been suggested that they also have wide interorbital

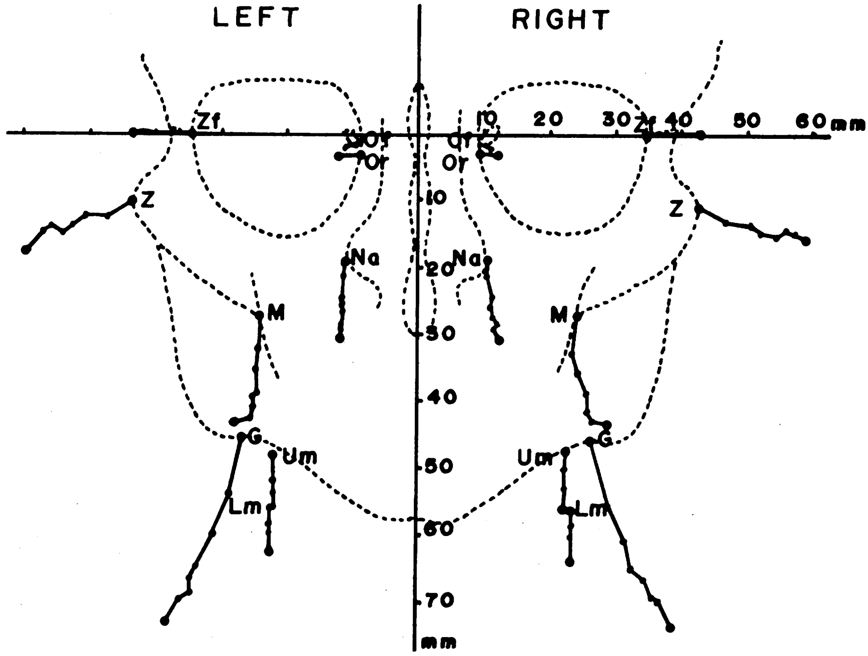



FIGURE 10. Growth direction from birth to six years of BCLP

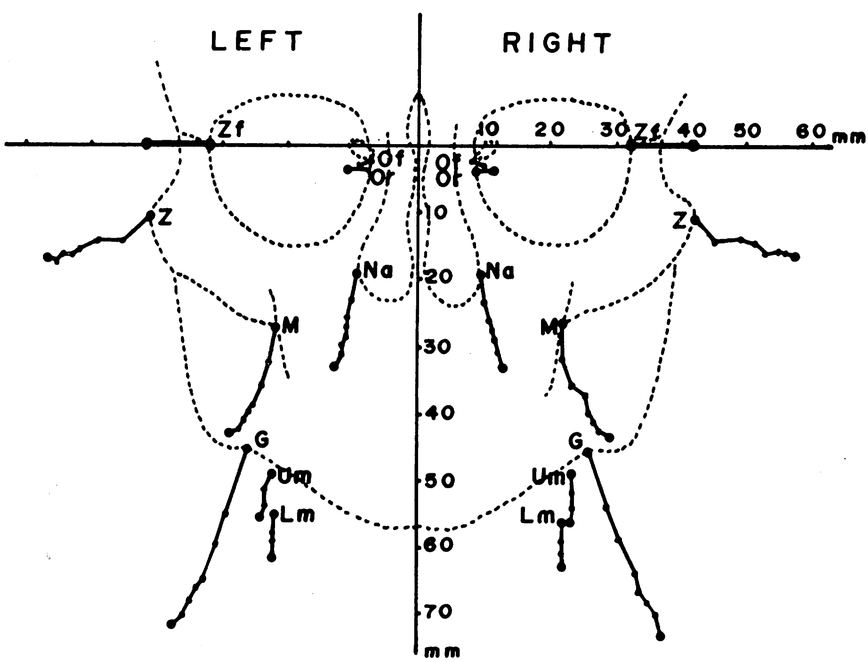



FIGURE 11. Growth direction from birth to six years of CP

breadth and wide zygomatic arch breadth. However, maxillary breadth and dental arch breadth vary with surgical factors and with cleft types.

In this study, the BCLP group, the most severe cleft-type, showed significantly greater facial breadths than did either of the other two cleft groups or non-cleft children. This was also true in bizygomatico-frontal suture breadth and bizygomatic arch breadth during the 0:3–6:0 period. A tendency to hypertelorism may be a predisposing morphological characteristic in BCLP (Dixon, 1966; Moss, 1965; Ross and Johnston, 1972). However, the UCLP and CP groups showed neither a hyperteloric tendency, nor a significant difference from each other in the upper face after 3:0. There was a difference which may depend on the severity of clefting at birth and/or prior to lip repair. A careful study of prenatal craniofacial growth changes and mechanisms of clefting may answer the interesting question, i.e., whether the hypertelorism is primarily an embryogenic characteristic or a secondary growth dysplasia or deviation in a severe cleft-type.

Most dental clinicians who treat cleft children have been interested in the growth changes of mid-facial and dental arch breadth. In 1960, Coupé and Subtelny presented a study of nasal cavity and zygomatico-maxillary suture breadth changes by means of cephalometric laminagraphy in cross-sectional cleft palate cases, 3:0 and younger. They reported that there was significantly greater over-all nasal width in the UCLP, and BCLP cleft-types as compared to non-cleft subjects, and that no significant difference of zygomatico-maxillary breathe was discernible between non-cleft subjects and any cleft-type. This observation before 3:0 seems to be confirmed by the present study. However, in our study, the relatively marked difference of nasal breadth and maxillary breadth at birth disappeared after three years of age. This finding may support the results of Nakamura *et al* (1972) to the effect that the right and left Ptm breadth does not show a significant difference when compared to the normal during the age-period 4:0–8:0. Furthermore, the points to which special attention should be paid in the present study are the changes in the nasal and maxillary breadths during the first postnatal year (Figure 4). In BCLP and UCLP, both breadths decrease between birth and 0:3 (prior to lip repair) and from four to six months (after lip repair), but the CP group showed a constant increase. The decrease in BCLP and UCLP is considered to be the effect of lip surgery and also to be a more desirable or adjustive change for future growth.

The present study also demonstrated that upper and lower dental arch breaths in all cleft-types are narrower compared to the Standard. However, the occlusal relationship shows only a slight cross-bite tendency in UCLP and no cross-bite in CP. We will present only a brief non-detailed summary, since Mazaheri and Harding *et al.* (1971) and Harding and Mazaheri (1972) have already reported the precise dental cast studies which deal with the same longitudinal data as does this study. It is suggested, remembering the mid-facial growth changes previously mentioned, in addition to the finding about cross-bite, that there is no need for early maxillary orthopedic treatment, although some cases may later require orthodontic expansion of the upper dental arch upon completion of the deciduous or permanent dentition.

The three cleft groups have a larger bigonial notch breath than the Standard.

This may be caused by a wider breadth between the right and left mandibular fossae of the temporal bone, which may be estimated because left patients have a wider bizygomatic arch breadth (Dixon, 1966).

FACIAL HEIGHT CHANGES IN CLEFT CHILDREN. As we stated earlier, there is no reason to feel that the lateral roentgenocephalogram is more reliable than the frontal for accurate facial height measurements, because a few degrees of up-down rotation make a greater error of height measurements on the P-A X-ray headfilm (Ishiguro, 1973).

It is to be conculded from this study that occlusal height, i.e., upper and lower dental arch, upper facial height, i.e., maxillary bone height, and posterior total facial height, i.e., gonial notch height, in cleft groups seem to be greater than in non-cleft children, although both maxillary bone and gonial notch heights are close to the non-cleft by 6:0, which supports our previous study (Krogman, et al., 1975). However, the greater maxillary bone height found in the present study does not agree with the results of other studies (Narula and Harris, 1970; Ross and Coupé, 1965; Ross and Johnston, 1967), which have found that maxillary height is either below or equal to the normal value. This disagreement may be the result of the measurements of different landmarks in the maxilla and the method error with P-A X-ray headfilms.

ANALYSIS OF GROWTH DIRECTION AND FACIAL SYMMETRY. For the purpose of the analysis of symmetry and growth direction, the co-ordinate system was applied by us, as it was by Harvold (1954) and others (Aduss and Pruzansky, 1967; Coupé and Subtelny, 1960.). Even though the methods of establishing a baseline were slightly different between Harvold and his associates and the present study, the baselines seemed to be acceptably similar.

In the upper face and mandible, there are no noteworthy differences among the cleft groups, in either growth direction or facial symmetry. It was only in the mid-facial and dental areas that differences were found.

Nasal aperture (Na) point of the mid-face showed a downward growth pattern from 0:3–6:0 in both the right and left sides of BCLP and the affected side of UCLP. This was accompanied by a lateral and downward growth pattern on the normal side of UCLP and on both sides of CP. It is an interesting point that the UCLP group has an asymmetrical growth pattern. According to the comparison of the Na-point between the normal and the affected side, this asymmetry was recognized as a wider breadth during the first three or four years, followed by narrower breadth on the affected side. However, there is no significant difference in the nasal height of UCLP between right and left sides. In other words, this is a medial displacement on the affected side (Coupé and Subtelny, 1960). The BCLP group does not show any evidence of asymmetry in the breadth and height of the Na-point. The downward growth of this point, as shown in BCLP and the affected side of UCLP, may be a better intrinsic growth direction, since the significantly wider nasal breadth at birth approximates normal breadth by this downward growth. The symmetric pattern of lateral and downward growth in the CP group seemed to be closer to the normal than was found in the other cleft groups investigated.

The growth direction of the maxillary (M) point was most often similar to that of the Na-point in each cleft-type. To clarify this description, one important growth change is to be noted, viz., the rapid lateral growth from 5:0–6:0 which is clearly seen in BCLP. This change may be closely related to the eruption of upper permanent first molars and may be considered to be a kind of "catch-up" lateral growth compensating for the narrow maxillary breadth around four or five years of age. We feel that it is extremely important to continue further investigation regarding mid-facial breadth growth change, especially catch-up growth, after the age-period of this study.

A slight cross-bite, which is noted on both sides in BCLP and on the affected side in UCLP, was almost unchanged in extent during the period investigated (3:0–6:0). Therefore, it may be concluded that the dental arch form is acceptably stable, with no tendency to collapse.

GROWTH SITES. It is well known that the bones of face increase in size by sutural growth, by surface apposition mainly on alveolar margins and maxillary tuberosity, and by cartilaginous growth at mandibular condyle and in the nasal septum. In this section, we shall discuss the facial growth sites in cleft lip and palate.

According to our investigation of breadth and height increments from 0:3–6:0, total facial breadth (zygomatic arch breadth), upper facial height (maxillary bone height), and total posterior facial height (gonial notch height) did not show a marked difference, between the right and left sides in any of the cleft groups or among cleft-types. The slight incremental difference in the UCLP(1) group may be due to sample size and the difficulty of determining the rest position before tooth eruption. This means that none of the cleft groups show an asymmetrical growth pattern or a marked difference between groups in total facial breadth and height. However, several components which form total facial breadth or upper facial height, demonstrated differential growth increments peculiar to the types of cleft.

In UCLP, the maxillary breadth increment is relatively inhibited on the affected side, but the increment of Z-M breadth (zygomatic arch minus maxilla breadth) on this side compensates for the insufficient maxillary breadth growth, so that the zygomatic breadth is almost identical on both sides. The same situation was found in other cleft groups. The proportion of Z-M breadth increments for the total facial breadth increments becomes larger in the order of CP, UCLP, and BCLP. The growth of this Z-M component may be due mainly to the growth at the zygomatico-maxillary suture. Considering that Coupé and Subtelny (1960) found that the zygomatico-maxillary suture breadth did not show a significant difference between the right and left sides or between any cleft group and the normal, it may be assumed that the more severe the clefting, the more the zygomatico-maxillary sutural growth is activated to compensate for the discrepancy between the wide upper facial breadth and the relatively narrow or "normal" maxillary breadth. We need experimental and histological support to confirm this hypothesis.

In height increments the nature of the upper facial height increment in BCLP presents another interesting finding. The increments in nasal and zygomatic arch height for maxillary height (upper facial height) were less than in other cleft groups. The smaller increment of nasal height may be due to insufficient growth at the maxillo-frontal suture and to deviation or shortness of the nasal septum. A further cause for the deficiency may be reduced zygomatico-frontal suture growth. These structural factors in BCLP may be related to a tendency to hypertelorism. Here, again, further studies are required.

Data are being collected annually in our longitudinal files. We shall later present a further growth study based on lateral and frontal roentgenocephalograms after the age period (0:3–6:0) reported in this study and in our previous work (Krogman, et al, 1975). We look also to exploring three-dimensional changes, employing XYZ coordinates, of cleft lip and palate, hoping that this will aid in the solution of many morphological growth problems in cleft cases.

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