A Longitudinal Analysis of the Maxillary Growth Increments of Cleft Lip and Palate Patients (CLP)

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Introduction

This study is part of a longitudinal investigation on pre- and post-operative cleft palate patients at the Lancaster Cleft Palate Clinic. Through the measurement of arch perimeters, this article concentrates on the growth rate of the maxillary alveolar process which is divided into segments for comparisons. Included in the analysis is a comparison between the affected and unaffected side of the cleft lip and palate patients and a comparison to the normal casts from the Sillman collection.

Perspective

To date, measurement of maxillary lengths have been either straight line measurements perpendicular and parallel to a base line (*3*, *4*, *6*), or they have been measurements of the cord of the arc (*5*). Mazaheri (*4*) suggested that cord measurements of the arc might be more accurate than perpendicular-parallel straight line measurements in determining the arch perimeter of the affected or unaffected side of the CLP. Cord measurements, however, may have their inherent inaccuracy as suggested by Peyton (*5*) who used one cord for the unaffected side but two cords for the affected side, thereby introducing an inaccuracy since two cords will yield a greater length than a single cord for a given arc.

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In order to eliminate some of these discrepancies, this report measured specially prepared photocopies of maxillary casts with a millimeter ruler which was bent in close adaption to the curve of the crest of the alveolar ridge. These curvilinear measurements would indicate more accurately changes in alveolar length. No attempt was made to determine displasia of segments by the Stöckli method (7). Rather, we were concerned with hypoplasia or hyperplasia of the segments and the influence of lip and palatal surgery on the growth of these segments.

Method and Materials

The casts in the study were selected from among those in the longitudinal growth study in progress at the Lancaster Cleft Palate Clinic and from the Sillman collection of normal casts. A Xerox 914 photocopier was used in the graphic reproduction of the casts as described by Mazaheri (4).

The sample included 40 patients with complete unilateral cleft of the lip, alveolar process and palate, of which 23 were males and 17 females. Mean age of lip closure by the triangular flap method was 3.3 months. At 13.7 months, the hard palate was closed with a vomer flap to the incisive foramen, followed at 16.6 months by soft palate closure with a simple median suture method. This was the basic surgical plan and cleft palates repaired by other methods were not included in this group. Measurements were taken at 2 months, 6 months, 1 year, 1½ years, 2 years, 3 years, 4 years, 5 years and 6 years of age. The data were compared to normative data from the Sillman collection.

Curvilinear measurements were obtained by closely bending a plastic transparent ruler to photocopies of casts. Each measurement was taken in triplicate to 0.5 mm accuracy and averaged.

In order to facilitate the identification of landmarks, the following points were marked on the casts prior to photocopying.

1. The I point is the crest of the ridge on the line drawn from the labial frenum to the incisive papilla.
2. The anterior end point of the lesser segment was marked and called L.
3. The anterior end point of the greater segment was marked and called G.
4. Canine point C,C′ is the intersection of the groove of the lateral labial frenum and the crest of the ridge which coincided with the interproximal point between the canine and the first deciduous molar.
5. The tuberosity points T,T′ is the junction of the crest of the ridge with the outline of the tuberosity.

The following segments of the arch were measured (Figure 1)

I-G—The anterior portion of the clefted segment.

L-C′—The posterior portion of the clefted segment up through the distal of the canine.

I-C′—Incisor to canine length for the affected side was calculated as the sum of I-G and L-C′.

I-C—Incisor to canine length on the unaffected side.

C′-T′—Canine to tuberosity length of the affected side.

C-T—Canine to tuberosity length of the unaffected side.

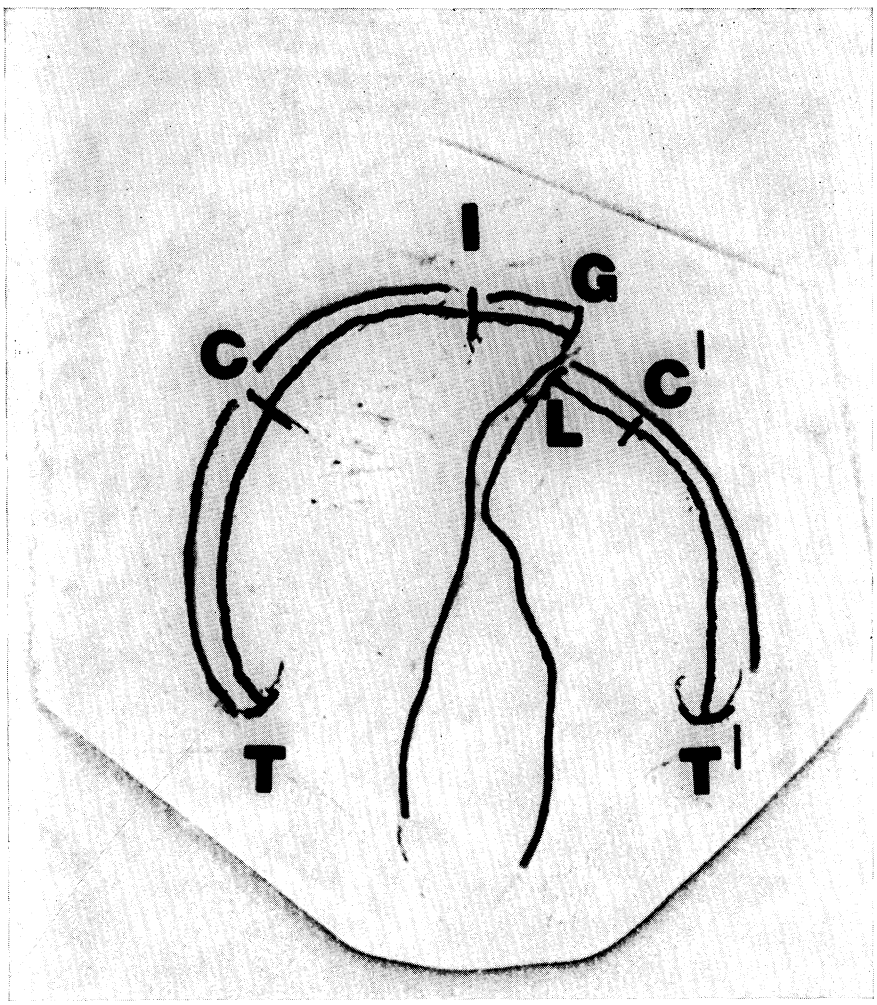

FIGURE 1. Photocopy of maxillary cast. Prior to photocopy, crest of ridge, mesial and distal border of the cleft, tuberosities, canines, and incisive points are marked on casts.

I-T′—Incisor to tuberosity length of the affected side was the sum of I-C′ and C′-T′.

I-T—Incisor to tuberosity length of the unaffected side.

These measurements were analyzed statistically:

1. to determine the degree of length symmetry between left and right alveolar ridges in the normal controls as a basis for comparison between the affected and unaffected side of the CLP (statistical test-t for correlated means),
2. to compare the CLP affected side with CLP unaffected side for length asymmetry (statistical test-t for correlated means),
3. to compare the CLP unaffected side to the normal for length symmetry (statistical test-t for independent means), and

TABLE 1. A comparison between affected and unaffected segments in cleft subjects.*

	2 mos.	*p*	*6 mos.*	*p*	*1 yr.*	*p*	*1.5 yr.*	*p*	*2 yr*	*p*	*3 yr.*	*p*	*4 yr.*	*p*	*5 yr.*	*p*	*6 yr.*	*p*
IC′																		
N	25		26		29		22		28		26		24		22		16	
Mean	11.9		13.0		14.4		14.4		15.1		15.9		15.8		16.1		17.1	
SD	2.3		2.2		2.4		2.9		3.0		2.4		2.8		2.7		3.3	
IC																		
Mean	14.4		15.2		17.0		18.7		19.1		19.2		19.3		19.0		18.6	
SD	2.4		1.8		2.1		2.7		2.2		2.2		1.9		1.8		2.0	
Δ Means	2.5	.001	2.2	.001	2.6	.001	4.2	.001	4.0	.001	3.3	.001	3.5	.001	2.9	.001	1.54	.05
t	4.68		4.0		5.1		5.3		5.5		5.9		5.0		4.50		2.29	
CT′																		
N	31		33		36		29		35		31		30		22		16	
Mean	19.1		21.3		23.1		23.2		23.3		24.3		25.2		27.3		29.1	
SD	2.1		2.4		1.9		2.0		1.8		1.9		1.4		1.3		2.8	
CT																		
Mean	18.2		20.1		22.2		21.5		22.5		23.5		24.7		26.9		29.2	
SD	2.5		2.1		2.2		1.9		1.9		1.5		2.1		1.8		2.3	
Δ Means	0.9	.01	1.2	.01	0.9	.05	1.7	.001	0.8	.01	0.8	.05	0.5	.20	0.4	N.S.	.17	N.S.
t	2.71		2.98		2.24		4.69		2.96		2.06		1.67		1.13		0.30	
IT′																		
N	25		26		29		22		28		24		24		17		16	
Mean	31.2		34.1		37.0		37.5		38.3		40.0		41.1		43.6		46.4	
SD	2.8		3.5		3.4		4.2		3.5		3.4		3.5		3.8		5.8	
IT																		
Mean	33.0		34.9		39.3		39.8		41.7		42.9		44.3		46.3		47.8	
SD	3.1		3.6		2.9		3.7		3.1		3.1		3.3		2.6		3.1	
Δ Means	1.8	.01	0.9	N.S.	2.3	.01	2.4	.05	3.4	.001	2.88	.01	3.3	.01	2.6	.01	1.3	N.S.
t	3.24		1.05		3.07		2.40		4.50		3.70		3.59		2.90		1.30	

* measurements in millimeters.

TABLE 2. Comparison between right and left segments in normal subjects according to age; comparison between normal right side and cleft palate segments according to age.

	2 mos.	*p*	*6 mos.*	*p*	*1 yr.*	*p*	*1.5 yr.*	*p*	*2 yr.*	*p*	*3 yr.*	*p*	*4 yr.*	*p*	*5 yr.*	*p*
IC^R																
N	15		16		17		24		20		13		17		18	
mean	14.7		16.2		17.7		18.3		19.4		18.9		19.8		19.7	
SD	0.9		1.1		1.0		1.5		1.6		1.3		1.0		1.5	
IC^L																
mean	14.6		16.4		17.9		18.0		19.4		19.1		19.7		19.7	
SD	1.1		1.3		1.0		1.5		1.4		1.3		1.2		1.5	
Δ means	.04	NS	0.2	NS	0.2	NS	0.28	0.2	0.07	NS	.11	NS	0.08	NS	.07	NS
t	0.21		0.87		0.93		1.54		0.43		0.49		0.33		0.23	
CT^R																
N	15		16		17		24		20		13		17		18	
mean	19.3		20.8		21.6		22.2		23.0		24.3		25.9		27.4	
SD	1.7		1.9		2.0		1.3		1.7		2.2		2.2		2.7	
CT^L																
mean	18.7		20.0		21.0		22.4		22.9		23.6		26.0		26.7	
SD	2.3		2.1		1.9		1.8		2.7		1.8		2.4		2.1	
Δ means	0.54	.20	0.7	0.02	0.5	0.10	0.26	NS	0.07	NS	0.7	.20	0.1	NS	0.7	.05
t	1.41		2.92		2.09		0.9		0.24		1.36		0.41		2.1	
IT^R																
N	15		16		17		24		20		13		17		18	
mean	33.9		37.0		39.5		40.4		42.3		43.3		45.7		47.2	
SD	1.6		2.4		2.4		1.8		2.6		1.9		2.3		3.1	
IT^L																
mean	32.9		35.7		39.0		40.1		42.5		42.6		45.7		46.4	
SD	2.7		2.7		2.1		2.4		2.6		2.0		2.5		2.6	
Δ means	1.0	.20	1.3	0.10	0.5	0.2	0.3	NS	0.23	NS	0.6	NS	0.0	NS	0.7	0.2
t	1.66		1.87		1.39		0.69		0.69		1.19		.09		1.57	

TABLE 2 (*Continued*)

	2 mos.	*6 mos.*	*1 yr.*	*1.5 yr.*	*2 yr.*	*3 yr.*	*4 yr.*	*5 yr.*
				IC^R vs. IC				
Means	0.3	1.0	0.7	0.4	0.3	0.3	0.5	0.7
t	0.56	2.27	1.55	0.61	0.55	0.52	1.11	1.34
p	NS	.05	.20	NS	NS	NS	NS	.20
				CT^R vs. CT				
Means	1.3	0.7	0.6	0.7	0.5	0.8	1.20	0.5
t	2.06	1.16	0.98	1.62	0.96	1.17	1.79	0.66
p	0.10	NS	NS	.20	NS	NS	0.1	NS
				IT^R vs. IT				
Means	0.9	2.10	0.2	0.6	0.6	0.3	1.4	0.9
t	1.18	2.23	0.24	0.68	0.72	0.36	1.60	0.91
p	NS	.05	NS	NS	NS	NS	.20	NS

* measurements in millimeters.

4. to calculate the growth rates (computed as growth increment over the time interval in which the increment occurred) for the normal, for the CLP affected side and for the CLP unaffected side for comparison (statistical test-t for independent means).

FINDINGS

A. Alveolar Length Data (Table 1, 2, Figures 2, 3, 4)

1. *Comparison of normal right side to normal left side.* The data indicated that the length of the alveolar crests for the left and right sides were

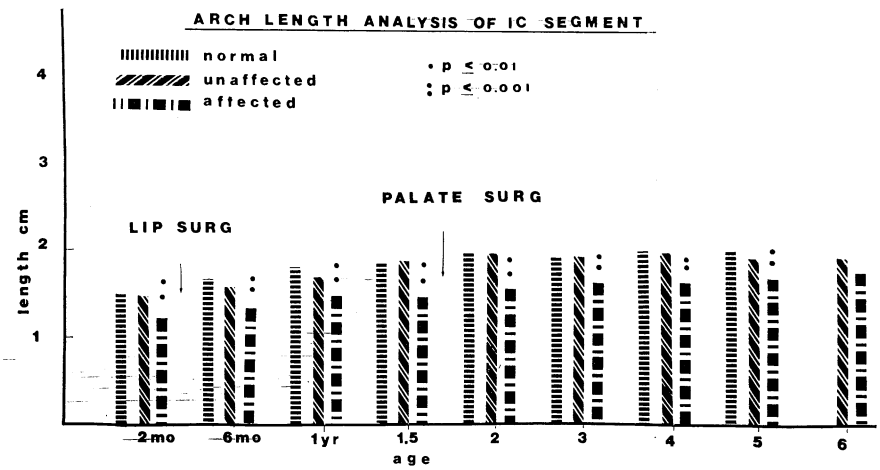

FIGURE 2

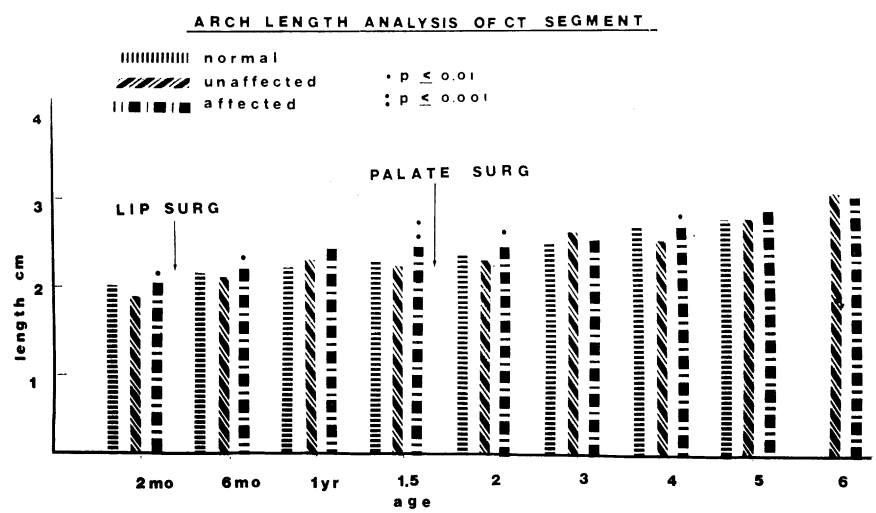

FIGURE 3.

FIGURES 2, 3, 4. Arch lengths of the I-C, C-T, I-T segments for the right side (R) and left Side (L) in normal subjects, unaffected and affected sides in cleft subjects according to age.

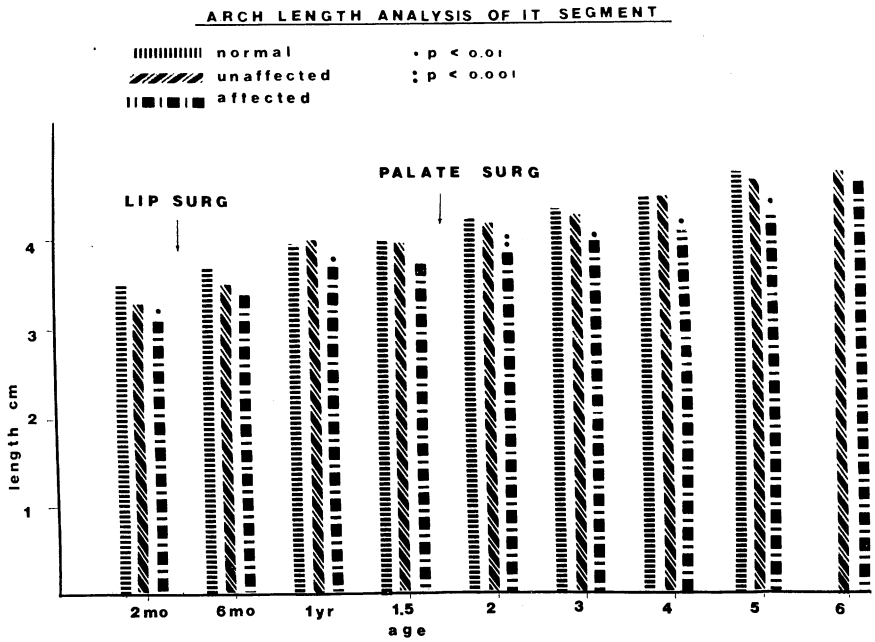

FIGURE 4

symmetrical for the incisor to canine segment (I-C). For the canine to tuberosity segment (C-T) there was some asymmetry at 6 months ($p \leq 0.02$) and 5 years ($p \leq 0.05$), probably due to the small sample sizes at those ages. Otherwise the C-T segments were symmetrical. For the incisor to tuberosity segment (I-T), no significant difference at ($p \leq 0.01$) level could be demonstrated between the length of the right and left alveolar ridges of the normal.

2. *Comparison of normal right side to unaffected side of CLP.* No significant differences at all ages in the I-C, C-T, or I-T segments were observed between the normal right side and the CLP unaffected side at ($p \leq 0.01$) level.
3. *Comparison of CLP affected side to CLP unaffected side.* The I-C′ segment of the affected side was significantly shorter than the unaffected side through the age of 6 years ($p \leq 0.05$). The difference between sides is 2.5 mm at 2 months and decreased to 1.5 mm at 6 years. The C′-T′ segment of the affected side, however, was significantly longer at the ages of 2 months, 6 months, 1.5 years, 2 years and 4 years than the unaffected side. The I-T′ segment, which was computed as the sum of the I-C′ segment plus the C′-T′ segment of the affected side is significantly shorter than the unaffected side at all ages except 6 months, 1.5 years, and 6 years. The greatest difference between the two sides occurred in the second year after completion of palatal surgery ($p \leq 0.001$).

B. Rate of Growth Analysis of Alveolar Length (Figures 5, 6, 7)

The CLP lip surgery occurred in the time interval between 2–6 months and the palatal surgery in the interval between 1–2 years.

1. Growth Rate of the I-C′ Segments (Figure 5)

The I-C and I-C′ length growth rates represented the growth rate of the

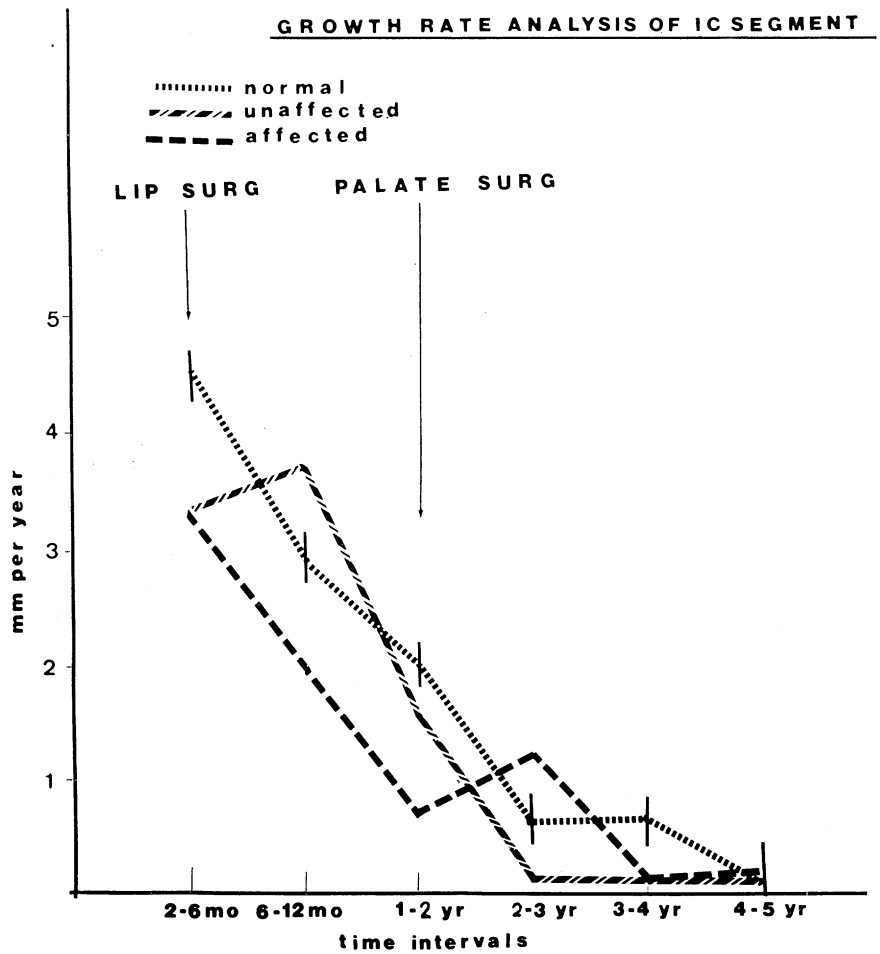

FIGURE 5

FIGURES 5, 6, 7. Velocity curve of the growth rate at serial time intervals for the I-cps, C-T and I-T segments for the unaffected and affected sides of cleft subjects, for the right side of normal subjects.

anterior segments of the arch. These segments showed a slower rate of growth than the normal during the interval in which CLP lip surgery and CLP palatal surgery occurred. During the time interval which followed lip surgery, 6–12 months, the I-C segment, but not the I-C′ segment recovered by growing faster than the normal. The I-C′ segment did not recover until later during the 2–3 year interval in which its growth rate exceeded the normal and that of the contralateral side. From the third year on, incremental growth was insignificant for all anterior segments.

2. Growth Rate of the C-T and C′-T′ Segments (Figure 6)

The C-T and C′-T′ length growth rates represented the growth rate of the posterior segments of the arch. The CLP unaffected side and the CLP affected side growth rates closely approximated each other and therefore shall be treated as a group. The CLP sides grew slower than the normal during the

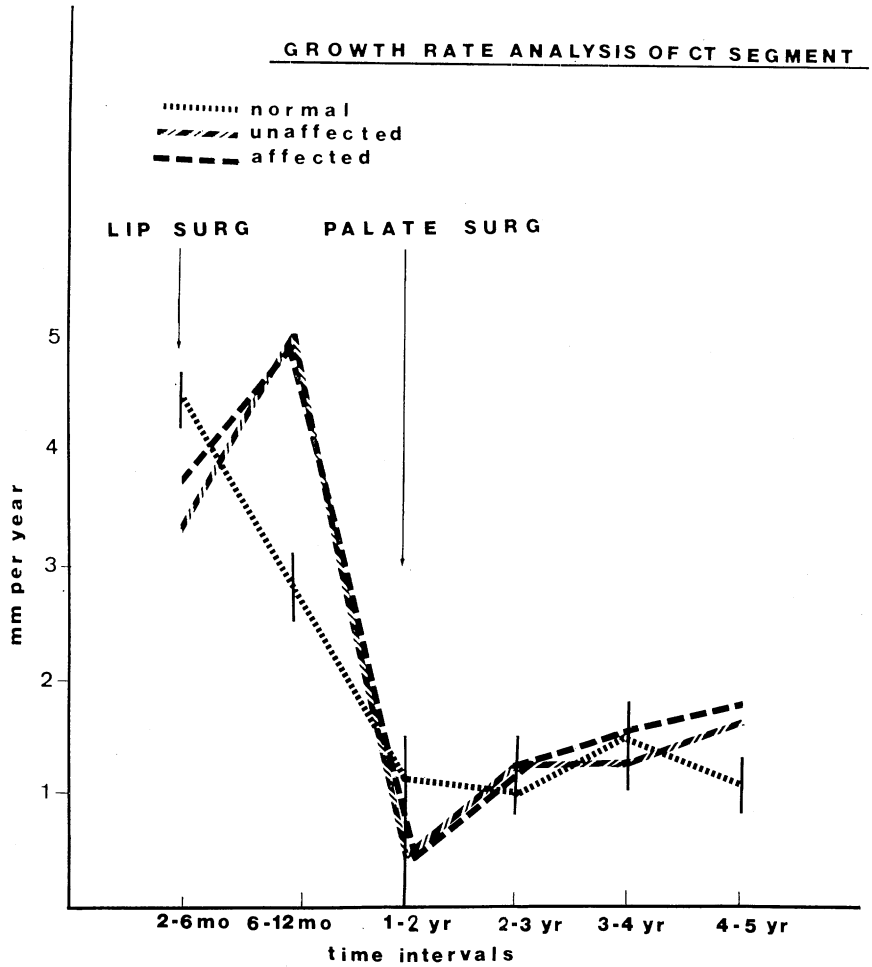

FIGURE 6

interval when CLP lip surgery occurred, but during the time interval which followed, 6–12 months, the CLP recovered as it grew markedly faster than the normal. A similar pattern was observed during and after palatal surgery. By the age of 5, the CLP was growing at the average rate of 1.62 mm per year while the normal grew at a rate of 1.2 mm per year.

3. Growth Rate of I-T and I′-T′ Segments (Fig. 7)

The I-T and I′-T′ length growth rates represented the growth rate for the entire side. The CLP affected and unaffected sides showed a slower rate of growth than the normal during the interval in which CLP lip surgery occurred. During the time interval which followed lip surgery, the CLP affected and unaffected sides had growth rates over and above that of the normal. Again, during CLP palatal surgery, the affected and unaffected side growth rate lagged behind the normal, but an accelerated period of growth followed in which the lag was overcome. The growth rates of normal, affected and unaffected sides approached each other from the third year on. The unaffected

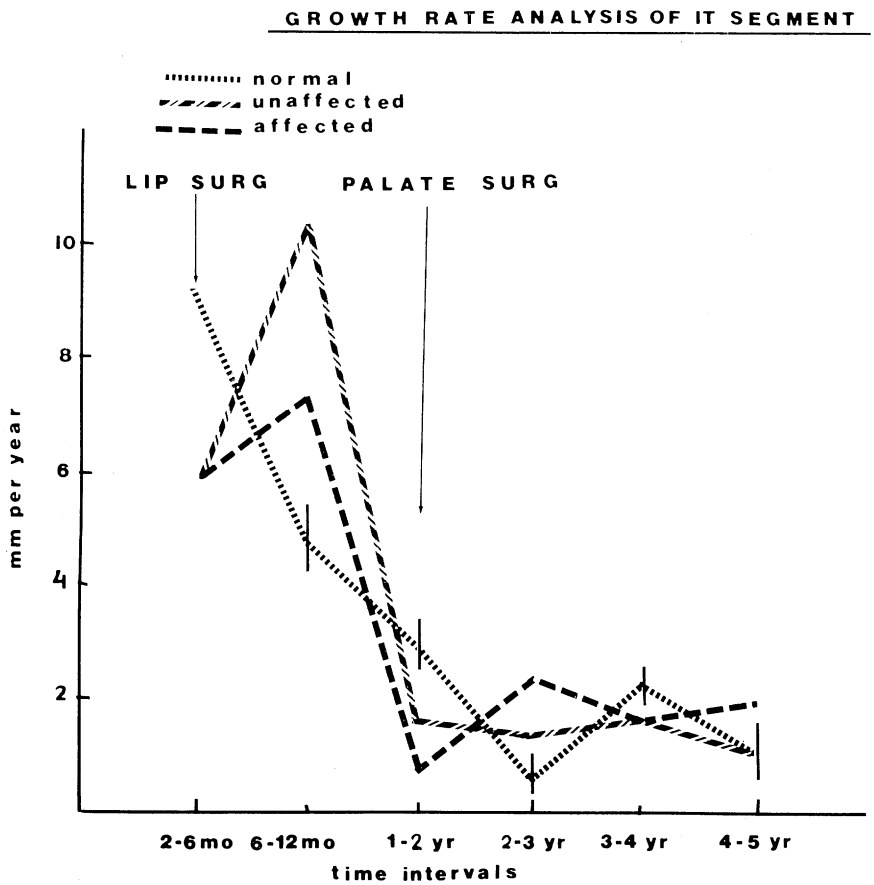

FIGURE 7

side growth rate shadowed that of the normal closer than the affected side during the time intervals from one year on.

Discussion

Comparison of the right and left side on the normal indicates that there is a high degree of length symmetry between each side in the normal individual. Supposedly, if there were no tissue deficiency in the CLP, one would expect symmetry there too. However, the high frequency of asymmetry between the affected and unaffected sides tends to indicate that there is a tissue deficiency in the CLP from birth which is slow to be replaced by hard and soft tissue. The analysis of segments shows that the asymmetry is primarily in the anterior I-C′, I-C segments which remain significantly asymmetrical through the sixth year ($p \leq 0.05$). Unexpectedly, the length analysis of the posterior C-T segment of the unaffected side is

shorter than the C′-T′ of the affected side by 0.9 mm at birth and is equal to it only in the 4th year ($p \leq 0.20$). This would suggest that the C′-T′ segment of the cleft side is hyperplastic since the contralateral side has essentially the same length measurements as the normal. It is clear, therefore, that the tissue deficiency in alveolar length of the CLP occurs primarily in the anterior I′C′ segment of the affected side and remains deficient into the sixth year. The combined length, however, of both the anterior and posterior segments yields an alveolar length on the affected side which is not significantly asymmetrical from the unaffected side by the sixth year.

In the CLP maxilla, the growth rate lags behind the normal during the time intervals in which surgery occurs. This lag is temporary since in the time intervals which follow surgery, there is an acceleration in growth rate over the normal. This suggests that the conservative surgery performed on these cases is not inhibitory to growth and that the tissue has the ability to compensate for a temporary lag. The I-C′ segment of the affected side, however, does not show an acceleration in rate after lip surgery. This can be explained in terms of the repositioning of the segments following lip surgery which causes some tissue compression and molding at the site of the cleft. After palatal surgery, this lag is compensated for by an acceleration in growth.

From the above findings, it appears that the cleft maxilla which has been repaired by conservative surgery, attempts to normalize itself through a mechanism which operates primarily by regulating local growth rate. One might hypothesize a mechanism of physiologic recovery which causes the maxillary growth rate to accelerate in order to overcome any temporary growth rate lag due to surgery. This mechanism operates in all four segments analyzed and only to the point where an approximation to the normal is achieved. Others (*1*) have similarly reported that the deviation from normal diminishes with growth for nasopharyngeal height, nasopharyngeal depth, but not for velar length. Indeed the initially shorter velum appears not to catch up, although it continues to grow (*2*).

Summary

The analysis of growth rate computed from growth increments, permits a better understanding of how the CLP maxilla compensates for growth lags caused by surgery. Results indicated that if surgery was sufficiently atraumatic the CLP could recuperate by accelerating its rate of growth in the year following surgery. Physiologic recovery from the affects of surgery on arch length approaches the normal for the cleft lip and palate patients included in this study.

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