

SERIAL BIOSTEREOMETRIC ANALYSIS OF GROWTH CHANGES IN THE FACE FROM BIRTH TO TEN YEARS OF AGE

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SUMMARY

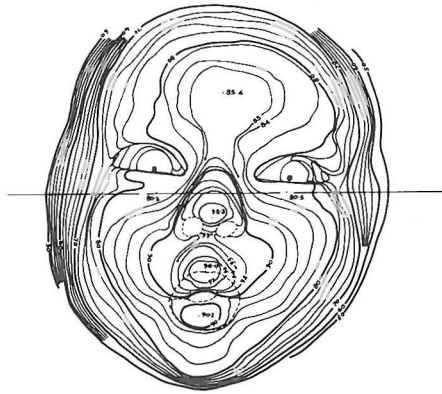
Using stereophotogrammetry, life-sized facial contour maps were recorded for a baby girl presenting with mild facial asymmetry from soon after birth until ten years of age. In the first two years of life, six plots were recorded at gradually increasing intervals, using a portable stereometric camera. Subsequently, eight annual plots were taken in a posed position in a static stereometric camera. Growth changes were measured through the series by:-

- (a) calculating the magnitude of 21 linear facial parameters connecting the soft tissue anatomical landmarks located by the plotter
- (b) calculating the areas of two pairs of bilateral triangles contained by various parameters to measure asymmetry.

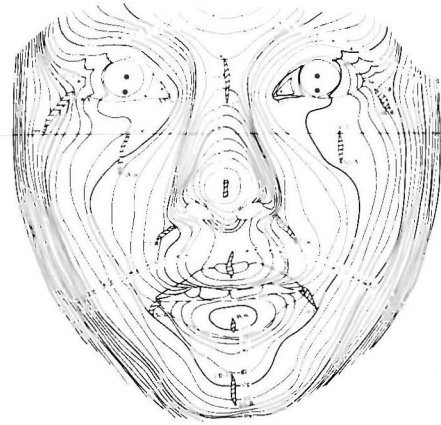
INTRODUCTION

The clinical use of measurements of the face derived from short base stereophotogrammetry was first reported by Thalmaan Degen (1944). Much of the published work using this technique has been concerned with the face, since the complexity of facial morphology and its changes related to growth and surgical or orthodontic treatment justify the sophisticated and expensive cartographic machinery involved; Björn, Lundquist, Hjelstrom (1954); Haga, Ukiya, Koshihara & Ota (1964); Savara (1965); McGregor, Newton & Gilder (1971); Berkowitz & Cuzzi (1977), have examined various aspects of clinical facial measurement using this technique. A simplified method of applying this technique for stereometric analysis of the face has been reported using a combined static stereometric camera and plotting machine by Beard & Burke (1967). A portable version of this stereometric camera was developed by Beard (1971). The accuracy of measurement using this technique has also been investigated in vitro by Burke & Beard (1967) and in vivo by Burke (1971). Facial growth was studied on measurements of serial plots for older children (a group of like-sexed twins) in the age range 9-16 years and revealed that growth velocities of most facial parameters during this period are minute (being of the order of 1 mm per year) but even so, there was evidence of an adolescent facial growth spurt, (Burke, 1979). This affected the middle third of the face (parameters 4-13, Fig.2(a)) whereas the measurements concerned with the eyes, Nos. 1, 2 & 3 (Fig.2(a)), showed very little growth. It was thought that these latter measurements were an example of the early "neural" pattern of growth in contrast with the "skeletal" pattern of growth, which includes an adolescent spurt and is not completed until near the end of the second decade (Scammon, 1930).

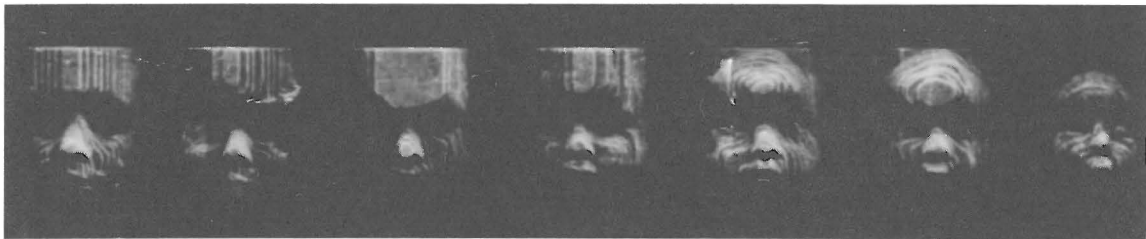
Serial data on soft tissue facial growth in very young children are rare, but Low (1952) measured 66 boys and 60 girls annually from birth to five years of age. Using anthropometric calipers, he measured the chin to occiput dimension and found that the growth velocity of this dimension in the first year of life for girls was of the order of 40 mm per year, in



(a)



(b)



(c)

Fig.1 (a) Facial plot at 3 weeks of age.
 (b) Facial plot at 10 years of age.
 (c) Facial models cut from plots recorded at 3 weeks, 3 months, 6 months, 1 year, 18 months, 2 years and 3 years.

the second year it had reduced to 10 mm per year and between 2 and 5 years the mean was 5 mm per year. The larger magnitude of growth velocities in the very young presents an opportunity to measure facial growth changes more easily than in the older children, and this study is concerned with the detailed measurement of the soft tissues of the face in one individual from birth (actually at 3 weeks of age) to the age of 10 years.

A different technique was used by Subtelny (1959), who measured growth of the soft tissues of the face in the midline, as recorded on cephalometric radiographs between the ages of 6 months and 18 years. He was therefore able to related the soft tissue growth changes to the underlying facial bones. Similar growth studies have been reported for this age range by Bowker & Meredith (1959); Wisth (1972) and Roos (1974).

MATERIALS AND METHOD

The material for this study consisted of a series of fourteen facial plots derived from stereo photographs recorded for a girl at the following ages: 3 weeks, 3 months, 6 months, 1 year, 18 months and 2 years (Fig.1). Subsequently, annual stereo pairs were recorded until the age of 10 years,

(Fig.1). The early records were taken with the portable camera, i.e., without posing, and the models were levelled optically for plotting. When the child became older and more co-operative, the face was posed by ear rods and an optical pointer at the time of photography.

When the child first presented at 3 weeks of age, there was a mild degree of facial asymmetry. As the years passed, the asymmetry appeared to diminish on a basis of clinical inspection.

The tip of the nose was given zero value in the plots and the depth plotted was either 50 mm or 60 mm (with one exception of 40 mm) (Fig.1).

The series of plots were measured in the following ways:-

1) Linear parameters (including the slope) were measured directly on the plot and the real dimensions were calculated by taking into account the contour height differences between the landmarks defining the parameter. Such parameters are not subject to a photographic posing error (Burke, 1972). However, the mobile nature of the tissues concerned with the eyes and the mouth increases the possibility of a physical posing error.

A group of 21 facial parameters was selected to use all the soft tissue landmarks which could be readily recognised and located by the plotter (Fig.2).

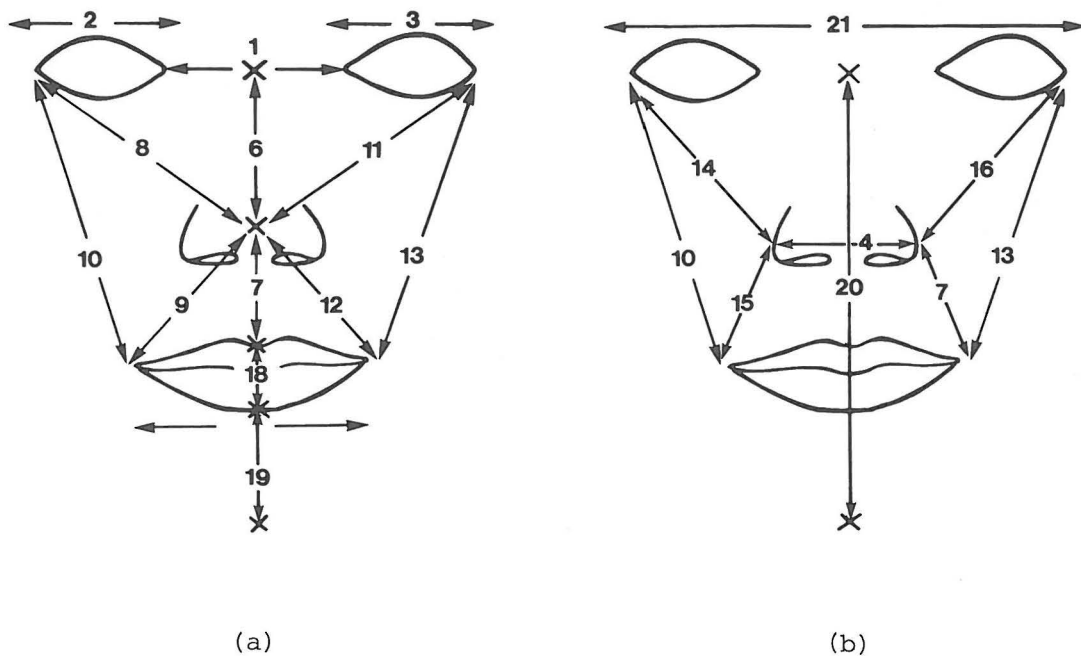


Fig.2 (a & b) Linear facial parameters between certain anatomical landmarks.

Where possible, the skin adjacent to, but not identifying, the landmarks was marked with a thin brush mark in photographic ink, to improve the accuracy of landmark location. Certain landmarks are self-identifying, e.g., external canthi, but others need careful definition (v.infra).

The soft tissue landmarks used to define the parameters are:-

1. right and left internal and external canthi of the palpebral fissures and the mid-point of the line joining the internal canthi
2. right and left alae and the tip of nose
3. right and left angles of the mouth and mid-points of upper and lower vermilion border of the lips
4. soft tissue pogonion.

In the original study on the older children, 13 parameters were selected specifically to avoid any overlap, and therefore partial duplication of measurement. In this study, an additional 8 parameters were measured to isolate areas of differential growth, i.e., of tip of nose and also to measure overall changes in facial height and width, which could then be analysed in terms of their component parameters (Fig.2b). All parameters were age-corrected (Tanner, Whitehouse & Takaishi, 1966).

2) The areas of two pairs of bilateral facial triangles defined by various parameters were compared to measure asymmetry. Both pairs of triangles had as their bases parameters 10 and 13, i.e., right and left external canthus to angle of mouth. The apex of the larger triangles was tip of nose and the apices for the smaller triangles were right and left alae of nose.

FINDINGS

Measurements of individual parameters and their growth velocities at different ages are given in Tables I & II. The patterns of growth of certain parameters are described below.

Overall facial growth

Overall facial growth was examined by summing the same 13 parameters (1-13) originally used for the older children, for comparison and to avoid distortion due to measuring any part of any parameter twice (Burke, 1979). In the final analysis, unlike the older group for whom parameters at eye level (1,2,3) were excluded since growth changes were so small, in this series these parameters were included as considerable growth changes occurred in the intercanthal distance (v.infra). The overall pattern of facial growth was characterised by:-

1. Very rapid growth in the first 6 months of life (360-395 mm), i.e., growth velocity 70 mm per year.
2. Slightly less rapid growth in the next 6 months (395-420 mm), i.e., growth velocity 50 mm per year; and overall growth velocity for the first year of 60 mm per year.
3. Slower growth in the second year of life (420-435 mm), i.e., growth velocity 15 mm per year.

Thus, in the first year of life, the total of these parameters increased by 60 mm, whereas in the second year the increase was only 15 mm; and this rate of increase was maintained subsequently fairly evenly between the age of 2 and 9 years; a larger increment of 36 mm occurred in the 10th year, indicating perhaps the beginning of the adolescent growth spurt (Fig.3a). The total of the 13 parameters increased from 360 to 590 mm from birth to 10 years, i.e. 230 mm. Of this amount, 75 mm (about 33 per cent) occurred in the first 2 years, and the average composite growth velocity in the period 2 to 10 years was almost 20 mm per year.

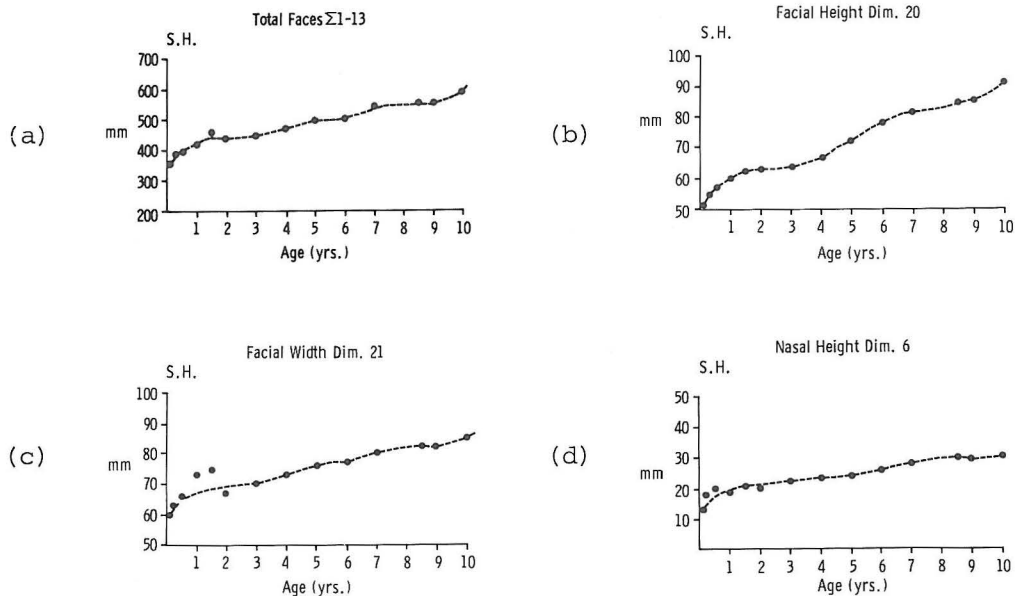


Fig.3 Growth curves for facial parameters

Total facial height (parameter 20)

This parameter was measured from soft tissue surface midpoint of the intercanthal line to chin (soft tissue pogonion), and at birth registered 9 mm less than facial width at 51 mm (Fig.3b). This dimension (one of the largest to be measured on the face) increased by 6 mm to 57 mm in the first 6 months of life (i.e., a growth velocity of 12 mm per year), and by a further 3 mm in the second six-monthly period, thus having a growth velocity of 9 mm per year in the first year of life. In the second year of life, the annual growth velocity was 3 mm and this was apparently followed by a resting period until the age of 3 years. Between 3 and 10 years, the increments of growth were fairly even at about 3 mm per year. For the next two years growth was slow, but in the final year the growth velocity was greater, leading to a facial height of 91 mm by 10 years of age. This was 6 mm greater than facial width at eye level at this age.

Growth in facial width at eye level

Right to left external canthi (Parameter 21)

This is the largest of width dimensions of face; at 3 weeks the distance between the external canthi was 60 mm (9 mm more than facial height) (Fig.3c). In the first six months, the increase was 5 mm and by interpolation in the second six-monthly period, about 1.5 mm; thus the annual growth velocity for the first year was 6.5 mm, whereas for the second year it was 2.5 mm; and between 2 and 10 years it was about 2 mm per year, producing a width of 85 mm by 10 years of age (6 mm less than total facial height at this age, and illustrating how the major proportions of the face change with differing growth velocities).

Some of the irregularities in the individual measurements of these parameters may be explained by a posing error related to blinking which

TABLE I

MAGNITUDE IN MILLIMETERS

<u>Parameter</u>	<u>3 weeks</u>	<u>6 months</u>	<u>1 year</u>	<u>2 years</u>	<u>10 years</u>
1	19.4	24.9	26.8	23.0	30.5
2	20.9	21.7	24.6	22.3	28.4
3	21.0	20.8	22.6	22.7	28.3
4	19.6	23.1	25.8	24.8	34.1
5	19.5	30.4	32.6	36.6	44.2
6	12.9	20.1	18.8	20.4	30.2
7	16.6	14.1	17.9	21.5	28.8
8	38.4	44.7	48.6	43.4	65.7
9	29.3	30.6	43.8	38.5	49.0
10	48.5	46.4	50.7	49.4	71.2
11	41.4	46.3	43.8	47.0	63.9
12	27.3	27.9	27.3	36.4	49.2
13	44.2	47.2	47.2	48.9	67.6
14	29.6	32.0	36.5	49.4	50.8
15	23.7	23.2	21.7	39.6	27.8
16	31.9	34.4	34.6	39.2	48.0
17	21.7	21.3	20.4	21.7	28.4
18	18.9	16.9	19.0	12.3	20.6
19	9.0	7.3	10.1	15.8	18.6
20	51.4	57.1	59.9	62.9	91.1
21	59.8	66.4	72.6	66.8	85.0
Sum of 13 Parameters	359.2	398.3	419.7	434.7	591.0

TABLE II

GROWTH VELOCITIES IN MILLIMETERS PER YEAR

<u>Parameter</u>	<u>0 - 6 mths</u>	<u>0 - 1 year</u>	<u>1 year to 2 years</u>	<u>2 years to 10 years</u>
1	11.0	7.4	0.0	0.9
2	1.5	3.6	0.0	0.8
3	0.0	1.6	0.1	0.7
4	7.0	6.2	0.0	1.2
5	21.8	13.1	4.0	0.9
6	14.4	5.9	1.6	1.2
7	0.0	1.3	3.6	0.9
8	12.6	10.2	0.0	2.8
9	2.6	14.5	0.0	1.3
10	0.0	2.2	0.0	2.7
11	9.8	2.4	3.2	2.1
12	1.2	0.0	9.1	1.6
13	6.0	3.0	1.7	2.3
14	4.8	6.9	12.9	0.2
15	0.0	0.0	17.9	0.0
16	5.0	2.7	4.6	1.1
17	0.0	0.0	1.3	0.8
18	0.0	0.1	0.0	1.0
19	0.0	1.1	5.7	0.3
20	11.4	8.5	3.0	3.5
21	13.2	12.8	0.0	2.3
Sum 1 - 13	78.2	60.5	15.0	19.5

could only be detected if, at the time of photography, the blink were complete. The photography could then be repeated.

Individual parameters of facial height

Nasal height (Parameter 6)

This parameter is defined superiorly by the midpoint of the inter-canthal line projected on the skin surface and inferiorly by the summit of the tip of nose. The plotter defines a circle of 4 mm diameter on the plateau and it is the centre of this circle which is the "tip".

With some variation, the growth curve for this parameter follows the typical skeletal pattern, increasing from 13 mm to about 19 mm, i.e., 6 mm in the first year; and from 19 mm to 20.5 mm in the second year (Fig.3a). During the subsequent 7 years, the growth velocity was fairly constant, the increase being from 20.5 mm to about 30.2 mm, i.e. about 1.2 mm per year.

Tip of nose to mid-point of upper lip (Parameter 7)

This parameter followed a very different pattern, showing very little increase in the first year of life (from 16.5 mm to 18 mm, i.e. 1.5 mm) and more in the second year, 18 mm to 21.5 mm (i.e. 3.5 mm) (Fig.4a). In the years 2 to 10 years, the increase was slow, 21.5 mm to about 28.8 mm (i.e., 7.3 mm); a growth velocity of 0.9 mm per year.

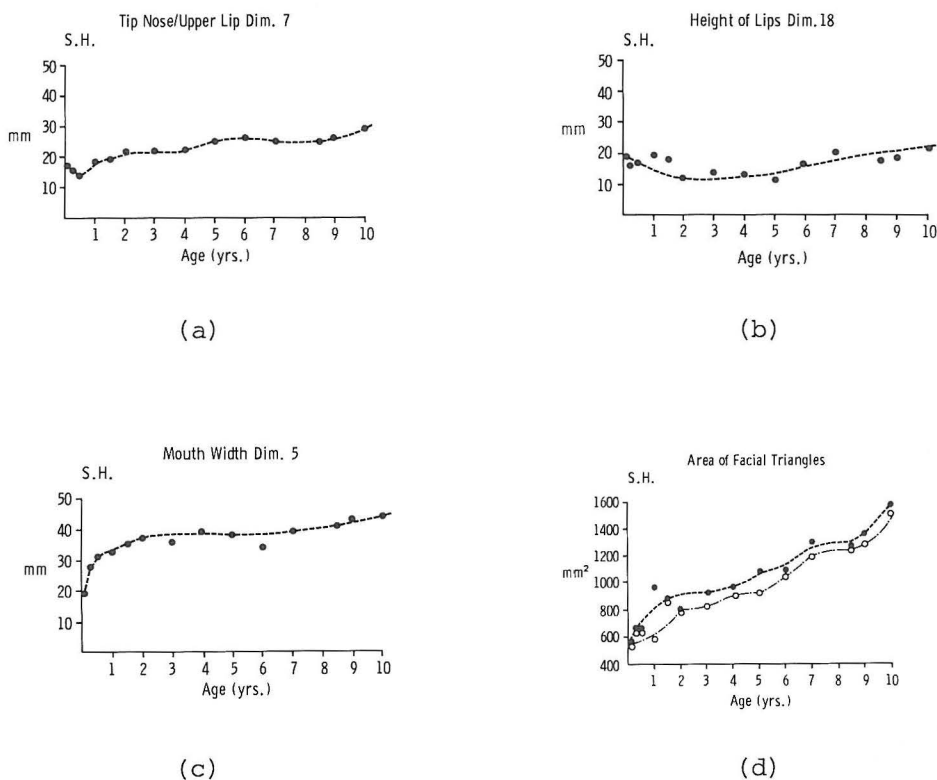


Fig.4. Growth curves for facial parameters and facial triangle areas.

Mid point of upper lip to mid point of lower lip (Parameter 18)

This parameter decreased in the first two years of life, from 19 mm to about 13 mm (Fig.4b). It remained at this value until 5 years. Between this age and 7 years, there was a considerable increase in lip height, from 13 mm to about 20 mm, and this value was maintained with some fluctuation, perhaps due to differing lip posture, until 10 years of age.

Width of mouth (Parameter 5)

The width of the mouth is measured between the plotter designation of right and left angles of the mouth. The increases for this parameter produced the largest growth velocities of all individual parameters in the first six months of life; an increase from 19.5 mm to 30.5 mm (giving a growth velocity of 22 mm per year, Fig.4c). In the next six months, this parameter increased from 30.15 mm to 32.5 mm, so that the annual growth velocity over the whole year was 12 mm per year. In the second year of life, it was 4 mm per year and subsequently between the ages of 2 and 10 years, averaged about 1 mm per year, so that it registered 44.2 mm by 9 years. The lateral growth velocities of the alae of the nose (Parameter 4) and the angles of the mouth were very similar.

Facial triangles as a measure of asymmetry

Oblique facial parameters - facial triangles involving nose tip (Parameters 8,9,10 and 11,12, 13)

Right and left bilateral triangles are formed by parameters connecting the following three landmarks - external canthus, tip of nose and angles of mouth. The pattern of changes in the areas of these triangles represent the integrated growth changes in all of these parameters, as well as measuring asymmetry, and therefore the individual parameter changes will not be described.

The area of the triangle on the right side was larger throughout the decade, although the asymmetry decreased in the later years. (Fig.4d). The proportional difference reduced from 15% at birth to 4% at 10 years. The growth patterns were both characterised by:-

1. rapid growth in the first 2 years
2. slow growth until 4 years
3. more rapid growth until 7 years
4. slow growth until 9 years
5. rapid growth between 9 and 10 years.

Facial triangles involving alae of the nose (Parameters 10,14,15 and 13, 16, 17)

In order to separate the growth contribution of the tip of the nose, further facial triangles were constructed again using the bilateral landmarks - external canthus and angle of mouth, but relating then to the alae of the nose and not the tip. These triangles showed a very different pattern of growth - no high post natal growth increments but a maintained very slow rate of growth. The right side was slightly larger until about 6 years, after which no significant asymmetry could be measured.

DISCUSSION

The measurements of this study show that most facial parameters of the face follow a growth pattern described in detail for facial height and the larger facial triangles (v.supra). These findings agree with measurements of Low (1952) and Subtelny (1959). Parameters concerned with the eyes show little growth, but mouth width shows very rapid growth (the largest growth velocity of all parameters in the first six months, even though it was a small parameter). This is related to change of function of the mouth from a sphincter for breast feeding to a slit for the access of food after weaning. These changes affect the height of the mouth (parameter 18).

Stereophotogrammetry of the very young is not easy, since they cannot be posed, although this problem was overcome in this study by confining measurements to linear parameters connecting defined anatomical landmarks. This also eliminated the difficulty imposed by the smooth skin of the infant, which reflects light and is therefore difficult to plot, unless the clinician has provided texture in the photographs in the area he wishes to measure.

However, these records have provided, for this patient, valuable clinical information monitoring the degree of facial asymmetry. They have also provided a wealth of biological information in three dimensions about the biological growth changes which affect the soft tissues of the face for one individual in the first decade, which could not have been produced by any method other than stereophotogrammetry.

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