A Quantitative Three-Dimensional Assessment of Abnormal Variations in Facial Soft Tissues of Adult Patients With Cleft Lip and Palate

Virgilio F. Ferrario, M.D.
Chiarella Sforza, M.D.
Claudia Dellavia, D.D.S.
Gianluca M. Tartaglia, D.D.S., Ph.D.
Davide Sozzi, M.D.
Armando Carù, M.D.

***Objective*: To supply quantitative information about the facial soft tissues of adult operated patients with cleft lip and palate (CLP).**

***Design, Setting, and Patients:* The three-dimensional coordinates of soft tissue facial landmarks were obtained using an electromagnetic digitizer in 18 Caucasian patients with CLP (11 males and 7 females aged 19 to 27 years) and 162 healthy controls (73 females and 89 males aged 18 to 30 years). From the landmarks, 15 facial dimensions and two angles were calculated. Data were compared with those collected in healthy individuals by computing z-scores. Two summary anthropometric measurements for quantifying craniofacial variations were assessed in both the patients and reference subjects: the mean z-score (an index of overall facial size), and its SD, called the craniofacial variability index (an index of facial harmony).**

***Results*: In treated patients with CLP, facial size was somewhat smaller than in normal individuals, but in all occasions the mean z-score fell inside the normal interval (mean ± 2 SD). Almost all patients had a craniofacial variability index larger than the normal interval, indicating a global disharmonious appearance. Overall, in patients pronasale, subnasale, and pogonion were more posterior, the nose was shorter and larger, the face was narrower, and the soft tissue profile and upper lip were flatter than in the reference population.**

***Conclusions*: The facial soft tissue structures of adult operated patients with CLP differed from those of normal controls of the same age, sex, and ethnic group. In this patient group, surgical corrections of CLP failed to provide a completely harmonious appearance, even if the deviations from the reference were limited. Further analyses of larger groups of patients are needed.**

KEY WORDS: *cleft lip and palate, face, soft tissues, three-dimensional*

The quantitative analysis of craniofacial variations plays a major role in the anatomical, anthropometric, and clinical description of both normal and diseased subjects (Goldberg et al., 1981; McCance et al., 1997; Vegter et al., 1997; Ferrario et al., 1999c; Hurwitz et al., 1999; Farkas et al., 2000, 2001; Ward et al., 2000; Vegter and Hage, 2001). Both the hard and soft tissue structures should be investigated to provide a complete evaluation of any given individual. Radiographic analyses have been performed extensively in the past, and quantitative assessments of the hard tissue situation of patients suffering from several alterations involving the craniofacial skeleton have been made, especially in the sagittal plane (Goldberg et al., 1981; Smahel et al., 1993; Ishii and Vargervik, 1996; Smahel and Mullerova, 1996; Laitinen et al., 1997; Zumpano et al., 1999; Bondarets and McDonald, 2000).

Unfortunately, radiographic analyses have several limitations. They use ionizing radiations, thus being invasive. They provide a two-dimensional assessment of the skeletal configuration, neglecting most of the soft tissues and projecting all structures onto a single (usually midsagittal) plane (Ras et al., 1994; Ferrario et al., 1996; Vegter and Hage, 2001). Moreover, it is well known that the facial structures have age-related-, sexual-, racial-, and ethnic-specific characteristics as well as secular variations (Hajnis et al., 1994; Farkas, 1996; Ferrario et al., 1996, 1999b, 1999c, 2001a, 2001b; Trenouth et al., 1999; Bondarets and McDonald,

Dr. Ferrario and Dr. Sforza are Professors of Human Anatomy, Dr. Dellavia is a postgraduate student, and Dr. Tartaglia is a Research Assistant, Functional Anatomy Research Center (FARC), Laboratorio di Anatomia Funzionale dell'Apparato Stomatognatico (LAFAS), Dipartimento di Anatomia Umana, Facoltà di Medicina e Chirurgia and Facoltà di Scienze Motorie, Università degli Studi di Milano, Milan, Italy. Dr. Sozzi is a postgraduate student, Cattedra e Divisione di Chirurgia Maxillofacciale, Università di Milano-Bicocca, Ospedale S. Gerardo, Monza, Milan, Italy. Dr. Carù is Head, Unità operativa di Chirurgia Plastica delle Malformazioni, Istituto Ortopedico Galeazzi, Milan, Italy.

Submitted June 2002; Accepted October 2002.

Address correspondence to: Prof. Virgilio F. Ferrario, Dipartimento di Anatomia Umana, via Mangiagalli 31, I-20133, Milan, Italy. E-mail farc@unimi.it.

2000). For a correct assessment of patients, the collection of normative data on comparable individuals is therefore essential. Currently, radiographic analyses cannot be performed on healthy subjects without a medical indication.

In contrast, anthropometry is noninvasive and three dimensional and considers all the facial structures, thus providing a more complete evaluation of the single patient (Farkas, 1994a, 1994b; Ferrario et al., 1998; Farkas et al., 2000, 2001; Ward et al., 2000; Vegter and Hage, 2001). The collection of normative data does not infringe any current ethical consideration.

Craniofacial data have been analyzed using two main approaches. Cephalometric and anthropometric measurements can be taken and the distance of each from a reference assessed, thus providing a detailed description of the abnormal morphology (Smahel et al., 1993; Hurwitz et al., 1999; Bondarets and McDonald, 2000; Duffy et al., 2000; Farkas et al., 2001).

In contrast, anatomic features can be combined and global indices obtained (Goldberg et al., 1981; Ras et al., 1994; Vegter et al., 1997; Hurwitz et al., 1999; Zumpano et al., 1999; Farkas et al., 2000; Ward et al., 2000). In particular, Ward et al. (2000) recently proposed two summary anthropometric measurements for quantifying craniofacial variations: the mean z-score (an index of overall facial size, compared with a reference population), and its standard deviation, called the craniofacial variability index (CVI, an index of facial harmony). Both measurements have been found to provide useful information in the classification of some craniofacial syndromes (Ward et al., 2000).

Many previous investigations have quantified the craniofacial characteristics of operated adult patients with cleft lip and palate (CLP). In particular, the features of the skeletal and soft tissue structures, as depicted by lateral cephalograms, have been widely detailed (Smahel et al., 1993; Ishii and Vargervik, 1996; Smahel and Mullerova, 1996; Laitinen et al., 1997; Vegter and Hage, 2001). The limitations of this radiographic approach have been reported. In contrast, a smaller number of investigations reported noninvasive soft tissue data (Ras et al., 1994; McCance et al., 1997; Vegter et al., 1997; Hurwitz et al., 1999; Duffy et al., 2000; Farkas et al., 2000; Vegter and Hage, 2001).

In the present study, the facial soft tissues of a group of adult patients with complete CLP were measured in three-dimensional space after the completion of several surgical procedures. The global facial characteristics of the patients were quantified using the mean z-score and the CVI of selected anthropometric measurements. The aim of this study was to measure the difference between operated adult patients with CLP and normal adults in an attempt to provide a final assessment of their facial outcome.

Materials and Methods

Patients

Data from 18 patients (11 males, 7 females) aged 19 to 27 years (mean 23 years, SD 2.61) with complete CLP without any other associated malformations were collected (Table 1). Five patients (3 men, 2 women) had a bilateral cleft (BCLP), five (3 women, 2 men) had a unilateral cleft (UCLP) on the right side, and all the other eight (6 men, 2 women) had a UCLP on the left side. All patients were Caucasian northern Italians, born between 1973 and 1981. They represented 64% of the 28 young adults asked to participate in the examination.

All patients had undergone several surgical procedures for the repair of their skeletal and soft tissue malformations. All surgeries were performed by the same team. Generally, primary cheiloplasty was carried out according to Le Mesurier (1949) between 4 and 8 months of age. Posterior palatal surgery was performed at 2 to 3 years of age (von Lagenbech, 1861), and anterior palatal surgery was carried out according to Perko (1974) between 5 and 7 years of age. Fifteen patients received an alveolar bone graft according to their dental age (eruption of the maxillary permanent canine). At the end of facial growth, after 18 (males) or 16 (females) years of age, six men and seven women also underwent a rhinoseptoplasty.

Reference data were collected in previous investigations performed on 73 female and 89 male normal subjects of the same ethnic group, age, and sex (Ferrario et al., 1999a, 2001a,

TABLE 1 Analyzed Patients with CLP and Sex and Age-Matched Reference Population*

Patient†	*Age (y)*		*Mean Z-Score*	*CVI*
M01	23	BCLP	−0.69	1.50
M02	19	BCLP	−0.26	1.27
M03	20	BCLP	−0.54	1.19
M04	19	UCLP–right	1.02	1.42
M05	24	UCLP–right	0.05	1.08
M06	24	UCLP–left	0.38	1.73
M07	23	UCLP–left	1.20	1.03
M08	24	UCLP–left	−0.45	1.26
M09	27	UCLP–left	0.36	1.54
M10	23	UCLP–left	−0.59	0.75
M11	21	UCLP–left	−0.94	0.91
Mean	22.45		−0.0418	1.244
SD	2.46		0.7076	0.292
Normality interval (reference population)				
−2 SD			−1.82	0.025
+2 SD			1.82	0.833
F01	23	BCLP	−1.55	1.11
F02	26	BCLP	−0.64	0.95
F03	19	UCLP–right	−0.78	1.31
F04	22	UCLP–right	0.22	1.44
F05	26	UCLP–right	−0.13	1.25
F06	24	UCLP–left	−1.08	0.89
F07	27	UCLP–left	−0.61	1.47
Mean	23.86		−0.6529	1.203
Sd	2.80		0.5832	0.228
Normality interval (reference population)				
−2 SD			−1.78	0.091
+2 SD			1.78	0.835
Mean	23.00		−0.2794	1.2278
SD	2.61		0.7131	0.2625

* CVI = craniofacial variability index, representing the SD of the mean z-scores computed for each patient or normal subject. BCLP = bilateral cleft lip and palate; CLP = cleft lip and palate; UCLP = unilateral cleft lip and palate.

† Mean z-scores were computed for each patient or normal subject over 17 facial soft tissue measurements.

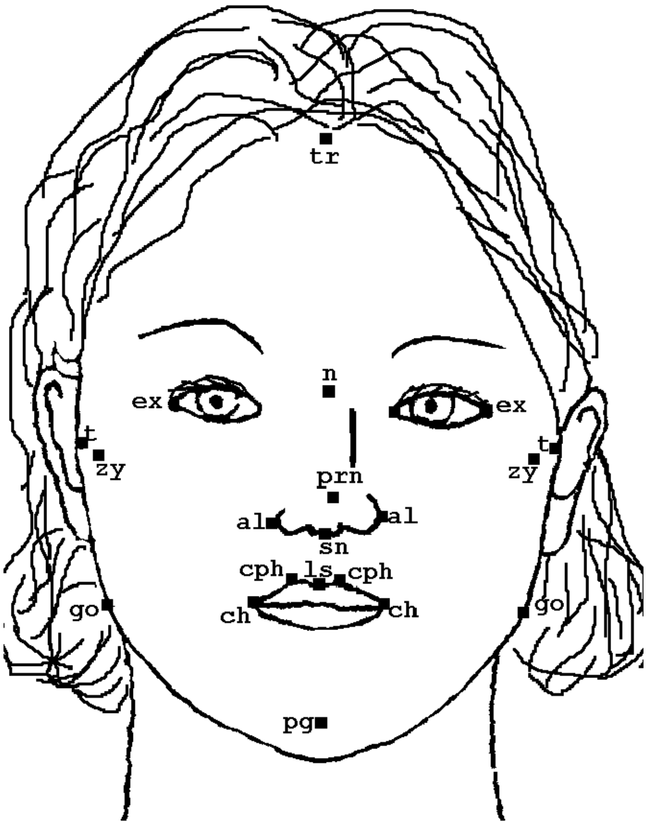

FIGURE 1 **Soft tissue facial landmarks digitized on all patients. The landmarks are defined in the text.**

2001b). All subjects gave informed consent before participating in the experiment.

Collection of Three-Dimensional Facial Landmarks

A detailed description of the data collection procedure can be found elsewhere (Ferrario et al., 1998). In brief, for each subject, a single experienced operator located and marked the landmarks on the cutaneous surface. During landmark marking, the subjects sat relaxed in a position suitable for a correct identification of facial features. The reproducibility of landmark identification, marker positioning, and data collection procedure were previously reported and found to be reliable (Ferrario et al., 1998).

Three-dimensional coordinates of the facial landmarks were then obtained with a computerized electromagnetic digitizer (3Draw, Polhemus Inc., Colchester, VT). Using the instrument stylus, a single operator digitized the marked landmarks while the subjects sat motionless with a natural head position. Data collection took less than 60 seconds. Three-dimensional (x, y, z) coordinates were recorded and analyzed using customized computer algorithms written by one of the authors.

Among the 50 soft tissue landmarks that are usually collected (Ferrario et al., 1998), the following were used in the present study (Fig. 1):

- Midline landmarks: tr, trichion; n, nasion; prn, pronasale; sn, subnasale; ls, labiale superius; pg, pogonion.
- Paired landmarks (right and left side noted r and l): ex_r, ex_l, exocanthion; zy_r, zy_l, zygion; t_r, t_l, tragion; al_r, al_l, alare; cph_r, cph_l, crista philtri; ch_r, ch_l, cheilion; go_r, go_l, gonion.

Landmark positions were defined according to Farkas (1994b). Midlandmarks were also mathematically derived as the midpoint between two homologous landmarks and noted as $landmark_m$.

Data Analysis

According to the geometric model of the face defined by Ferrario et al. (1998), the x, y, z coordinates of the landmarks obtained on each subject were used to calculate the following 15 linear distances (millimeters) and two angles (degrees):

- Head: forehead height (tr-n); skull base width (t-t).
- Face: face height (n-pg); lower face height (sn-pg); face width (zy-zy); width of the mandible (go-go); upper face depth ($n\text{-}t_m$); midface depth ($sn\text{-}t_m$); lower face depth ($pg\text{-}t_m$).
- Orbits: biorbital width (ex-ex).
- Nose: nose height (n-sn); length of the nasal bridge (n-prn); nose width (al-al); angle of facial convexity (n-prn-pg).
- Labio-oral: mouth width (ch-ch); width of the philtrum (cph-cph); nasolabial angle (ls-sn-prn).

As indicated by Ward et al. (2000), a mean z-score and its SD (CVI) were computed from the 17 measurements as follows. Individual measurements obtained in the 18 patients were transformed to z-scores by subtracting its sex and age reference mean value from it and dividing by the relevant reference SD. For each patient, descriptive statistics of his/her 17 z-scores were computed, thus obtaining a CVI. Individual z-scores were also calculated for the normal subjects as well as mean z-scores and CVI. The two variables were averaged within each sex. For each subject, computer time to perform all calculations was about 3 min.

Male versus female and UCLP versus BCLP patient data were compared by two-tail Student's *t* tests for independent samples, with a level of significance set at 5% ($p < .05$).

RESULTS

Table 1 reports the mean z-score and CVI (calculated using 17 measurements) of each of the analyzed patients, together with the relevant intervals of normality (mean $\pm$ 2 SD) calculated in the reference population (18- to 30-year-old men, 18- to 30-year-old women) matched for sex and age (Ferrario et al., 1999a, 2001a, 2001b). In the reference subjects, the average of the individual mean z-scores was zero, as would be expected (by definition, in each age and sex group, the z-score has a mean of 0 and SD of 1). The SD of the average mean z-scores was less than 1 (0.91 in males, 0.89 in females) because it was calculated on a distribution of means, not individual z-scores (Ward et al., 2000).

The patients had a mean z-score of −0.28 (SD 0.71). That is, they had, on average, a smaller facial size than the normal individuals. In all patients, the mean z-score fell inside the normal interval (mean ± 2 SD). Some variability was found, with five patients scoring a positive z-score (face larger than reference), 12 patients scoring a negative z-score, and one (M05) scoring a z-score close to 0. All females but one (F04) had a negative z-score, and four males had a positive z-score. Nevertheless, the mean z-score did not significantly differ between sexes (Student's *t* test for independent samples, $p > .05$). All patients with BCLP had a smaller face than the reference, and a variable pattern was found in UCLP. Again, the relevant mean z-scores were not significantly different, but the reduced number of patients prevented any conclusive assertion on this matter.

The mean CVI in the patients was 1.23 (SD 0.26), and 17 of 18 patients had a CVI larger than the normal interval, thus indicating a global disharmonious appearance. No significant male versus female or UCLP versus BCLP differences were found ($p > .05$).

When examining the distribution of the single z-scores of the 17 selected measurements, all patients had a reduced length of the nasal bridge (n-prn), and most (all females, 7/11 males) had a diminished nose height (n-sn). In 15 patients, the nose width (al-al) was larger, and in 11 patients the philtrum (cph-cph) was wider than in the reference population. Facial width at the gonia and tragi as well as facial depth at the nasion, subnasale, and pogonion was reduced in most patients. In all but two men, facial width at the zygia was also reduced. In the lower third of the face, the distance sn-pg was reduced in all but one woman. In contrast, it was larger than the norm in nine men. As a result, total facial height (n-pg) was increased in males and reduced in females. The angle of facial convexity (n-prn-pg) was smaller than the norm in 13 patients and somewhat higher in five patients. Fifteen patients had a less prominent upper lip, and three had the opposite morphology. No consistent patterns were observed in patients with UCLP, compared with BCLP.

Overall, in adult operated patients with CLP, pronasale, subnasale, and pogonion were more backward relative to the intertragi (the face was less deep), the nose was shorter and larger, the face was narrower, and the soft tissue profile and upper lip were flatter than in the reference population.

Discussion

Anthropometry is a useful tool for the assessment of head and face soft tissue anatomy, supplying the clinician with quantitative indications about the structures and regions that differ the most from the norm (Vegter et al., 1997; Farkas et al., 2000, 2001; Vegter and Hage, 2001). Conventional anthropometry has several limitations (complexity, time, lack of computerized instruments), making data collection time consuming and very demanding for both the clinician and the patient (Ferrario et al., 1998; Hurwitz et al., 1999).

Current technology provides several instruments that can be used for indirect anthropometric assessments (Ras et al., 1994; McCance et al., 1997; Hurwitz et al., 1999; Duffy et al., 2000). A laser-scanning technique, which provided a detailed analysis of facial characteristics based on about 80,000 soft tissue points but did not assess single anatomical landmarks, was employed by McCance et al. (1997) in adult patients with CLP and Duffy et al. (2000) in child patients with CLP. One of the main limitations of these methods is the lack of a direct identification of cutaneous landmarks. In fact, the landmarks of interest are recognized only on the digitized reconstructions of the face, with some loss of precision (see Ferrario et al., 1998, for a detailed discussion).

A recent investigation described a photographic image analysis system for indirect anthropometry in patients with CLP and reported data on a group of children (Hurwitz et al., 1999). These authors recognized the limitations of their two-dimensional approach, which, nevertheless, performed better than conventional direct anthropometry in terms of assessment time, computerized calculations (form and shape quantification), and patient cooperation (Hurwitz et al., 1999).

The present three-dimensional approach could combine the benefits of conventional anthropometry and computerized photographic or laser systems, thus proving a simple, fast, and direct computerized anthropometry. Currently, the system is being used on normal 3-year-old children (Dellavia et al., 2001) and may be employed on child patients with CLP.

In the present study, the three-dimensional electromagnetic digitizer allowed the quantitative analysis of the facial soft tissue characteristics of a group of treated adult patients with CLP. Data were compared with those collected in normal subjects of the same age, sex, and ethnic group by using two indices, namely the mean z-score and CVI (Ward et al., 2000). These two indices should provide a global assessment of the standardized deviation of facial size (mean z-score) and shape (CVI).

On average, the patients with CLP had a negative mean z-score (i.e., a smaller facial size than the normal individuals). Nevertheless, the entire mean z-scores fell inside the normal interval (mean plus two SD; Ward et al., 2000). In contrast, 17 of 18 patients had a CVI larger than the normal threshold, thus indicating a global disharmonious appearance. Nevertheless, the CVIs were smaller than those found by Ward et al. (2000) in patients having one of five craniofacial syndromes (Brachmann-de-Lange, Prader-Willy, Rubinstein-Taybi, Smith-Magenis, Sotos). In the women studied, the CVI ranged between 0.89 and 1.47; in men, it ranged between 0.75 and 1.73. Ward et al. (2000) found values up to 3.57.

Indeed, we could not use the same anthropometric measurements employed by Ward et al. (2000) because our digital method does not provide head circumference or facial curvature. Some of the alternative measurements were selected based on reports by Farkas (1994a) and Farkas et al. (2000, 2001). As recommended in previous studies (Ward et al., 2000), the measurements selected for the present investigation adequately covered all three facial thirds in all three spatial dimensions. They also embraced five (head, labio-oral, nose, orbits, and face) of the six (all five plus the ear) craniofacial regions analyzed by Farkas et al. (2001). The selected measurements covered the entire face, focusing on the eyes, nose, and lips; that is, those parts of the face that are usually considered while looking at another person (Farkas, 1994a).

In the present study, no significant male-female differences were observed in the mean z-score and CVI. Nevertheless, although all female patients but one had negative z-scores, only 6 of 11 male patients had negative z-scores. Moreover, some sex-related characteristics were found in the vertical dimension of the facial lower third, which was deficient in females and increased in males, compared with a normal reference population.

Ishii and Vargervik (1996) analyzed the longitudinal growth patterns of treated male patients with BCLP. They found deficient horizontal growth of the nose and maxilla and normal or excessive vertical growth. In addition, Smahel et al. (1993) reported that the main differences in the craniofacial skeleton between patients with cleft and normal controls consist of deficient forward growth of the maxilla and excessive vertical growth of the lower face. In adult treated patients with CLP, Farkas et al. (2000) found a narrow mandible (intergonial distance), increased nose width together with a small nasal tip protrusion, and a small upper face height (nasion-stomion). These observations are in accord with the present results: most males had a more posterior position of pronasale, subnasale, and pogonion, with a shorter nose, but an increased vertical dimension of the facial lower third. Unfortunately, neither Ishii and Vargervik (1996) nor Smahel et al. (1993) compared adult female patients with normal controls. Both in normal individuals (Ferrario et al., 1999c) and patients with CLP (Smahel and Mullerova, 1996), postpubertal facial growth is noticeable only in males, females ending their growth at the age of 13 to 15 years. This sex-related pattern of facial growth can explain the present different morphology of adult patients with CLP. Farkas et al. (2000) compared their adult female patients with normal controls but did not report separate data for the sexes.

Farkas et al. (2000) found several differences in facial proportions between patients with UCLP and BCLP, but the present limited number of patients prevents any conclusive assertion about specific characteristics.

In conclusion, the facial soft tissue structures of the present adult treated patients with CLP differed from those of normal controls of the same age, sex, and ethnic group. The current surgical corrections of CLP failed to provide a completely harmonious appearance in both sexes. Nevertheless, the deviations from the reference were limited, and the analysis pointed out those areas and structures (anteroposterior facial dimensions, nasal dimensions) that differed the most from the norm (McCance et al., 1997; Farkas et al., 2000).

Further analyses of larger groups of patients as well as longitudinal assessments of the patterns of craniofacial growth and development are needed.

References

Bondarets N, McDonald F. Analysis of the vertical facial form in patients with severe hypodontia. *Am J Phys Anthropol.* 2000;111:177–184.

Dellavia C, Colombo A, Ferrante V, Quasso L, Ferrario VF. Growth and development of facial soft-tissues in healthy male subjects from 3 to 18 years of age. *It J Anat Embryol.* 2001;106:S87.

Duffy S, Noar JH, Evans RD, Sanders R. Three-dimensional analysis of the child cleft face. *Cleft Palate Craniofac J.* 2000;37:137–144.

Farkas LG. Accuracy of anthropometric measurements: past, present and future. *Cleft Palate Craniofac J.* 1996;33:10–18.

Farkas LG. Asymmetry of the head and face. In: Farkas LG, ed. *Anthropometry of the Head and Face.* 2nd ed. New York: Raven Press; 1994a:103–111.

Farkas LG. Examination. In: Farkas LG, ed. *Anthropometry of the Head and Face.* 2nd ed. New York: Raven Press; 1994b:3–56.

Farkas LG, Forrest CR, Philips JH. Comparison of the morphology of the ''cleft face'' and the normal face: defining the anthropometric differences. *J Craniofac Surg.* 2000;11:76–82.

Farkas LG, Katic MJ, Forrest CR, Litsas L. Surface anatomy of the face in Down's syndrome: linear and angular measurements in the craniofacial regions. *J Craniofac Surg.* 2001;12:373–379.

Ferrario VF, Sforza C, Ciusa V, Dellavia C, Tartaglia GM. The effect of sex and age on facial asymmetry in healthy subjects: a cross-sectional study from adolescence to mid-adulthood. *J Oral Maxillofac Surg.* 2001a;59:382–388.

Ferrario VF, Sforza C, Ciusa V, Serrao G, Tartaglia GM. Morphometry of the normal human ear: a cross-sectional study from adolescence to mid-adulthood. *J Craniofac Genet Dev Biol.* 1999a;19:226–233.

Ferrario VF, Sforza C, Colombo A, Duncan V, Carvajal R, Palomino H. Dental arch size in human permanent healthy dentitions: ethnic differences as assessed by discriminant analysis. *Int J Adult Orthod Orthognath Surg.* 1999b;14:153–162.

Ferrario VF, Sforza C, Colombo A, Schmitz JH, Serrao G. Morphometry of the orbital region: a soft-tissue study from adolescence to mid-adulthood. *Plast Reconstr Surg.* 2001b;108:285–292.

Ferrario VF, Sforza C, Poggio CE, Cova M, Tartaglia G. Preliminary evaluation of an electromagnetic three-dimensional digitizer in facial anthropometry. *Cleft Palate Craniofac. J.* 1998;35:9–15.

Ferrario VF, Sforza C, Poggio CE, Schmitz JH. Soft tissue facial morphometry from 6 years to adulthood: a three-dimensional growth study using a new modeling. *Plast Reconstr Surg.* 1999c;103:768–778.

Ferrario VF, Sforza C, Poggio CE, Serrao G. Facial three-dimensional morphometry. *Am J Orthod Dentofacial Orthop.* 1996;109:86–93.

Goldberg JS, Enlow DH, Whitaker LA, Zins JE, Kurihara S. Some anatomical characteristics in several craniofacial syndromes. *J Oral Surg.* 1981;39:489–498.

Hajnis K, Farkas LG, Ngim RCK, Lee ST, Venkatadri G. Racial and ethnic morphometric differences in the craniofacial complex. In: Farkas LG, ed. *Anthropometry of the Head and Face.* 2nd ed. New York: Raven Press; 1994:201–218.

Hurwitz DJ, Ashby ER, Llull R, Pasqual J, Tabor C, Garrison L, Gillen J, Weyant R. Computer-assisted anthropometry for outcome assessment of cleft lip. *Plast Reconstr Surg.* 1999;103:1608–1623.

Ishii K, Vargervik K. Nasal growth in complete bilateral cleft lip and palate. *J Craniofac Surg.* 1996;7:290–296.

Laitinen SH, Heliovaara A, Ranta RE. Craniofacial morphology in young adults with the Pierre Robin sequence and isolated cleft palate. *Acta Odontol Scand.* 1997;55:223–228.

Le Mesurier AB. Method of cutting and suturing lip in complete unilateral cleft lip. *Plast Reconstr Surg.* 1949;4:1.

McCance AM, Moss JP, Fright WR, Linney AD, James DR. Three-dimensional analysis techniques. Part 1. Three-dimensional soft-tissue analysis of 24 adult cleft palate patients following Le Fort I maxillary advancement: a preliminary report. *Cleft Palate Craniofac J.* 1997;34:36–45.

Perko MA. Primary closure of the cleft palate using a palatal mucosal flap: an attempt to prevent growth impairment. *J Maxillofac Surg.* 1974;2:40–43.

Ras F, Habets LLMH, Van Ginkel FC, Prahl-Andersen B. Three-dimensional evaluation of facial asymmetry in cleft lip and palate. *Cleft Palate Craniofac J.* 1994;31:116–121.

Smahel Z, Betincova L, Mullerova Z, Skvarilova B. Facial growth and development in unilateral complete cleft lip and palate from palate surgery up to adulthood. *J Craniofac Genet Dev Biol.* 1993;13:57–71.

Smahel Z, Mullerova Z. Postpubertal growth and development of the face in unilateral cleft lip and palate as compared to the pubertal period: a longitudinal study. *J Craniofac Genet Dev Biol.* 1996;16:182–192.

Trenouth MJ, Laitung G, Naftel AJ. Differences in cephalometric reference values between five centres: relevance to the Eurocleft Study. *Br J Oral Maxillofac Surg.* 1999;37:19–24.

Vegter F, Hage JJ. Facial anthropometry in cleft patients: a historical appraisal. *Cleft Palate Craniofac J.* 2001;38:578–581.

Vegter F, Mulder JW, Hage JJ. Major residual deformities in cleft patients: a new anthropometric approach. *Cleft Palate Craniofac J.* 1997;34:106–110.

Von Lagenbech BRK. Operation der angehorenen totalen spaltung des harten gaumens nach einer neurer methode. *Dtsch Klin.* 1861;13:231.

Ward RE, Jamison PL, Allanson JE. Quantitative approach to identifying abnormal variation in the human face exemplified by a study of 278 individual with five craniofacial syndromes. *Am J Med Genet.* 2000;91:8–17.

Zumpano MP, Carson BS, Marsh JL, Vanderkolk CA, Richtsmeier JT. Three-dimensional morphological analysis of isolated metopic synostosis. *Anat Rec.* 1999;256:177–188.