Maxillary Arch Dimensions in Normal and Unilateral Cleft Palate Subjects

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If the upper jaws of normal children are compared with those with cleft lip and palate defects, certain fundamental differences of size and shape between them are apparent; these differences have been studied in some detail by Coupe and Subtelny (*2*), Peyton (*4, 5*), and Subtelny (*6*). Although these four studies have been cross-sectional in nature, they have usually included all the different types of cleft in the same investigation. In addition, the age range of the subjects studied was wide and so the number of cases of any one type in a particular age group was therefore rather small. In some cases there had also been surgical closure of the clefts before any measurements were made.

Peyton (*4, 5*) concluded there was probably little deficiency of tissue. Subtelny (*6*) showed that the nasopharynx and posterior part of the maxilla were significantly wider in subjects with cleft palate, and that the width was normal in children with only lip and alveolar clefts. Coupe and Subtelny (*2*) concluded that there was deficiency of tissue in all groups except those with lip and alveolar clefts, although there was considerable variation between individual cases. There was evidence of lateral displacement of the maxillary segments in all the groups they studied, although in the unilateral cases this was only present during the first year after birth.

The aim of the present investigation was to compare the maxillary arches of thirty normal children with thirty children with complete unilateral clefts of the lip, alveolus, and palate before the commencement of any treatment.

Procedure

The normal children were born in the Maternity Department, Copthorne Hospital, Shrewsbury, and the cleft palate subjects were among those referred to the Regional Plastic Surgery Unit from various parts of the Birmingham Regional Hospital Area.

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This study was carried out under the auspices of the Research Sub-Committee of the Birmingham Regional Hospital Board.

Impressions were taken of all the infants' upper jaws within fourteen days of birth using compound impression material (Paribar), and plaster models cast from these.

PHOTOCOPYING AND ANALYSIS OF MODELS. The measurement of a plaster model is greatly facilitated if it is graphically reproduced, so that only two of its three dimensions are considered at any one time. For the purpose of the present investigation, this was done by photocopying the models using a Rank-Xerox 914 photocopying machine. The technique for doing this had been developed in close cooperation with the Statistics Department, Birmingham Regional Hospital Board, for a previous study by one of the authors (*3*) to produce highly accurate graphic reproductions of models easily and rapidly.

The main error present when reproducing the horizontal view was found to be due to the model's having depth. This, however, can be reduced to a constant and insignificant amount if the model is orientated in a constant horizontal plane, and if it is always located in the same position in the photocopying apparatus. Because of the scarcity of landmarks on the predeciduous maxillary models, the only reasonable plane of orientation that could be used was the one which the model assumed when placed face downwards on its alveolar ridges on a flat surface, and so that position was used. The constancy of its location was obtained by means of a sheet of plastic, which had a small square opening cut out of its center, just large enough to accommodate the model and which accurately covered the glass window of the photocopying machine. The model was placed face downwards on the glass window of the machine and the center line of the nasal septum in cleft cases (or the midline in normal cases) made to correspond with a mark in the center of one side of the square opening in the center of the plastic sheet.

In order to assist in the identification of landmarks on the horizontal view, the following were marked on the cleft models, prior to photocopying: the crest of the alveolar ridge; the margins of the cleft; the anteroposterior line of the posterior third of the underside of the nasal septum (the para-midline plane); the posterior limit of the crest of the alveolar ridge, (postgingivale) on either side; and a line joining the anterior dental papilla to the upper labial frenum.

Marked on the casts for the normal subjects were the crest of the alveolar ridge; the posterior end of the median palatal raphé; and a line joining the anterior dental papilla to the upper labial frenum. To reduce the possibility of error in the location of these points, the models were duplicated using a high accuracy duplicating material, and the duplicate models similarly marked.

All the markings on the models were done by one member of the team (A.G.H.). The original and duplicate models were then each photocopied twice to reduce any error involved in locating the points marked on the models on the photocopies, and also to reduce any error involved in the drawing of construction lines. Finally, all measurements were taken twice to reduce experimental error still further.

THE HORIZONTAL VIEW. Landmarks and factors are defined in Figure 1. On the photocopies, the point where a line which joined the anterior dental papilla to the labial frenum crossed the crest of the alveolar ridge was designated as point A; this corresponded to Prosthion on the plaster model.

Since in unilateral cleft palate cases, the midsagittal plane cannot be identified, the line of the underside of the posterior third of the nasal septum was used as the anteroposterior plane of reference instead and was designated as the 'para-midline plane'.

All transverse lines were drawn and measurements made at 90° to this plane. In the normal subjects with intact palates the anteroposterior midline plane was obtained by joining point A to the posterior end of the median palatal raphé.

When demarcating the area to be studied, while the crest of the alveolar ridge formed a convenient and readily identifiable boundary anteriorly and laterally, it was difficult to define an acceptable posterior limit. This problem was handled by postulating that the posterior boundary should be a specific distance from point A.

Preliminary studies made by one of the authors (A.G.H.) prior to investigating the changes resulting from presurgical dental orthopedic treatment (*3*) established that a distance of 20 mm was the most suitable value to use for the purpose of measuring maxillary arch form and dimension at birth.

A posterior palatal plane was, therefore, constructed 20 mm from point A and at 90° to the para-midline plane (or the corresponding plane in the normal cases). Where the posterior palatal plane cut the crest of the alveolar ridge on the greater segment was designated as point B and, on the lesser segment, point C.

In the normal subjects, point B was on the crest of the *right* alveolar ridge and C on the *left* (Figure 2). The other specific landmarks used are illustrated and defined in Figure 1 for the cleft subjects and Figure 2 for the normals.

THE TRANSVERSE VIEW. To complete the measuring and analysis of the models, the duplicate models were sectioned transversely along the posterior palatal plane and the cut surface also photocopied twice. Prior to this, however, the base of the model was trimmed parallel to the horizontal plane of orientation to enable the slope of the palatal shelves (the sides of the palate) relative to the horizontal plane to be determined by measuring the angle between the shelves and the base of the model.

Also prior to photocopying, to assist in identification, the crest of the alveolar ridge on each side and the margins of the palatal cleft were marked on the cut surface of the cleft models. In the normal group,

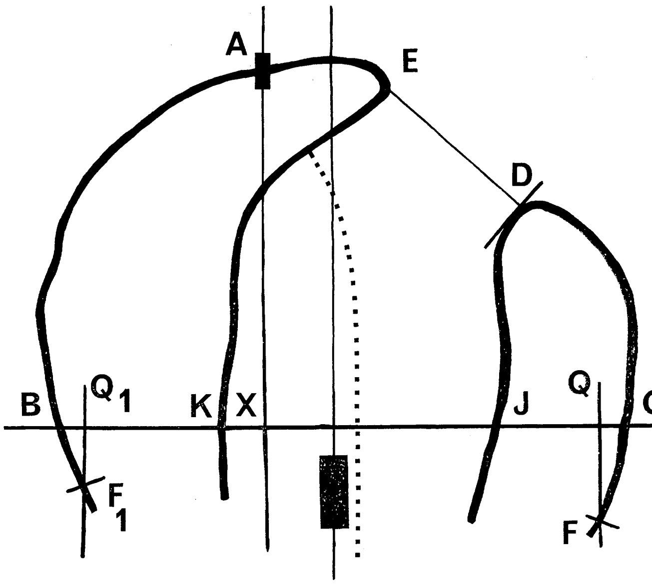

FIGURE 1. Diagram of a photocopy of a maxillary arch with a unilateral cleft of the lip, alveolus, and palate in the horizontal view. The thick outlines represent the crest of the alveolar ridges and margins of the cleft. The nasal septum is represented by the dotted line and the line of its posterior third is extended to form the para-midline plane. The following points are marked: A, where a line which joins the anterior dental papilla to the labial frenum crosses the crest of the alveolar ridge (this corresponds to Prosthion on the original model); B, where the posterior palatal plane, which is drawn at 90° to the para-midline plane and at a distance of 20 mm from A, crosses the crest of the alveolar ridge on the greater segment; C, where the posterior palatal plane crosses the crest of the ridge in the lesser segment; D, where a line at 45° to the posterior palatal plane touches the anterior end of the lesser segment; E, where a line parallel to the para-midline plane touches the anterior end of the greater segment; F, postgingivale on the lesser segment; F_1, postgingivale on the greater segment; J, where the posterior palatal plane cuts the margin of the palatal cleft on the lesser segment; K, where the posterior palatal plane cuts the margins of the palatal cleft on the greater segment; Q, where a line through F parallel to the para-midline plane cuts the posterior palatal plane; Q_1, where a line through F_1 parallel to the para-midline plane cuts the posterior palatal plane; X, where a line through A parallel to the para-midline plane cuts the posterior palatal plane.

The following factors were measured or calculated: Factor Ha, overall size, the area enclosed by a line ABCDEA; Factor Hb, cleft area, the area enclosed by a line EKJDE; Factor Hc, greater segment area, the area enclosed by a line ABKEA; Factor Hd, greater segment tissue area, Hc/cosine angle Tj (Tj is defined in Figure 4); Factor He, lesser segment area, the area enclosed by a line DJCD; Factor Hf, lesser segment tissue area, He/cosine angle Tl (Tl is defined in Figure 4); Factor Hg, total tissue area, Hd + Hf; Factor Hh, posterior arch width, line BC; Factor Hi, intact side width, line BX; Factor Hk, cleft side width, line CX; Factor Hm, ratio of asymmetry, BX/CX; Factor Hn, palatal cleft width, line JK; Factor Ho, position of postgingivale (greater segment), line Q_1F_1; Factor Hp, position of postgingivale (lesser segment), line QF; Factor Hq, retroposition of lesser segment, $QF - Q_1F_1$.

the crest of the alveolar ridge was marked on each side and also the median palatal raphé. All the above markings were done by one author (A.G.H.) The landmarks used are illustrated and defined in Figure 3 for the normal subjects and Figure 4 for the cleft subjects.

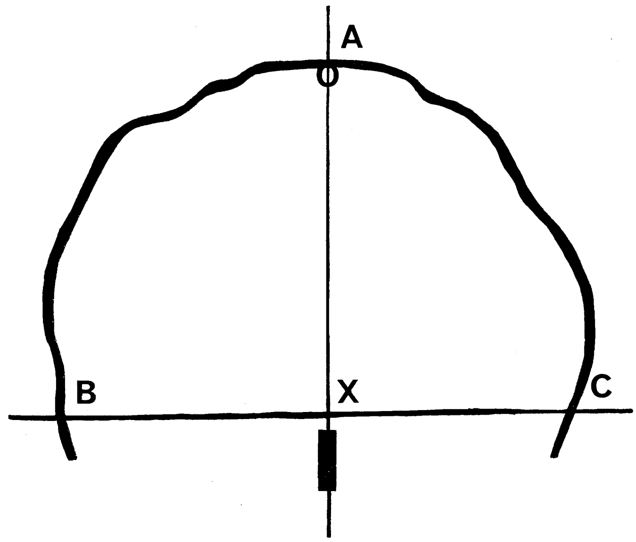

FIGURE 2. Diagram of a photocopy of a normal maxillary arch in the horizontal view. The thick outlines represent the crest of the alveolar ridge and, in the midline, the posterior end of the median palatal raphé. The midline plane was defined as a line joining point A (defined in Figure 1) to the posterior end of the median palatal raphé. Other landmarks are B, where the posterior palatal plane, drawn at a distance of 20 mm from A and at 90° to the midline plane, cuts the crest of the alveolar ridge on the right side; C, where the posterior palatal plane cuts the crest of the alveolar ridge on the left side; X, where the posterior palatal plane cuts the midline plane.

Factors are as follows: Factor Ha, overall size, the area enclosed by the line ABCA; Factor Hg, total tissue area, Ha/cosine [Tk + Tm)/2] (Tk and Tm are defined in Figure 3); Factor Hh, posterior arch width, line BC; Factor Hj, normal right side width, line BX; Factor Hl, normal left side width, line CX; Factor Hm, ratio of asymmetry was computed as lesser width/greater width, i.e., Hj/Hl or Hl/Hj (see text).

Measurement Technique. In the normal cases, the factors investigated on the horizontal photocopies are given in Figure 2 and, in the transverse section photocopies, in Figure 3. In the cleft subjects, the factors investigated on the horizontal photocopies are shown in Figure 1 and, on the transverse, in Figure 4. All measurements were made twice on each photocopy to reduce observer error.

On the horizontal views, therefore, because the original and duplicate models had each been photocopied twice, each factor studied was measured eight times and from these a mean value for the measure obtained.

On the transverse views, however, because only the duplicate model had been sectioned and photocopied, each factor was only measured four times. Linear measurements were made with a Vernier caliper gauge reading to 0.1 mm and area measurements with a planimeter.

All factors studied are identified by letters as shown in the legends to Figures 1–4 and are presented in Tables 1 and 2 for easy reference. Factors studied in the horizontal photocopies are prefixed with H (Ha,

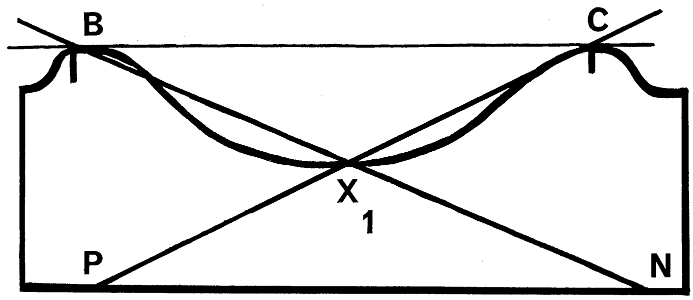

FIGURE 3. Diagram of a photocopy of a normal maxillary arch in the transverse view. The section is made in the posterior palatal plane (line BC in Figure 2) and the base of the model is trimmed so as to be horizontal when the model rests face downwards on its alveolar ridges. Landmarks are B, crest of the alveolar ridge on the right side; C, crest of the alveolar ridge on the left side; X_1, median palatal raphé; N, where the extension of the straight line BX_1 cuts the base of the model; P, where the extension of the straight line CJ_1 cuts the base of the model.

The following factors were measured or calculated: Factor Ta, cross-sectional area, B (along the palate) X_1 (along the palate) CB; Factor Tb, mean palatal height, Ta/Hh (Hh is defined in Figure 2); Factor Tc, unit palatal height, Tb/Hh; Factor Te, normal right tissue width, straight line BX_1; Factor Tg, normal left tissue width, straight line CX_1; Factor Ti, total normal tissue width, Te + Tg; Factor Tk, right palatal slope, angle BNP (the line BC is not used for measuring the slope of the sides of the palate because local vertical variations in the height of the alveolar ridge at B or C could mean this line was not parallel to the horizontal plane of orientation which the models adopted when laid face downwards on their alveolar ridges); Factor Tm, left palatal slope, angle CPN.

Hb, Hc, *et cetera*) and, in the transverse photocopies, with T (Ta, Tb, Tc, *et cetera*).

Results

The results were subjected to statistical analysis. The mean values for the various factors, the range of values, SDs, and results from statistical tests of significance are summarized in Tables 1 and 2.

The greater segment tissue area (Hd) was on the average 64.84% of the total tissue area (Hg) and the correlation coefficient between them was .74 (significant at .1%). The lesser segment likewise had a tissue area (Hf) on the average 35.16% of the total tissue area, with a correlation coefficient between the two of .54 (significant at 1%). There was no significant correlation, however, between the area of tissue on the greater segment and that on the lesser segment.

In the cleft palate subjects, the posterior arch width (Hh) was 7.75 mm greater than in the normals; this was considered to be due to lateral segmental displacement, as suggested by Subtelny (*6*). If this is related to the palatal cleft width (Hn) however, which was 14.41 mm on average, the width of the cleft remaining, after allowance had been made for any widening due to segmental displacement, was 6.66 mm (that is 14.41 minus 7.75 mm).

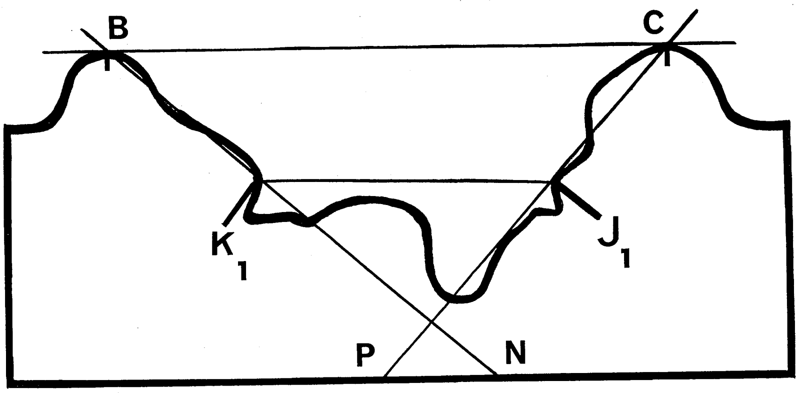

FIGURE 4. Diagram of a photocopy of a maxillary arch with a unilateral cleft of the lip, alveolus, and palate in the transverse view. The section is made in the posterior palatal plane and the base of the model is trimmed, so that it is horizontal when the model is placed face downwards on its alveolar ridges. Landmarks are B, crest of the alveolar ridge on the greater segment; C, crest of the alveolar ridge on the lesser segment; J_1, margin of the palatal cleft on the lesser segment; K_1, margin of the palatal cleft on the greater segment; N, where the extension of the straight line BK_1 cuts the base of the model; P, where the extension of the straight line CJ_1 cuts the base of the model.

The following factors were measured or calculated: Factor Ta, cross-sectional area, the area enclosed by a line B (along the palate) K_1J_1 (along the palate) CB; Factor Tb, mean palatal height, Ta/Hh; Factor Tc, unit palatal height, Tb/Hh; Factor Td, greater segment tissue width, straight line BK_1; Factor Tf, lesser segment tissue width, straight line CJ_1; Factor Th, total cleft tissue width, Td + Tf; Factor Tj, greater segment slope, angle BNP; Factor Tl, lesser segment slope, angle CPN.

The total tissue width in the cleft cases (Th), however, amounted to 26.01 mm, compared to 30.13 mm in the normal cases (Ti) and there was therefore a tissue deficiency of 4.12 mm (13.7% of the mean tissue width of the normal palates) in the posterior palatal plane (significant at .1%).

Nevertheless, this still left 2.54 mm (6.66 minus 4.12 mm) of the cleft width unaccounted for by either segmental displacement or tissue deficiency. A possible explanation of this is the much steeper slope of the palatal shelves in the cleft subjects (Tj and Tl) as compared with Tk and Tm in the normal group (Figure 5). Using the results obtained, it can be calculated that in the posterior palatal plane, the width of the cleft is made up of the following factors in the following proportions: lateral displacement of segments, 53.78%; deficiency of tissue, 28.59%; and increased slope of the palatal shelves, 17.63% (Figure 6).

The difference between the overall size of the arches (Ha) in the two groups was 80.54 mm^2, and showed the cleft subjects to have significantly larger arches but, nevertheless, there was a mean tissue deficiency of 104.94 mm^2 in this group. On the average, the area of the cleft was 230.00 mm^2 but tissue deficiency and lateral segmental displacement only accounted for a cleft area of 185.48 mm^2 (80.54 plus 104.94 mm^2).

TABLE 1. Results of study of horizontal view. Factors are described in detail in Figures 1 and 2. Asterisks indicate significance at .1% level.

factor	*Ha*	*Hb*	*Hc*	*Hd*	*He*	*Hf*	*Hg*	*Hh*	*Hi*	*Hj*	*Hk*	*Hl*	*Hm*	*Hn*	*Ho*	*Hp*	*Hq*
general description	*overall size (mm²)*	*cleft area (mm²)*	*greater segment area (mm²)*	*greater segment tissue area (mm²)*	*lesser segment area (mm²)*	*lesser segment tissue area (mm²)*	*total tissue area (mm²)*	*posterior arch width (mm)*	*intact side width (mm)*	*normal right side width (mm)*	*cleft side width (mm)*	*normal left side width (mm)*	*ratio of asymmetry*	*palatal cleft width (mm)*	*pos. of postging-ivale (greater segment) (mm)*	*pos. of postging-ivale (lesser segment) (mm)*	*retroposition of lesser segment (mm)*
clefts																	
minimum	468.75	160.00	173.75	215.06	73.75	97.72	360.99	28.49	8.2	—	19.0	—	0.29	10.35	−4.2	−0.7	−0.2
mean	586.21	230.00	238.71	290.26	115.96	157.39	447.65	35.13	13.14	—	22.02	—	0.605	14.41	0.09	4.32	4.23*
SD	49.81	47.11	33.04	40.35	22.55	30.42	46.60	3.14	2.48	—	2.14	—	0.13	1.87	2.51	3.06	2.83
maximum	612.50	371.25	315.00	382.50	173.75	229.76	537.24	41.66	19.20	—	27.8	—	0.89	17.96	6.1	12.9	13.4
normals																	
minimum	455.00	—	—	—	—	—	480.57	22.6	—	12.6	—	12.00	0.79	—	—	—	—
mean	505.67	—	—	—	—	—	552.59	27.38	—	13.98	—	13.54	0.922	—	—	—	—
SD	33.42	—	—	—	—	—	40.63	2.98	—	1.55	—	1.70	0.01	—	—	—	—
maximum	588.75	—	—	—	—	—	672.10	37.15	—	18.15	—	18.80	0.99	—	—	—	—
difference between means	80.54*	—	—	—	—	—	104.94*	7.75*	0.84		8.48*		0.317*	—	—	—	—

TABLE II. Results of study of transverse view. Factors are described in detail in Figures 3 and 4. One asterisk indicates significance at .1% level, two asterisks indicate significance at 1% level.

factor	*Ta*	*Tb*	*Tc*	*Td*	*Te*	*Tf*	*Tg*	*Th*	*Ti*	*Tj*	*Tk*	*Tl*	*Tm*
general description	*cross sectional area (mm^2)*	*mean palatal height (mm)*	*unit palatal height (mm)*	*greater segment tissue width (mm)*	*normal right tissue width (mm)*	*lesser segment tissue width (mm)*	*normal left tissue width (mm)*	*total tissue width (clefts) (mm)*	*total tissue width (normals) (mm)*	*greater segment slope (degrees)*	*right palatal slope (degrees)*	*lesser segment slope (degrees)*	*left palatal slope (degrees)*
clefts													
minimum	105.00	3.37	0.09	8.85	—	9.82	—	19.04	—	22.25	—	32.50	—
mean	178.33	5.04	0.14	13.14	—	12.87	—	26.01	—	34.13	—	42.07	—
SD	40.54	0.94	0.03	1.86	—	1.30	—	2.959	—	5.74	—	4.95	—
maximum	260.00	6.67	0.19	16.60	—	15.62	—	31.72	—	44.87	—	51.50	—
normals													
minimum	50.0	2.10	0.08	—	12.3	—	12.4	—	25.30	—	16.0	—	14.75
mean	94.50	3.38	0.12	—	15.13	—	15.00	—	30.13	—	23.25	—	23.65
SD	32.46	0.795	0.02	—	2.05	—	1.84	—	3.405	—	3.60	—	3.16
maximum	220.00	6.04	0.17	—	20.3	—	21.5	—	41.80	—	30.0	—	29.00
difference between means	83.83**	1.663*	0.018**	1.99*		2.13*		4.12*		10.88*		18.42*	

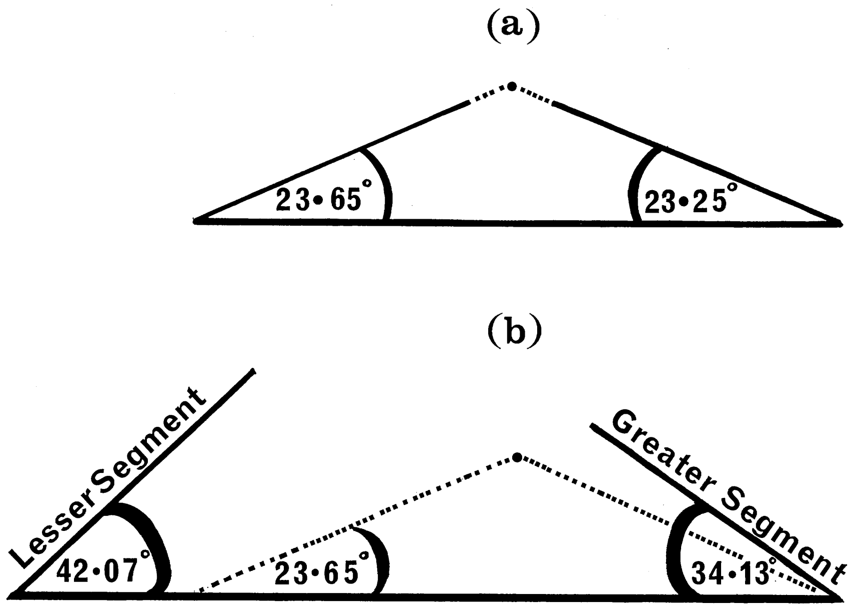

FIGURE 5. (a) Diagram showing the width of the palatal cleft due solely to a 13.7% tissue deficiency. The angle of slope corresponds to that of the sides of normal palate. (b) Diagram showing the width of a palatal cleft due to a 13.7% tissue deficiency in association with lateral segmental displacement and an increased slope of the palatal shelves. The amount of displacement, and the slope of the sides of the palate shown, represent the average values in the cleft cases studied. For comparison, a normal palate is represented by the dotted lines and the two are superimposed on point B (the crest of the alveolar ridge on the greater segment). This does not imply, however, that the lateral displacement is due solely to movement of the lesser segment.

There was, therefore, 44.52 mm^2 of the cleft area unaccounted for by either tissue deficiency or lateral segmental displacement.

Bearing in mind the effect already noted in the transverse plane of the increased slope of the palatal shelves, it seems probable that this factor is also responsible for the discrepancy of 44.52 mm^2 in the horizontal plane.

In the horizontal photocopies, some of the tissue was outside the area studied (that is, posterior to the posterior palatal plane) because of retroposition of the lesser segment relative to the greater (Hq). The area of tissue on the lesser segment consequently excluded from being measured as a result of this was 12.87 mm (lesser segment tissue width, Tf) times 4.23 mm (amount of retroposition, Hq) *equals* 54.44 mm^2.

In the horizontal plane, therefore, the cleft is due to the following factors in the following proportions (Figure 7): a) lateral displacement of the segments, 35.02%; b) retroposition of the lesser segment, 23.67%; c) deficiency of tissue, 21.95%; and d) increased slope of the palatal shelves, 19.36%.

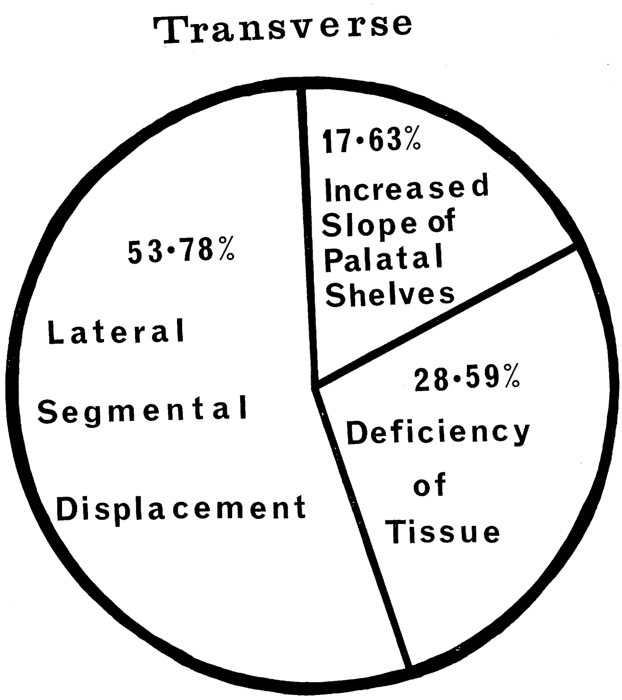

FIGURE 6. Diagram illustrating the percentage contribution made by deficiency of tissue, lateral segmental displacement, and increased slope of the palatal shelves towards the width of the palatal cleft.

Discussion

The present study confirms the views of earlier workers, insofar as they apply to unilateral clefts of the lip and palate, that the posterior arch width (Hh) is significantly wider than normal in these cases. This also applies to the overall size of the arch (Ha) as well. Our findings agree with the explanation given by Subtelny (*6*) that the difference is due to the unopposed pull of the pterygoid muscles in the absence of a functional tensor palati muscle, although the effect of the tongue forcing its way into the cleft must also be taken into account.

The investigations also showed that in the transverse plane, of the three factors contributing to the width of the cleft (lateral segmental displacement, tissue deficiency and increased slope of the palatal shelves), it is the first of these, lateral segmental displacement, which is the most important, being responsible for over half the width of the cleft.

Whether or not, however, the greater and lesser segments both participate or whether this is confined to the lesser segment only is impossible to say. In the horizontal plane, segmental displacement was also seen as a retroposition of the lesser segment relative to the greater, and, in this

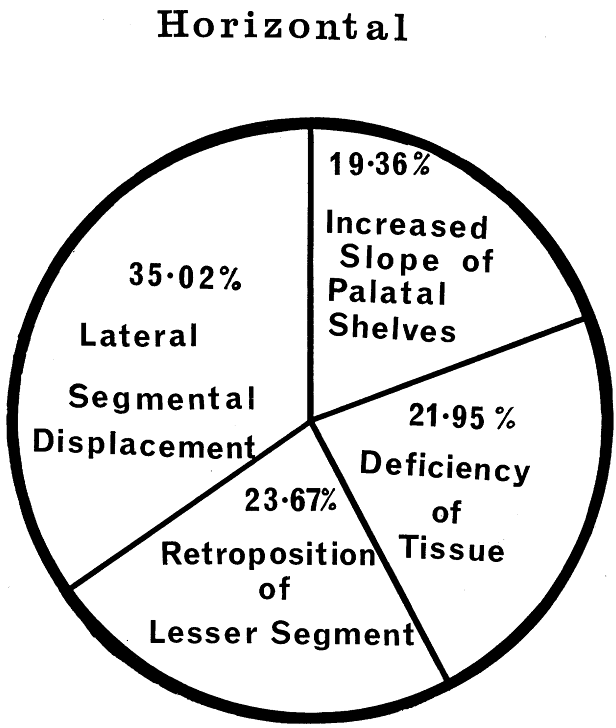

FIGURE 7. Diagram illustrating the percentage contribution made by deficiency of tissue, lateral segmental displacement, retroposition of the lesser segment, and the increased slope of the palatal shelves towards the area of the cleft.

plane, there was a tissue deficiency of 18.95% compared to 13.7% in the transverse plane. If the tissue was included, however, which was originally not measured because it lay posterior to the posterior palatal plane (due to retroposition of the lesser segment), the tissue deficiency in the horizontal plane decreased to 9.10%. This implies that there is a greater formation of tissue anteriorly than posteriorly in unilateral cleft cases, but that this tissue is displaced backwards away from the front of the mouth, thereby increasing the width of the alveolar cleft. This makes more tissue available posteriorly for the creation of a long functional soft palate, thereby perhaps aiding speech, in contrast to cases of simple cleft palate only, where segmental retroposition cannot occur.

Because of the confusion which might easily arise when discussing tissue deficiency, particularly in the horizontal plane, great care must be taken by future investigators in this field to clearly define descriptive terms and areas of measurement. Only by such efforts can results of different studies be compared.

Although, on the average, the cleft group had a transverse tissue deficiency of 13.7%, it was thought that some of the subjects might not have any deficiency at all, particularly in the heavier babies, since statistical investigation had shown a correlation coefficient of 0.53 (significant at 1%) between birth weight and total tissue width (Th), and a coefficient of 0.71 (significant at .1%) between birth weight and total tissue area (Hg).

Both normal and cleft subjects were accordingly grouped into a series of weight ranges and average values obtained for total tissue area (Hg) and total tissue width (Th and Ti) for both the cleft and the normal cases in each.

When these were compared (Table 3) it was found that the average values for the cleft subjects were still less than the normal averages in any given weight range. Within the weight groups, therefore, each cleft subject was now examined to see whether the total tissue width lay above the average values for the normal subjects in the weight group, or between the normal and cleft average values, or below those for the cleft subjects (Table 4).

No cleft subjects were found with a greater-than-normal tissue area or tissue width, with the exception of 3 cases in Group 3 (6 lbs., 8 oz., to 7 lbs., 7 oz. weight).

While the smallness of the numbers available in each weight range must limit the significance of these findings, nevertheless there does seem to be an indication that most of the cleft subjects had a deficiency of tissue, both of area and width to a greater or lesser extent. Somewhat unexpectedly, the increased steepness of the sides of the palate in the cleft subjects (Tj and Tl) appeared to make a not inconsiderable contribution to the width (17.63%) and area (19.36%) of the cleft. It must be emphasized, however, that although the increased slope of the palatal shelves increase the width of the palatal cleft (as defined in the study by the distance KJ in Figure 1 and K_1J_1 in Figure 4) the width of the actual opening into the nasal cavity might conceivably, on occasions, be narrowed by the proximity of the free margin of the palatal shelf of the lesser segment to some structure in the nasal cavity not studied in this investigation, even though the width KJ was increased in the process. The practical significance of this, however, is probably not very great.

In the case of the lesser segment, where the palatal slope was almost twice the normal steepness, the shelf appeared like an incompetent valve, being forced open by pressure from the tongue. On the greater segment, the increased slope of the palatal shelf could possibly be due to lack of downward growth of the nasal septum. The lateral displacement of the whole of the underside of the septum towards the intact side in unilateral cases, which has already been noted by Atherton (*1*), might also be a factor as well.

One result of the greater steepness of the sides of the palate in conjunction with the lateral segmental displacement was to almost double the cross-sectional area of the palate (Ta) in the cleft subjects. In consequence, atypical muscle behavior patterns of the tongue might pos-

TABLE III. Tissue area (in mm^2) and total tissue width (in mm) for cleft and normal groups, by birth weight category.

group	*birth weight category (lbs, oz)*	*N*	*birth weight (lbs, oz)*		*tissue area (mm^2) Hg, both groups*		*total tissue width (mm) Th, clefts; Ti, normals*	
			mean	*range*	*mean*	*range*	*mean*	*range*
normal	less than 5, 8	5	5, 4	5, 0 to 5, 7	516.35	502.29 to 530.36	27.51	25.30 to 29.50
cleft		4	5, 0¾	4, 7¾ to 5, 5	392.26	377.16 to 410.53	22.25	19.04 to 24.34
normal	5, 8 to 6, 7	7	6, ½	5, 10 to 6, 7	556.69	494.47 to 672.10	31.01	25.30 to 41.80
cleft		5	6, 0	5, 14 to 6, 5	406.31	360.99 to 473.54	23.93	22.22 to 26.00
normal	6, 8 to 7, 7	7	6, 14½	6, 8 to 7, 7	535.61	480.57 to 563.91	29.37	28.0 to 31.6
cleft		10	7, 0	6, 11 to 7, 7	451.87	396.06 to 519.69	27.55	23.07 to 31.72
normal	7, 8 to 8, 7	8	7, 15	7, 8 to 8, 4	570.75	542.18 to 600.51	31.85	29.2 to 32.9
cleft		8	7, 14	7, 9 to 8, 0	481.75	446.29 to 516.38	26.53	22.40 to 29.44
normal	more than 8, 8	3	8, 13½	8, 8 to 9, 0½	594.61	558.36 to 642.60	32.93	30.5 to 36.6
cleft		3	8, 14	8, 8 to 9, 6	485.43	417.59 to 537.24	28.44	27.63 to 29.69
group mean								
normal		30	6, 14		552.59		30.13	
cleft		30	7, 0		447.65		26.01	

TABLE IV. Tissue area (in mm²) and tissue width (in mm) of cleft palate subjects for three categories relative to the average for the normal group, by birth weight category. For example, in no instance does a cleft palate subject have a tissue area greater than the average for normal subjects in the same birth weight group; only three cleft palate subjects have a tissue width greater than the average for normal subjects in the same birth weight group.

category	*birth weight categories*									
	less than 5 lbs, 8 oz		*5 lbs, 8 oz to 6 lbs, 7 oz*		*6 lbs, 8 oz to 7 lbs, 7 oz*		*7 lbs, 8 oz to 8 lbs, 8 oz*		*more than 8 lbs, 8 oz*	
	range	*N*	*range*	*N*	*range*	*N*	*range*	*N*	*range*	*N*
tissue area (mm²)										
1. less than average for cleft group	less than 392.26	2	less than 406.31	3	less than 451.87	6	less than 481.75	4	less than 485.43	1
2. between averages for normal and cleft groups	392.26 to 516.35	2	406.31 to 556.69	2	451.87 to 535.61	4	481.75 to 570.75	4	485.43 to 594.61	2
3. greater than average for normal groups	more than 516.35	0	more than 556.69	0	more than 535.61	0	more than 570.75	0	more than 594.61	0
tissue width (mm)										
1. less than average for cleft group	less than 22.25	2	less than 23.93	2	less than 27.55	5	less than 26.53	3	less than 28.44	2
2. between averages for normal and cleft groups	22.25 to 27.51	2	23.93 to 31.01	3	27.55 to 29.37	2	26.53 to 31.85	5	28.44 to 32.93	1
3. greater than average for normal groups	more than 27.51	0	more than 31.01	0	more than 29.37	3	more than 31.85	0	more than 32.93	0

sibly arise in cleft cases due to the larger size of the oral cavity within which the tongue must function. The need to seal off the nasal cavity from the mouth during feeding could also be an important factor in producing possible myo-functional disturbances, but in the present state of knowledge the connection between this and later speech difficulties is, at the moment, impossible to evaluate.

The values obtained for the widths of the intact side of the cleft group (Hi) and for the widths of the right and left sides of the normal palates (Hj and Hl) were almost identical. These similarities would appear to indicate that, if the anterior end of the greater segment is displaced to the unaffected side, the displacement affects the whole of the arch on that side, and not just the anterior portion.

The ratios of asymmetry (Hm) for the two groups show conclusively that unilateral cleft lip and palate cases are very asymmetrical at birth as compared with normal babies. In the cleft group the mean ratio of asymmetry was 0.605. In none of the thirty individuals was it greater than 1.0; no subject, then, showed medial "collapse" of the lesser segment at birth.

In the normal cases, the individual ratios of asymmetry were calculated as lesser width/greater width (that is, Hj/Hl or Hl/Hj, as the case might be); the average ratio was 0.922. This is an index of the general asymmetry of the arch in newborn normal infants, but it does not say whether it is left or right sided. Nevertheless, the results show that, even in normal cases, some asymmetry is present within the first fourteen days after birth. Whether this is merely birth moulding or whether it persists, and if so, for how long, is not ascertainable from the present investigation.

Summary

Thirty newborn normal children and 30 newborn children with complete unilateral clefts of the lip and palate were compared by measuring photocopies taken in the horizontal and transverse planes of models of their upper jaws. Highly significant differences were found between the two groups, including a 13.7% tissue deficiency in the posterior palatal plane. The width of the cleft, however, was mainly due to displacement of the bony segments, although the increased steepness of the sides of the palate also played a part. The segmental displacement was demonstrated in the lateral dimension as well as anteroposteriorly, as a retroposition of the lesser segment relative to the greater. That displacement was responsible for 23.67% of the area of the cleft. The implications of these and other findings are considered.

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