A Roentgen Stereophotogrammetric Study of Implant Stability and Movement of Segments in the Maxilla of Infants with Cleft Lip and Palate

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Three implants (tantalum pins 1.5 × 0.5 mm) were inserted in each lateral segment of the *cleft maxilla* of ten *infants* aged three to 33 months. To check the *stability of the implants* in the bone the distances between the three implants within each segment were measured by means of *roentgen stereophotogrammetry* (accuracy 0.05 mm) at intervals of 7, 35, 63, 147, and 287 days after the initial examination and at varying intervals thereafter (maximal observation time 833 days). No implants were lost and 18 of 60 measured distances were stable (final changes less than 0.2 mm). The three implants were regarded as a rigid-body model which represented the segment in the calculations of motion. In all infants with complete clefts, transverse narrowing occurred immediately after primary closure of the lip, or primary palate repair, while subsequent movement followed individual patterns.

Introduction

In roentgen studies of facial growth in man, metallic implants have been used as bone markers for more than 20 years. Standardized lateral of posteroanterior cephalograms have been superimposed and changes in position between the bones studied independently of changes in bone contours as described by Björk (1955, 1963, 1968).

To be valid as measurement points, the implants must remain in their original positions in the bone. However, this stability has not been ascertained in two-dimensional coordinate systems.

In a roentgen stereophotogrammetric method developed for the study of movement between bones (Selvik, 1974), implant stability is checked three-dimensionally with a high degree of accuracy. The method was used in a study of the cleft maxilla in three infants (Rune et al., 1977a, 1977b), and it was found that movement between the segments could be recorded provided the implants remained stable. After this finding, it was decided to study implant stability in an extended number of infants and to record movement between the segments within a programmed examination schedule after primary closure of the lip or after primary palate repair.

Materials and Methods

MATERIAL. The sample consisted of ten consecutively admitted infants, aged three to 33 months. Seven had complete unilateral clefts of the lip and palate (UCLP), six on the left (Patients 2, 3, 5, 6, 7, and 9) and one on the right side (Patient 1). Two patients had bilateral clefts of the lip and palate (BCLP) (Patients 4 and 10), and one patient had a cleft of the lip and primary palate (UCL) on the right side (Patient 8).

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IMPLANTS. At the time of primary closure of the lip (lip adhesion) (Patients 1 and 9) or primary palate repair (Patients 2, 3, 4, 5, 6, 7, and 10), three implants (tantalum pins 1.5 × 0.5 mm) were inserted in each lateral segment of the maxilla (Figure 1). In Patient 8 the implants were inserted at the time of tympanotomy.

ROENTGEN EXAMINATION. Initially, stereo roentgenograms of the infants were obtained one to four days after the insertion of the implants and thereafter at programmed intervals of about 7, 35, 63, 147, and 287 days (except Patient 8) (Figure 2 and 3, Table 1).

Orientation for stereo roentgenography. During exposure the child's head was placed in the calibration cage (Figure 2). At the initial examination the head was oriented with its cardinal axes (Figure 4) parallel to the axes of the laboratory coordinate system of the cage. In all subsequent examinations the implant configuration in the reference segment, i.e. the maxillary segment which was regarded as fixed, was reoriented to its initial position in the laboratory coordinate system by computer operation. This technique eliminated identical orientation of the head.

Calculations. Implants are used as the only measurement points in the roentgen stereometric method. The stability of the implants in the bone is checked at each examination by calculating the distance between either of the two implants in each segment and comparing the actual value to that of the initial or the preceding examination. Two implants in the same segment are regarded as stable in the bone when the distance between them had changed by less than 0.2 mm. Three implants in one segment are regarded as a rigid-body model (R-B M), and the validity of the R-B M is ascertained at each examination in a test of rigid-body fitting. The resultant mean error (ME) includes deviations of the implants from their original positions in the bone and measurement errors.

The R-B M's represent the segments in the calculations of motion. Movement between the R-B M's is calculated from their original positions in the coordinate system of the initial examination and is expressed in terms of rotations about and translations along the cardinal axes of the head (Figure 4). Classic kinematic principles for rigid-body movement are used. The rotation angles are valid for any part of the bone segment provided no deformity of the bone occurs. Translation is calculated for the center of gravity of the R-B M. For a complete account of the roentgen stereophotogrammetric method see Selvik (1974).

The term "non-cleft segment" was used for the maxillary bone on the unaffected side and "cleft segment" for the maxillary bone lateral

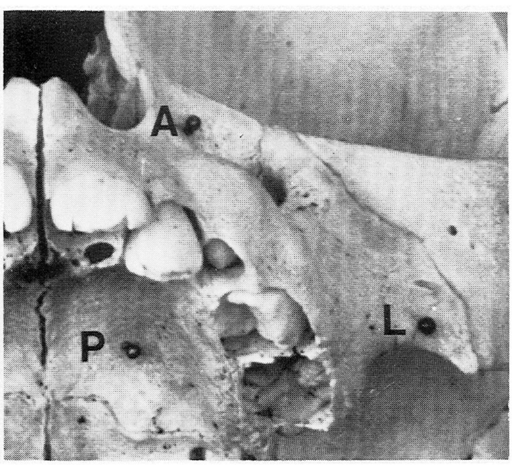

FIGURE 1. Locations of implants. L = inferior ridge of the infrazygomatic crest; A = anterior aspect of the maxilla, medial to and at the level of the infraorbital foramen; P = oral aspect of the palatal shelf halfway between the incisive foramen and the transverse palatine suture.

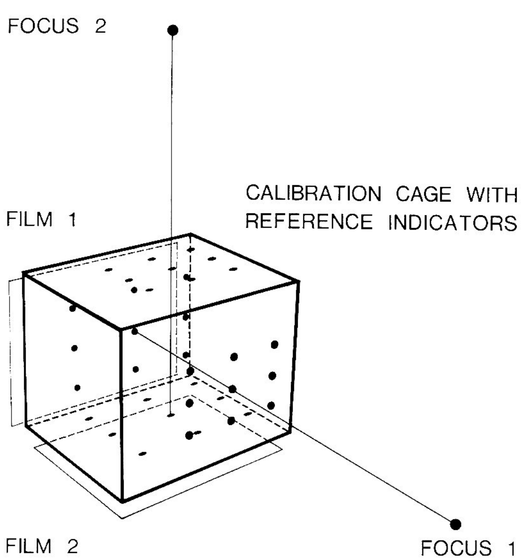

FIGURE 2. Set-up for roentgen stereophotogrammetric recording.

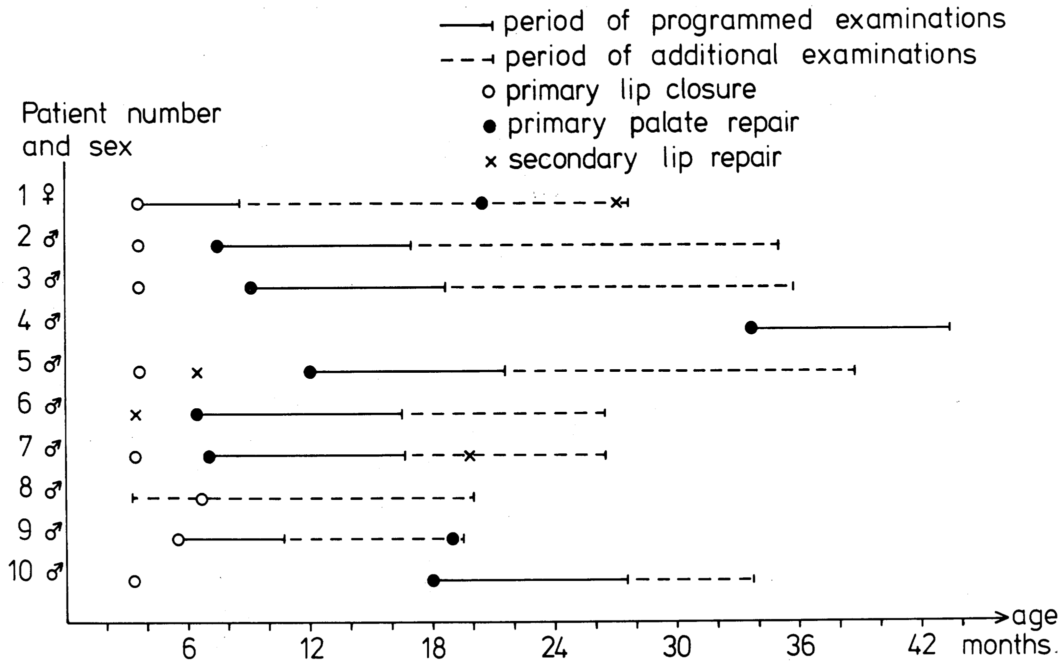

FIGURE 3. Surgical treatment and roentgen examinations given in relationship to age.

TABLE 1. Observation periods, days after first examination, and intervals—days after previous examination (in brackets)

patient	*observation periods*							
	1–2	*1–3*	*1–4*	*1–5*	*1–6*	*1–7*	*1–8*	*1–9*
1	6 (6)	34 (28)	62 (28)	146 (84)	398 (252)	515 (117)	525 (10)	722 (197)
2	7 (7)	35 (28)	63 (28)	147 (84)	287 (140)	567 (280)	833 (266)	
3	— —	35 (35)	63 (28)	147 (84)	287 (140)	469 (182)	819 (350)	
4	7 (7)	35 (28)	63 (28)	140 (77)	287 (147)			
5	7 (7)	35 (28)	63 (28)	147 (84)	287 (140)	448 (161)	812 (364)	
6	7 (7)	35 (28)	70 (35)	147 (77)	294 (147)	631 (337)		
7	7 (7)	35 (28)	63 (28)	147 (84)	294 (147)	336 (42)	392 (56)	574 (182)
8	42 (42)	105 (63)	112 (7)	119 (7)	301 (182)	483 (182)		
9	6 (6)	34 (28)	62 (28)	153 (91)	405 (252)			
10	7 (7)	35 (28)	63 (28)	147 (84)	287 (140)	469 (182)		

to the cleft on the affected side. The R-B M in the non-cleft segment in UCL and UCLP patients was regarded as fixed and was used as a reference in the calculations, while in BCLP patients the R-B M in the right segment was regarded as fixed.

ADDITIONAL RECORDS. An alginate impression was taken of the upper jaw at each examination and the intercanine and the intertuberosity width was measured (Hellquist and Skoog, 1976). Body height (in infants under two years, recumbent length) and body weight were recorded to define general physical development, and the values were compared with a norm (Karlberg et al., 1973).

ETHICS. The infants underwent conventional cleft lip and palate surgery, and no change of procedure was made because of their participation in this study. The use of implants and roentgen examinations is a recognized, established method, and its application was approved by the committee of ethics of the Faculty of Medicine, University of Lund, and by the parents. Since morphological structures are of no interest in the roentgen recording, exposure factors are adjusted to give a clear image only of the implants, thereby reducing the thyroid radiation dose to 200–250 μGy for one pair of stereo films (Rune et al., 1977b).

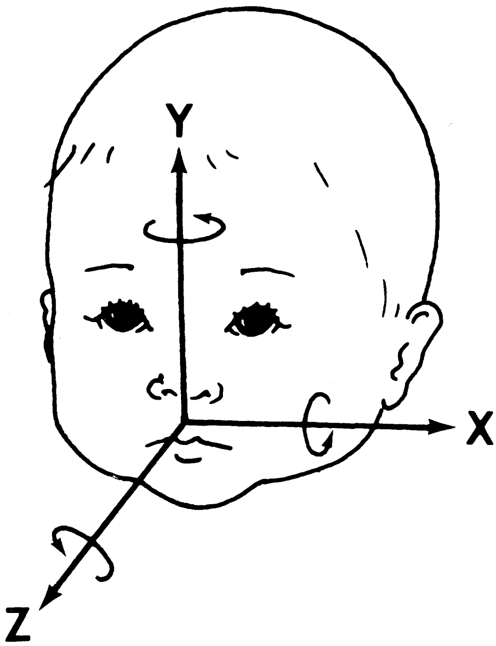

FIGURE 4. Directions of the cardinal axes about and along which rotations and translations for the maxillary segments are calculated. The positive directions of the rotations are indicated.

Results

IMPLANT STABILITY. No implants were lost. Of 60 measured distances between implants in each separate segment, 29 had increased, 13 had decreased, and 18 had remained unchanged (changes less than 0.2 mm) at the time of final examination. Twenty-seven implants were considered stable in the bone (Figure 5). Implant stability was the same in non-cleft and cleft segments (Table 2). Mean changes in the distances between implants within a segment were compared for two periods of 28 days and for two periods of 147 days. Greater changes were found in the second 28-day period and smaller changes in the second 147-day period (Table 3). Analysis of variance showed better implant stability within the same infant than between infants over the observation intervals (L-A : $F = 4.4$, $p < 0.001$ - A-P : $F = 5.4$, $P < 0.001$ - P-L : $F = 2.0$, $P < 0.05$) (Figure 1).

MOVEMENT OF INDIVIDUAL IMPLANTS. The distances between implants L-A and P-L increased steadily in five non-reference R-B M's for approximately 63 days after the initial examination, while the distances between implants A-P remained almost stable (Figure 5). Movement of the five L- implants was computed relative to the reference R-B M's from the initial to the last examination and found to be modest along the X- and Z-axes, while it was marked along the Y- axis (Table 4).

The mean error in rigid-body fitting (ME) remained less than 0.2 mm in three R-B M's in all observations, while it increased beyond this value in the remaining R-B M's (Table 5). A mean error of 0.2 mm was considered the limit for rigid-body behaviour.

Movement between the segments (R-B M's) was modest and followed individual patterns. Movement in Patient 3 (UCLP), in whom the R-B M's behaved as rigid bodies, except for the last observation interval, is shown in Figure 6.

During the initial observation periods, translation toward the midsagittal plane, i.e. transverse narrowing, occurred in all children with complete clefts.

In UCLP patients examined after primary lip closure (Patients 1 and 9), the cleft segment had been translated anteriorly (along the Z-axis) by 1.7 mm in Patient 1 and by 0.7 mm in Patient 9 at 398 and 153 days respectively (prior to primary palate repair) and also caudally (along the Y- axis) by 2.0 mm in Patient 1 and cranially by 1.9 mm in Patient 9.

In UCLP patients examined after primary palate repair (Patients 2, 3, 5, 6, and 7), a common finding at 35 days was medial translation of the cleft segment (mean 0.4 mm, range 0.0 to 1.2 mm) with rotation medially of the lateral alveolar ridge (about the Z-axis). A common finding at 147 days was medial rotation of the lateral alveolar ridge (about the Z- axis) and the posterior part of the cleft segment (about the Y- axis). At the final examination (mean observation time 734 days) lateral translation was recorded, i.e. transverse widening (mean 0.7 mm, range 0.1 to 1.7 mm).

During the entire observation period, continuous translation, amounting to 2.1 and 6.3 mm, of the cleft segment cranially (along the Y- axis) occurred in Patients 3 and 5, and caudally in Patient 7, amounting to 4.6 mm at the final examination. At the same time, the cleft segment was translated posteriorly (along the Z- axis) by 2.6 and 0.9 mm in Patients 2 and 3 and anteriorly by 4.0 mm in

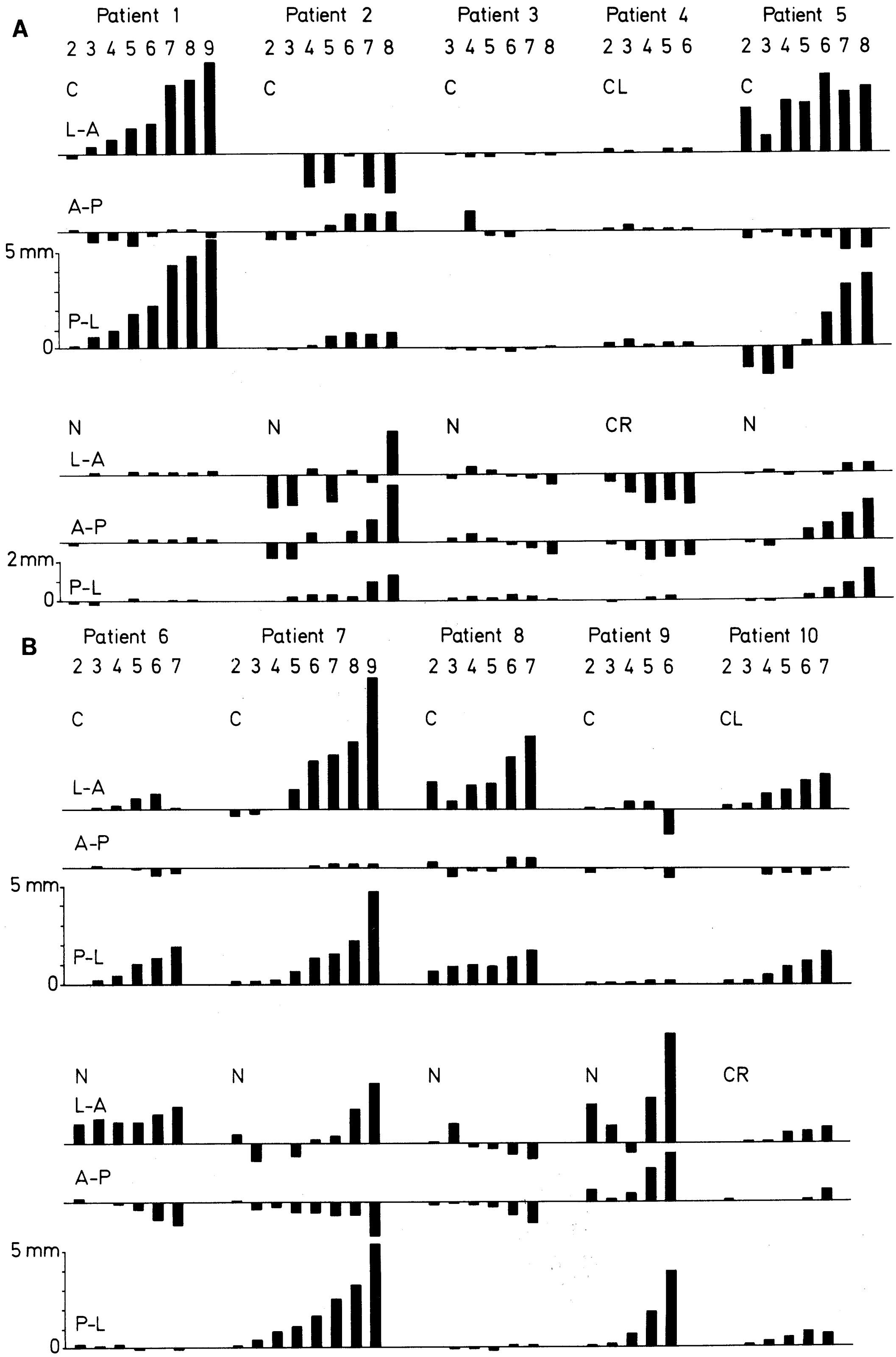

FIGURE 5. Distance changes from initial examinations between implants (L,A,P) in cleft (C) and non-cleft (N) segments. The figures indicate the actual examination according to Table 1. CR = right and CL = left segment in bilateral clefts (Patients 4 and 10).

TABLE 2. Implant stability (mean change in mm of distances L-A + A-P + P-L, Fig. 2) in non-cleft (N) and cleft (C) segments according to programmed observation intervals (Table 1).

	1–2 (n)	*2–3 (n)*	*3–4 (n)*	*4–5 (n)*	*5–6 (n)*
N	0.422 (18)	0.286 (21)	0.424 (21)	0.544 (21)	0.429 (15)
C	0.248 (30)	0.200 (33)	0.292 (33)	0.304 (33)	0.403 (27)

TABLE 3. Implant stability, given as mean change in mm of the distance L-A, A-P, and P-L (Figure 1) and as mean value of mean error in rigid-body fitting (ME), for two periods of 28 and for two periods of 147 days (programmed observations 2-3, 3-4 and 1-5, 5-6, Table 1). Student t-test of paired observations.

	2–3 (n = 18)	*3–4 (n = 18)*	*diff. P*	*1–5 (n = 14)*	*5–6 (n = 14)*	*diff. P*
L–A	0.352	0.627	<0.001	0.867	0.648	<0.001
A–P	0.210	0.225	<0.01	0.300	0.250	<0.01
P–L	0.138	0.178	<0.001	0.449	0.338	<0.01
ME	0.219	0.313		0.480	0.343	

TABLE 4. Translations (mm) along the cardinal axes, X = transverse axis, Y = longitudinal axis, and Z = sagittal axis of five lateral implants (L) in non-reference segments computed relative to the reference R–B M's. The positive direction of the X-axis is to the left, of the Y-axis upwards, and of the Z-axis forwards.

patient	*observation time (days)*	*cardinal axis*		
		X	*Y*	*Z*
1[x)]	722	−0.2	−9.5	3.2
5	812	−0.4	−5.5	−1.2
7	574	−0.4	−11.4	2.9
8[x)]	483	2.6	−7.5	−1.5
10	469	0.7	−2.8	0.9

[x)] In Patients 1 and 8 translations along the X-axis are given as for implants in the left segment, i.e. negative values indicate motion toward the mid-sagittal plane.

Patient 7. Movement of the cleft segment in Patient 2 is shown in Figure 7. In the BCLP patients, examined after primary palate repair, Patients 4 and 10 showed similar patterns of motion (Figure 8).

In the single UCL patient examined after primary lip closure (Patient 8), continuous translation laterally, i.e. transverse widening, amounting to 2.3 mm at 483 days, occurred.

CHANGES IN TRANSVERSE DIMENSIONS MEASURED BY ROENTGEN STEREOMETRY AND ON CASTS. In about one-third of the roentgen measures (Table 6) distances between contralateral implants decreased, and individual implants moved medially along the X- axis. About the same ratio of transverse narrowing was found in measures on casts, but no agree- (A-A) and posterior (L-L) widening by 0.5 ment was found between roentgen measures and measures on casts for each individual. The mean values of the roentgen measures in the UCLP patients after primary palate repair (Patients 2, 3, 5, 6, and 7) showed anterior and 0.8 mm and the "corresponding" measures on casts (a-a_1 and T-T_1) a mean of 0.8 and 3.9 mm, respectively.

PRECISION AND ACCURACY OF THE ROENTGEN STEREOPHOTOGRAMMETRIC METHOD. Reliability of the method was estimated by reevaluating 12 stereo-pairs and by performing 12 repeated examinations. The standard deviations for rotations and translations are given in Table 7.

In the precision tests, the mean error in rigid-body fitting varied from 5 to 104 μm for the 2 × 12 = 24 R-B M's. In the accuracy tests, the mean error ranged from 9 to 199 μm. In the precision tests, 692 distances between implants were compared and, in the accuracy tests, 437 distances. The largest differences between two distances were 0.225 and 0.537 mm for the two conditions respectively. The mean distance error was 0.045 mm for the precision tests and 0.091 mm for the accuracy tests.

The measurement error on casts, i.e. the standard deviation of double determinations of the same cast (precision), was 0.25 mm for intercanine width (a-a_1) and 0.33 mm for intertuberosity width (T-T_1).

HEIGHT AND WEIGHT. Increase in body height and body weight of the infants was

TABLE 5. Mean error in rigid-body fitting (µm) for implant triangles (R–B M's) in non-cleft (N) and cleft (C) segments, calculated from the initial examination.

patient	*segment*	*observation periods*							
		1–2	*1–3*	*1–4*	*1–5*	*1–6*	*1–7*	*1–8*	*1–9*
1	N	50	101	27	104	96	105	114	98
	C	485	341	535	751	875	1,762	1,910	2,290
2	N	706	689	202	590	241	641	1,339	
	C	160	174	719	680	423	909	1,027	
3	N	—*	130	219	91	146	199	347	
	C	—*	68	96	89	143	89	88	
4	C right	245	396	640	593	685			
	C left	107	168	48	93	106			
5	N	55	154	86	243	428	613	933	
	C	1,326	820	1,525	1,179	1,833	1,781	1,930	
6	N	441	578	501	610	867	1,162		
	C	22	122	196	447	609	882		
7	N	203	487	351	655	725	1,118	1,430	2,454
	C	179	156	148	584	1,295	1,423	1,839	3,481
8	N	116	495	112	173	398	556		
	C	580	444	579	610	1,145	1,592		
9	N	898	362	411	1,156	2,529			
	C	137	55	176	190	610			
10	C right	119	142	180	360	544	641		
	C left	108	140	389	507	737	913		

* Films not evaluated due to inferior quality.

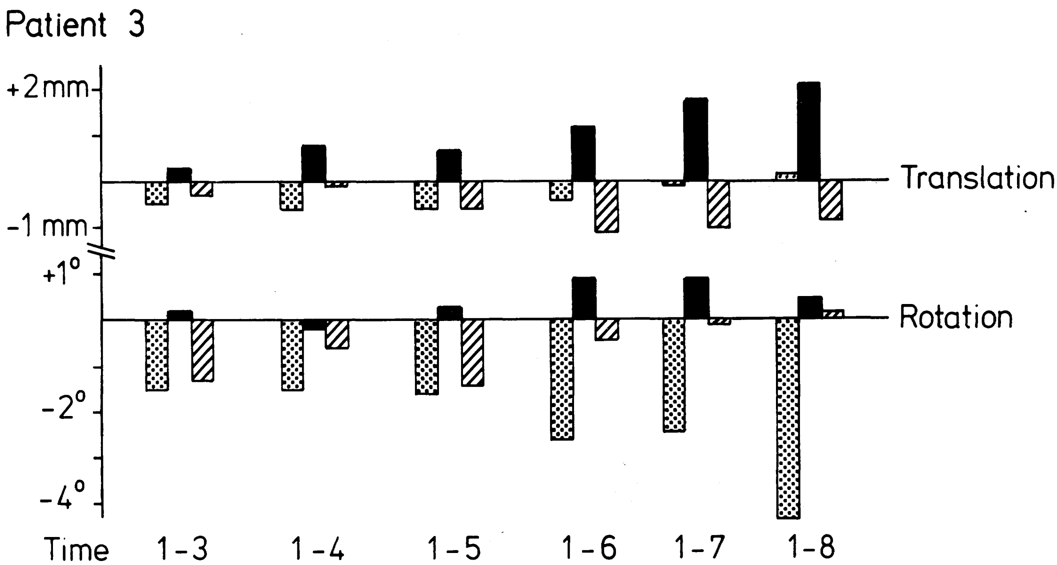

FIGURE 6. Movement of the cleft segment relative to the non-cleft segment of Patient 3, calculated from the initial examination, given as rotations about and translations along the body-fixed cardinal axes with positive rotation directions as indicated in Figure 4. Movement relative to the X- axis is given by stippled bars, to the Y- and Z- axes by filled and striped bars, respectively. The cleft (left) segment moved medially during the period of 147 days, time 1–5, (in a negative direction along the X- axis), after which it moved slightly laterally (in a positive direction along the X- axis). It also moved posteriorly during a period of 287 days, time 1–6, (in a negative direction along the Z-axis). During the entire observation period of 819 days, the segment moved continuously in a cranial direction (positive along the Y- axis) and, at the same time, turned cranially with its anterior part (rotation in a negative direction about the X- axis). An initial rotation medially of the lateral alveolar ridge (negative direction about the Z-axis) was reversed after 147 days, time 1–5. After 819 days, the cleft segment had moved cranially and posteriorly, and the anterior part of the segment had rotated cranially. Transverse widening was negligible.

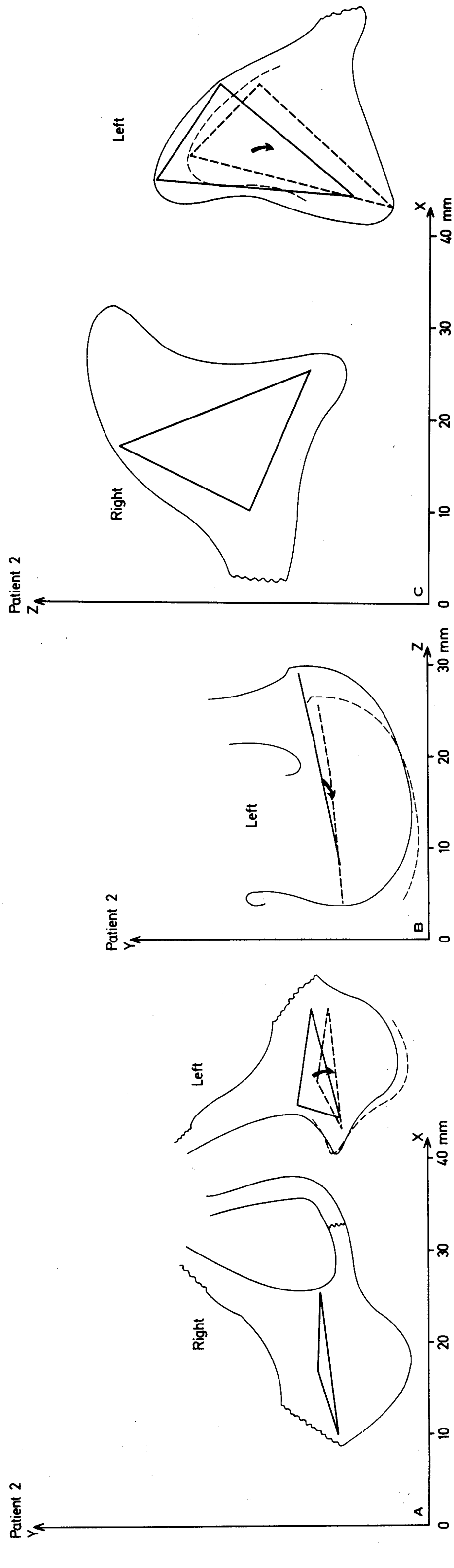

FIGURE 7. Computed movement between implant triangles (R-B M's) in Patient 2. The triangles are projected on the three cardinal planes, the frontal (XY), the sagittal (ZY), and the transverse (XZ) planes. The changes (broken lines) are given in relationship to the positions in the coordinate system of the first examination. Observation time, 567 days. Outlines of the segments are drawn from standard roentgenograms.

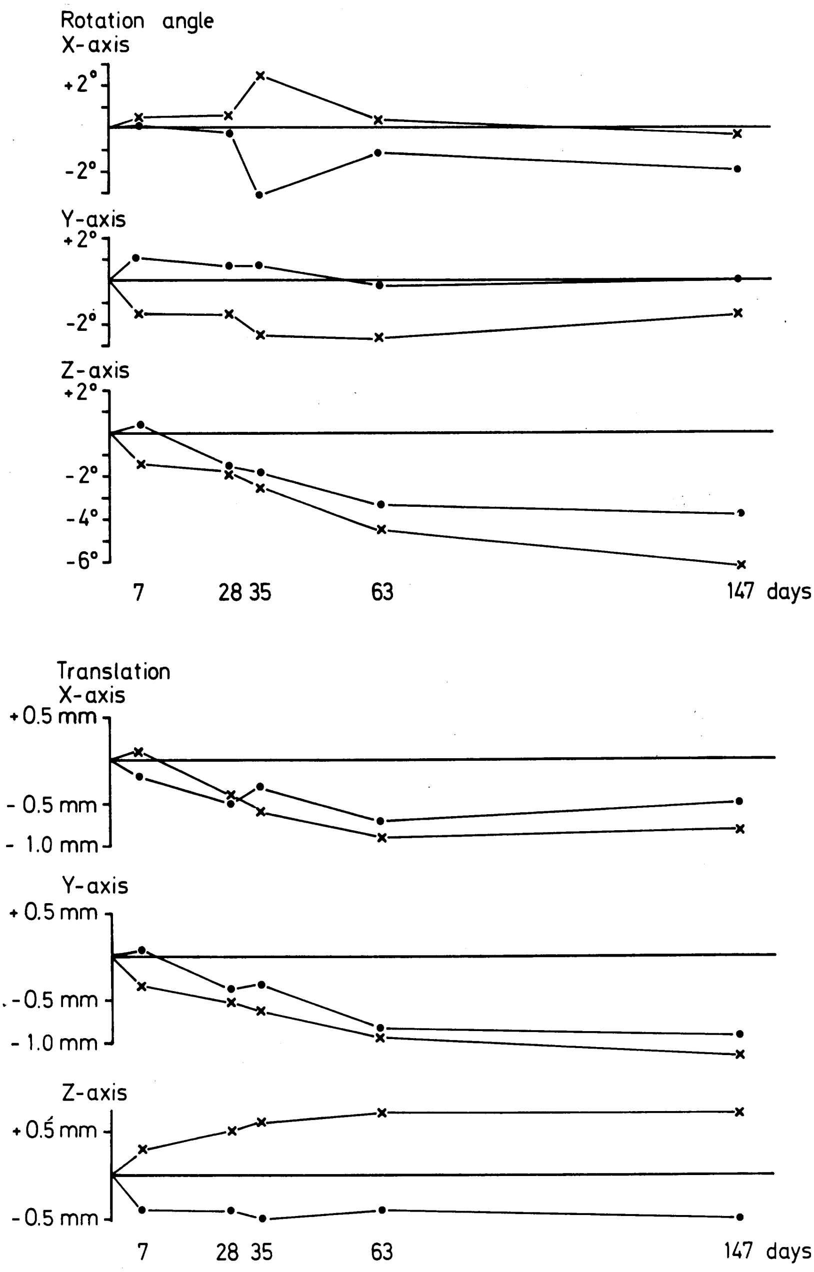

FIGURE 8. Movement in BCLP patients after primary palate repair at 33 and 18 months of age in Patient 4 (= •) and Patient 10 (=x). The anterior part of the moving (left) segment turned medially in Patient 10 (rotation in a negative direction about the Y- axis), while no such rotation occurred in Patient 4. The lateral alveolar ridge of the moving segment turned medially in both patients (rotation in a negative direction about the Z- axis) with greater transverse narrowing of the dental arch in Patient 10. The moving segment was also translated medially in both patients (in a negative direction along the X- axis) but more so in Patient 10. The results show that transverse narrowing of the dental arch occurred to a greater extent after primary palate repair at the age of 18 than at the age of 33 months. Very little movement occurred after two months following surgery in either infant.

TABLE 6. Changes in transverse distances (mm) between contralateral implants, translation of individual implants along the X-axis calculated relative to the reference R–B M, and transverse changes measured on casts (a–a_1: intercanine width, T–T_1: intertuberosity width).

patient	observation time (days)	implants			translation along X-axis of implants			measures on casts	
		L–L	A–A	P–P	L	A	P	a–a_1	T–T_1
1*	398	0.9	0.5	0.4	0.5	0.4	−0.1	−0.8	−0.1
2	287	−0.7	0.0	−0.3	−0.6	−0.4	−0.7	−2.2	3.3
3	287	−0.2	−0.1	−0.6	−0.5	−0.4	−0.4	1.5	3.1
4	287	−0.7	0.1	−1.1	−0.5	−0.3	−0.7	−0.3	−3.4
5	287	1.9	0.2	−0.2	2.1	−0.3	0.1	4.2	4.1
6	294	2.2	1.3	1.1	1.3	1.7	0.6	1.5	4.8
7	294	0.6	0.5	−0.6	0.2	0.8	0.2	−0.9	4.1
8*	301	3.1	2.2	1.9	2.1	1.8	1.7	3.1	−1.6
9	405	4.5	2.7	0.8	1.1	1.6	1.7	4.8	1.2
10	287	0.1	−1.6	−1.4	0.2	0.9	−1.1	−1.9	1,6

* Translations of implants along the X-axis are given as for implants in the left segment, i.e. negative values indicate motion toward the mid-sagittal plane.

TABLE 7. Reliability of the roentgen stereophotogrammetric method.

	standard deviations rotation about (degrees)			
	X-axis	Y-axis	Z-axis	total
Precision (12 d.f.)	0.25	0.19	0.26	0.40
Accuracy (12 d.f.)	0.36	0.35	0.38	0.63
	translation along (mm)			
	X-axis	Y-axis	Z-axis	total
Precision (12 d.f.)	0.063	0.088	0.106	0.152
Accuracy (12 d.f.)	0.087	0.115	0.145	0.205

within the normal range (Karlberg et al., 1973).

Discussion

Metallic implants tend to move from their original positions when inserted in the maxillary bones of young children (Friede et al., 1977, Shaw, 1977, 1978). Accordingly, implant stability must be checked at each examination. In the present study, this was done by means of roentgen stereometry (Rune et al., 1977a) and, to permit interindividual comparison of implant behavior, examination intervals were kept, as far as possible, identical in all patients.

Detection of implant instability in roentgen studies depends on the accuracy of the measurements. With the present roentgen stereometric method, implants are considered stable in the bone when the change in distance between them is less than 0.2 mm, which should be regarded as a favorable limit for implants measuring 1.5 × 0.5 mm.

Displacement of the smaller cleft segment and its relative deficiency of bone (Atherton, 1967 a,b) make insertion of implants in this segment more difficult than in the larger non-cleft segment. Contrary to our expectations however, these morphological conditions caused no more faulty insertions in the cleft segments, i.e. implant stability was the same (Student t-test) in cleft and non-cleft segments for the programmed intervals (Table 2).

As indicated by the high proportion of unstable L- implants, the amount of bone in the infrazygomatic crest is limited in infants and easily missed at insertion (Figure 5). Our experience differs from that of Friede et al. (1977) who, in a two-dimensional study of implant stability in 51 infants, reported "the highest success rate" in this location, while it supports the findings of Shaw (1978), who lost 17 of 48 implants inserted in the molar region during a two-year period. After closely studying five steadily moving L- implants (Table 4) we suggest that these may have been displaced by erupting teeth.

Implant stability improved with time (Table 3) starting from about 147 days after the initial examination. This finding is in agreement with Aronson's report of improved implant stability in the fibula of five children aged 4.9 to 11.3 years after an initial period (one to 2 months) of stabilization (1976).

Implant stability varied more between than within infants, possibly because of individual variations in structure, degree of mineralization, and growth activity of the bone. The mean error in rigid-body fitting (ME) increased with time (Table 5), but it should be noted that displacement of the center of gravity of the R-B M was reduced to a minimum when the change in distance between implants L-A, A-P, and P-L was approximately the same. Although 27 of 60 implants remained stable, only three of 20 segments held three stable implants, i.e. R-B M's which behaved as rigid bodies. Errors of calculated movement because of deviations from rigid body behavior of the reference R-B M's can be eliminated, however, if a stable reference R-B M can be established outside the maxilla.

MOVEMENT BETWEEN THE SEGMENTS (R-B M's). Movement was computed for one maxillary segment relative to another, both influenced by surgery and other forces. Consequently, the results do not represent the actual movement of the segments in the face. A reference R-B M established outside the maxilla would overcome this limitation and allow recording of movement of the segments independent of each other. Our intention was to insert the implants in similar locations in all infants as the calculated translation depends on the anatomical position of the center of gravity of the R-B M's, and, although variations cannot be accounted for, we consider the positions of the centers of gravity to be comparable.

Transverse contraction immediately after surgery and prolonged narrowing between the segments were nearly consistent findings. This result is in contrast to that of Ishiguro et al. (1976), who reported a mean increase in maxillary width of 4.3 mm in infants with UCLP from the age of three months (n = 32) to two years (n = 30) as measured on posteroanterior cephalograms. The discrepancy may be due to differences in measurement methods, or it may indicate an actual difference between the groups because of biological variations and treatment procedures. In relation to type of cleft, transverse widening was greatest in the child with an unaffected secondary palate (Patient 8). In relation to age of surgery, transverse narrowing was less at 33 months than at 18 months (Patients 4 and 10). The latter finding agrees with the results of Bernstein's study of casts (1968) from which he concluded that growth of the maxilla is "altered if the palatal operation is performed—before the age of 24–30 months." Retardation as well as "catch-up" occurred both vertically and sagittally, but no consistent pattern of movement was found. This may be because the segments were displaced in various directions preoperatively and because clefts that appear similar may be quite different.

Discrepancies between changes in transverse dimensions measured between individual implants and measures on casts may be the result of implant instability as well as of faulty recognition of poorly defined measurement points on the casts. It should be pointed out, however, that our roentgen measures concern movement of the body of the maxilla, while measures on casts record changes between the alveolar ridges which undergo appositional growth and remodelling. We regard this as the principle explanation for the discrepancy between measurements obtained from roentgen films and those taken directly from casts. Measurement errors do not explain the observed implant instability and are of no significance in the reliability of the calculations of movement (Rune et al., 1977a, Rune et al., 1977b).

Summary and Conclusion

Implants tend to move from their original positions in the bone when inserted in the cleft maxilla of infants and should, therefore, not be used as measurement points unless their stability is checked.

Implant stability in infants has been studied at programmed intervals with a high degree of accuracy. Implant stability improved with time. Implants were accepted by and behaved the same way in the cleft and noncleft segments, and implant stability varied more between than within infants. Implants remained relatively stable when inserted in the palatal shelf and in the anterior aspect of the maxilla medial to the infraorbital foramen (change in distance less than 1.0 mm between these two implants).

With the roentgen stereometric method, it has been possible to demonstrate the timing and direction of the movement of individual implants in the bone. This suggests that it may be necessary to replace migrating implants in long-term studies. Additionally, establishment of a stable reference outside the maxilla would lessen the draw-back of unstable implants in the maxilla and would allow the movement of the segments to be recorded independently of each other.

Movement of the body of the maxillary segments in infants with clefts has been recorded independently of appositional growth and remodelling and with identical three-dimensional orientation of the reference segment in all examinations.

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