Three-Dimensional Lip Morphometry in Adults Operated on for Cleft Lip and Palate

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Measurements were taken from 18 patients operated on for cleft lip and palate, aged 19 to 27 years, and 162 control subjects matched for sex, age, and ethnic group. Nine soft-tissue landmarks on the lips were digitized by a three-dimensional electromagnetic instrument. From the landmarks, several linear distances (mouth width, philtrum width, vermilion height of upper and lower lip, total vermilion height, total lip height), the interlabial angle, and some areas (vermilion of upper lip, vermilion of lower lip, total vermilion) and volumes (upper lip volume, lower lip volume, total lip volume) were calculated. Patient and reference data were compared by *t* tests and Watson-Williams tests. In the men, significant differences ($p < 0.05$) were found in width of the philtrum, height and area of the vermilion part of the upper lip, and total vermilion height and area (all larger in male patients than in controls). In the women, significant differences were found in the height and area of the vermilion part of the upper lip (larger in female patients than in controls), and in the height and area of the vermilion part of the lower lip (smaller in patients than in controls). In both sexes, the interlabial angle was smaller than in the reference population. In conclusion, the upper lip of adult patients operated on for cleft lip and palate differed from that of healthy controls of the same age, sex, and ethnic group. Surgical correction of cleft lip and palate failed to provide a completely normal appearance. The analysis pointed out those parts of the lips and mouth (in particular, the vermilion part of the upper lip) that differed the most from the norm. The method may be used to indicate to the surgeon and patient where additional procedures might be performed to approximate the morphologic characteristics of a reference population. (*Plast. Reconstr. Surg.* 111: 2149, 2003.)

The craniofacial characteristics of adult patients operated on for cleft lip and palate have been analyzed in a large number of investigations. In particular, the features of the skeletal and soft-tissue structures, as depicted by lateral cephalograms, have been widely detailed.[1–6] Unfortunately, radiographic analyses have limitations: they use ionizing radiation and thus are invasive; and they provide a two-dimensional assessment of the skeletal configuration, neglecting most of the soft tissues and projecting all structures on a single (usually midsagittal) plane.[6–8] Moreover, it is well known that facial structures have characteristics specific for age, sex, race, and ethnicity, as well as secular variations.[8–15] 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, three-dimensional, and considers all of the facial structures, thus providing a more complete evaluation of the single patient.[6,16–19] The collection of normative data infringes on no current ethical consideration.

Noninvasive soft-tissue data have been reported only in a limited number of adult patients operated on for cleft lip and palate.[6,18,20–22] In particular, data on the quantitative three-dimensional characteristics of the lips and mouth are still missing.

In the present study, the facial soft tissues of a group of adult patients with complete cleft lip and palate were measured three-dimensionally after completion of several surgical procedures. Using a geometric-mathematical mod-

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el,[23,24] several anthropometric measurements of the lips (linear distances, interlabial angle, vermilion area, volume) in the three-dimensional space were performed and were compared with those collected from healthy individuals of the same sex, age, and ethnic group. The aim of the study was to measure the difference between adult patients operated on for cleft lip and palate and healthy adults in an attempt to provide a final assessment of the facial outcome of surgery.

Patients and Methods

Patients

In the present study, data were collected from 18 patients (11 male, seven female), aged 19 to 27 years (mean, 23 years; SD, 2.61), with complete cleft lip and palate and no other associated malformations (Tables I and II). Five patients (three male, two female) had a bilateral cleft, five (two male, three female) had a unilateral cleft on the right side, and eight patients (six male, two female) had a unilateral cleft on the left side. All patients were white northern Italians and were born between 1973 and 1981. They represented 64 percent of the 28 young adults asked to participate in the examination.

All patients had undergone several surgical procedures for repair of their skeletal and soft-tissue malformations; the same team performed all procedures. Generally, primary cheiloplasty had been performed according to Le Mesurier[25] between 4 and 8 months of age. Posterior palatal surgery had been performed at 2 to 3 years of age,[26] whereas anterior palatal surgery had been performed according to Perko[27] between 5 and 7 years of age. Fifteen patients had received an alveolar bone graft according to their dental age (eruption of the maxillary permanent canine). At the end of facial growth, after 18 (male) or 16 (female) years of age, six male and seven female patients also underwent rhinoseptoplasty.

Reference data were collected in previous investigations performed on 73 female and 89 male healthy individuals of the same ethnic group and sex, born between 1973 and 1985.[11,14,15] All participants gave their informed consent to the experiment.

Collection of Three-Dimensional Facial Landmarks

A detailed description of the data collection procedure can be found in Ferrario et al.[17] In brief, for each subject, a single experienced operator located the landmarks and marked them on the cutaneous surface. During the marking process, 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.[17]

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

TABLE I
Three-Dimensional Linear Distances (mm) in Male Patients with Cleft Lip and Palate versus Controls[a]

			Width		Vermilion Height			
Patient	Age (yr)	Disorder	Mouth (ch_r–ch_l)	Philtrum (cph_r–cph_l)	Upper Lip (*ls–sto*)	Lower Lip (*sto–li*)	Total (*ls–li*)	Total Lip Height (*sn–sl*)
M01	23	BCLP	43.38	11.07	15.37	9.45	24.82	48.09
M02	19	BCLP	51.21	11.50	14.23	14.14	28.38	45.77
M03	20	BCLP	56.61	18.81	11.57	8.41	19.96	48.85
M04	19	UCLP, R	49.12	16.04	9.94	8.39	18.32	42.00
M05	24	UCLP, R	47.87	16.20	9.86	4.85	14.71	41.50
M06	24	UCLP, L	51.82	18.48	12.97	5.98	18.86	54.31
M07	23	UCLP, L	52.63	16.73	11.95	9.28	21.21	46.36
M08	24	UCLP, L	53.44	12.69	11.48	8.67	20.15	40.59
M09	27	UCLP, L	55.33	11.42	7.60	14.39	21.93	37.24
M10	23	UCLP, L	48.24	13.14	10.18	3.69	13.86	41.50
M11	21	UCLP, L	50.51	13.85	6.47	4.12	10.58	30.72
Mean	22.45		50.92	14.54*	11.06**	8.31	19.34**	43.36
SD	2.46		3.75	2.84	2.65	3.60	5.03	6.33
Reference mean			51.90	12.32	6.84	8.80	15.39	42.24
SD			3.35	2.00	2.21	2.73	2.98	3.82

[a] *t* test for independent samples; 98 degrees of freedom: * $p < 0.05$; ** $p < 0.01$. M, male; BCLP, bilateral cleft palate; UCLP, unilateral cleft palate; R, right; L, left; SD, standard deviation.

TABLE II

Three-Dimensional Linear Distances (mm) in Female Patients with Cleft Lip and Palate versus Controls[a]

Patient	Age (yr)	Disorder	Width: Mouth (ch_r–ch_l)	Width: Philtrum (cph_r–cph_l)	Vermilion Height: Upper Lip (*ls*–*sto*)	Vermilion Height: Lower Lip (*sto*–*li*)	Vermilion Height: Total (*ls*–*li*)	Total Lip Height (*sn*–*sl*)
F01	23	BCLP	43.83	5.91	12.29	6.53	18.67	40.51
F02	26	BCLP	46.58	8.85	13.70	5.53	19.20	42.28
F03	19	UCLP, R	50.32	9.26	8.26	5.85	14.12	37.11
F04	22	UCLP, R	50.02	10.13	7.59	7.07	14.66	39.08
F05	26	UCLP, R	50.63	11.42	8.93	5.87	14.79	36.58
F06	24	UCLP, L	44.88	11.36	10.96	5.89	16.84	36.05
F07	27	UCLP, L	52.44	16.60	11.95	9.25	21.20	37.95
Mean	23.86		48.39	10.50	10.53	6.57	17.07	38.51
SD	2.80		3.27	3.27	2.30	1.29	2.71	2.26
Reference mean			48.52	10.84	6.62**	9.09*	15.49	39.00
SD			3.43	2.22	2.38	2.76	2.77	3.42

[a] *t* test for independent samples; 78 degrees of freedom: * $p < 0.05$; ** $p < 0.01$. F, female. For definition of other abbreviations, see Table I.

marked landmarks while the subjects sat motionless with a natural head position. The files of the three-dimensional (*x, y, z*) coordinates were then obtained, and computer programs devised and written by one of the authors were used for all subsequent calculations.

Among the 50 soft-tissue landmarks usually collected,[17] the following were used in the present study (Fig. 1):

- midline landmarks: *sn*, subnasale; *ls*, labium superius oris; *sto*, stomion; *li*, labium inferius oris; *sl*, sublabium
- paired landmarks (right and left sides indicated by r and l): cph_r and cph_l, crista philtrum; ch_r and ch_l, cheilion

The landmark positions were defined according to Farkas.[16]

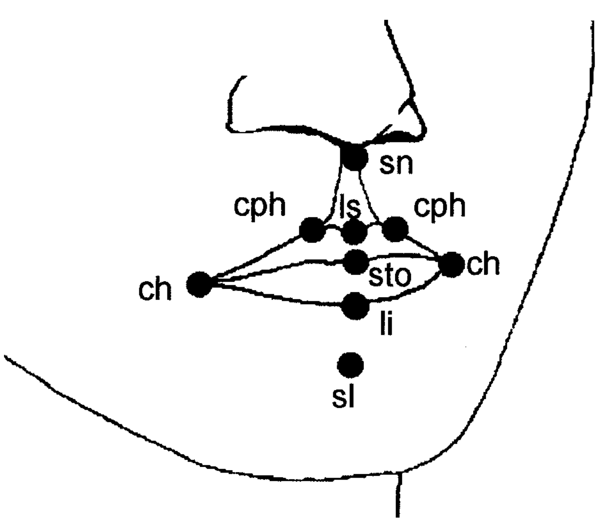

FIG. 1. Digitized soft-tissue three-dimensional landmarks.

Data Analysis

According to the geometric model of the lips defined by Ferrario et al.,[23,24] the *x, y, z* coordinates of the landmarks obtained on each subject were used to calculate the following parameters:

- linear distance (mm): mouth width (ch_r to ch_l); width of the philtrum (cph_r to cph_l); vermilion height of the upper lip (*ls* to *sto*); vermilion height of the lower lip (*sto* to *li*); total vermilion height (*ls* to *li*); and total (cutaneous) lip height (*sn* to *sl*)
- angle (degrees): interlabial angle ([*sn* to *ls*] $\wedge$ [*li* to *sl*])
- area (cm^2): vermilion of the upper lip (area of the quadrangle between ch_r, *ls*, ch_l, *sto*); vermilion of the lower lip (area of the quadrangle between ch_r, *li*, ch_l, *sto*); total vermilion (area of the quadrangle between ch_r, *ls*, ch_l, *li*)
- volume (cm^3): upper lip volume (approximated from the volumes of two tetrahedra: the first tetrahedron had the plane ch_r, ch_l, *ls* as its base and its vertex in *sn*, the second had the plane ch_r, ch_l, *ls* as its base and its vertex in *sto*); lower lip volume (as above, first tetrahedron with the plane ch_r, ch_l, *li* as its base and its vertex in *sl*, the second with the plane ch_r, ch_l, *li* as its base and its vertex in *sto*); total lip volume (sum of the four tetrahedra).

All measurements were performed in the three-dimensional space; i.e., the position of the points relative to all three planes (frontal, lateral, and horizontal) was considered simultaneously (no projections).

Descriptive statistics (mean and standard deviation) for each measurement were computed within sex separately for patients and control subjects. Angular statistics was used for the interlabial angle.[8] The patients were also subdivided according to bilateral cleft (five subjects) and unilateral cleft (13 subjects). Patient and control data were compared by two-tail *t* tests for independent samples (univariate statistics), and by Watson-Williams tests (bivariate statistics), without correction for multiple testing. A level of significance of 5 percent ($p < 0.05$) was used for all analyses.

Results

Tables I through IV report the anthropometric measurements computed in the 18 cleft lip and palate patients and in the control subjects matched according to age, sex, and ethnic group. Overall, in both sexes most of the significant differences were found in the correspondence of the vermilion part of the upper lip.

In the male patients, the width of the philtrum was significantly larger than in the control subjects, and the vermilion part of the upper lip was higher and had a larger area (Tables I and III). Also, the total vermilion height and area were larger than in the control subjects. The interlabial angle was 12 degrees smaller than in the reference population, a difference significant at $p = 0.027$.

In the female patients, the vermilion part of the upper lip was also significantly higher and had a larger area than in the control subjects (Tables II and IV). In contrast, the lower lip had a smaller vermilion compared with the control group. The patients' lips were significantly more prominent than those of the control subjects.

Male and female patients differed only at the labium philtrum (significantly wider in men according to *t* test, $p = 0.02$) and at the interlabial angle (about 1 degree larger in men according to Watson-Williams test, $p = 0.02$). In the reference population, significant differences were found for mouth and philtrum width, total lip height, and all three labial volumes (all larger in men according to *t* test, $p = 0.001$).

In the bilateral cleft patients, the vermilion of the upper lip was approximately 3.5 mm larger than in the unilateral cleft patients (*t* test, $p = 0.003$), and the corresponding area was 1 cm^2 larger ($p = 0.01$). Also, the total vermilion height was 5 mm larger ($p = 0.024$).

Discussion

Anthropometry is a useful tool for assessment of the soft-tissue anatomy of the head and face, supplying the clinician with quantitative indications about the structures and regions that differ the most from the norm.[18,21,22,28] Conventional anthropometry has limitations (e.g., complexity, time, lack of computerized instruments), making data collection time-consuming and very demanding for both clinician and patient.[17,29] Moreover, it does not

TABLE III

Lip Angles (degrees), Areas (cm^2), and Volumes (cm^3) in Male Patients with Cleft Lip and Palate versus Controls[a]

Patient	Disorder	Interlabial Angle (*sn–ls*) (*li–sl*)	Vermilion Area			Volume		
			Upper Lip	Lower Lip	Total	Upper Lip	Lower Lip	Total
M01	BCLP	135.03	3.92	2.41	6.33	2.71	2.43	5.15
M02	BCLP	114.22	4.01	3.98	7.99	2.61	3.11	5.71
M03	BCLP	123.06	3.98	2.88	6.87	6.00	4.13	10.12
M04	UCLP, R	126.37	2.74	2.31	5.06	2.63	2.38	5.01
M05	UCLP, R	129.06	3.06	1.50	4.56	3.54	2.84	6.37
M06	UCLP, L	142.67	3.90	1.76	5.66	3.84	3.69	7.54
M07	UCLP, L	130.91	3.47	2.68	6.15	3.59	2.66	6.25
M08	UCLP, L	120.72	3.41	2.57	5.98	3.15	2.38	5.53
M09	UCLP, L	100.15	2.45	4.72	7.16	2.96	4.39	7.35
M10	UCLP, L	136.80	3.10	1.12	4.22	3.77	2.62	6.40
M11	UCLP, L	155.86	1.83	1.16	2.99	1.66	1.75	3.40
Mean		128.63*	3.26*	2.46	5.73**	3.32	2.94	6.26
SD		4.41	0.71	1.12	1.44	1.10	0.81	1.72
Reference mean		141.05	2.01	2.62	4.62	3.33	2.59	5.92
SD		12.95	0.71	0.85	0.93	0.86	0.72	1.29

[a] Angles: Watson-Williams test; 1,98 degrees of freedom. Areas and volumes: *t* test for independent samples; 98 degrees of freedom. * $p < 0.05$; ** $p < 0.01$. For definition of abbreviations, see Table I.

TABLE IV

Lip Angles (degrees), Areas (cm^2), and Volumes (cm^3) in Female Patients with Cleft Lip and Palate versus Controls[a]

Patient	Disorder	Interlabial Angle (*sn–ls*) (*li–sl*)	Vermilion Area			Volume		
			Upper Lip	Lower Lip	Total	Upper Lip	Lower Lip	Total
F01	BCLP	125.01	3.04	1.57	4.61	2.03	2.13	4.16
F02	BCLP	130.72	3.78	1.52	5.29	3.22	2.09	5.31
F03	UCLP, R	152.99	2.30	1.62	3.92	1.81	2.00	3.80
F04	UCLP, R	109.52	2.31	2.16	4.47	3.63	2.94	6.57
F05	UCLP, R	125.45	2.67	1.75	4.42	2.65	2.93	5.57
F06	UCLP, L	126.02	2.87	1.54	4.40	2.39	1.53	3.92
F07	UCLP, L	125.30	3.41	2.63	6.03	2.30	1.99	4.29
Mean		141.05*	2.91**	1.83*	4.73	2.58	2.23	4.80
SD		12.95	0.55	0.42	0.70	0.65	0.52	1.04
Reference mean		139.03	1.83	2.56	4.38	2.70	2.22	4.92
SD		14.35	0.71	0.84	0.88	0.76	0.69	1.23

[a] Angles: Watson-Williams' test; 1,78 degrees of freedom. Areas and volumes: *t* test for independent samples; 78 degrees of freedom. * $p < 0.05$; ** $p < 0.01$. For definition of abbreviations, see Table I.

provide coordinate data that could be used for computerized calculations (form and shape quantification).[30]

Current technology provides several image analysis systems for indirect anthropometry in cleft lip and palate patients, such as photographic,[21,22,29] stereophotogrammetric,[7,31] and laser scanning[20,30] instruments. The limitations of these systems have been pointed out by the same authors who applied them (e.g., photographs are two-dimensional; stereophotogrammetry does not directly identify the cutaneous landmarks: actually, the landmarks of interest are recognized only on the digitized reconstructions of the face; inaccuracy in some spatial directions for occasional landmarks).[7] Laser scanning provides a wealth of points but not actual anatomical landmarks, and analysis is best performed in facial "areas."[20]

All of these instruments collect surface data using noncontact techniques. In contrast, the electromagnetic digitizer used in the current investigation provides the three-dimensional coordinates of landmarks that are actually touched, one by one, by the instrument's stylus.[17] The method, therefore, could couple the benefits of conventional anthropometry and computerized systems and thus provide a simple, fast, and direct computerized anthropometry. The major limitation seems to be the requirement to remain motionless during all data collection (approximately 1 minute), which may hamper its use in children. Indeed, the system is currently being used in healthy 3-year-old children,[32] and it may also be used in children with cleft lip and palate.

The current study analyzed lip characteristics in adult patients operated on for cleft lip and palate. Several previous investigations reported both two-dimensional and three-dimensional information on lip dimensions in healthy adults, as widely detailed by Ferrario et al.[24] In earlier studies, three-dimensional data on normal lip structure were also collected using an optoelectronic digitizer.[23,24] The method individualized single anatomical landmarks, identified by retro-reflective marks by a noncontact method, and mathematically calculated their spatial coordinates. One of the limitations of the optoelectronic instrument was the marker dimension (2 mm), which limited the number of landmarks collectable per unit of facial surface. The marker dimensions do not limit the accuracy of landmark identification (the image analyzer detects the center of gravity of the marker, that is, a single spatial point for each landmark, independently of the physical dimension of the marker), but in some facial regions (e.g., lips, ears) the markers relative to different landmarks touch each other or are partly superimposed.[17] The recognition of landmarks, therefore, may be laborious and time-consuming. Furthermore, whereas the retro-reflective markers cannot be used to identify stomion, the electromagnetic digitizer can be used with the scope. A larger number of landmarks was therefore used in the current study, and, in particular, the limitation due to the lack of landmark stomion was overcome.[23,24] Overall, considering the different technique, the present reference data seem comparable with the findings previously reported in healthy subjects of the same ethnic group.[24]

It is of note that lip area and volume were obtained from a geometric model of the lips in which only some discrete landmarks were sampled (Fig. 1), and the surfaces between contiguous landmarks (actually curved) were approximated by linear planes. Therefore, the calculations cannot provide the actual anatomical measurements, but rather only an approximation of their values.[23,24,33]

The main differences between the current 18 adult patients operated on for cleft lip and palate and their healthy reference peers were located in the vermilion part of the upper lip (Tables I through IV). Overall, the vermilion of the upper lip was significantly larger in patients than in controls. Indeed, the average differences were very limited (<5 mm in the *ls* to *sto* distance, 1.5 cm^2 in the vermilion area). In contrast, when individual patients were analyzed, differences of up to 8.5 mm (*ls* to *sto*, patient M01), 1.7 mm (patient F02), and 2 cm^2 (area, patients M02 and F02) were measured.

The difference was most striking in the bilateral cleft patients: on average, the *ls* to *sto* distance was 13.4 mm in bilateral cleft patients and 9.9 mm in unilateral cleft patients. Upper lip vermilion area was 3.75 cm^2 in bilateral cleft patients and 2.89 cm^2 in unilateral cleft patients. Similar findings were reported also by Duffy et al.[30] in 8- to 11-year-old children with cleft lip and palate, and by Vegter et al.[21] in 19- to 25-year-old adults with cleft lip and palate. It is of note that, according to Vegter et al.,[21] a too short upper lip may have a poorer appearance than a too long lip.

Also the philtrum was significantly wider in male patients than in controls (Table I), whereas no differences were found in the women. Sex differences in mouth size and shape may explain this finding, as well as a large intragroup variability: in women, four of seven patients had a philtrum narrower than the reference; in men, three of 11 had a narrower philtrum (Tables I and II).

Lip prominence, as depicted by the interlabial angle (*sn* to *ls*) $\wedge$ (*li* to *sl*), was significantly larger in patients with cleft lip and palate than in the reference group. No differences were found between patients with bilateral cleft and those with unilateral cleft. This angle evaluates upper versus lower lip position, and it is independent from other face and head landmarks, thus providing an intrinsic assessment of relative lip position. In contrast, the lip index suggested by Vegter et al.[22] relies on an external landmark for its assessment (tragion), and it supplies lip position relative to the other facial structures.

It seems that the surgical procedures used in the present group of cleft lip and palate patients failed to obtain a completely normal lip structure. The result was better in the cutaneous part of the lip: no differences were found in total lip height (*sn* to *sl*) and volume, which considers both the cutaneous and the vermilion parts of the lip.[23,24] The defect in the vermilion part of the lip may be caused by both the kind of reconstructive surgery performed and the timing of the interventions.

Smahel et al.[1] reported that patients operated on for cleft lip and palate had a reduced growth of the upper lip, which was particularly evident in the vermilion part of the lip. This growth deficit resulted in an insufficient height of the upper lip, an effect worsening after puberty in male patients.[3] Both intrinsic tissue deficiency and the surgical technique of repair were examined to explain the finding.[1] In contrast, as cited by Vegter and Hage, Farkas and Lindsay found normal development in the upper lip of patients operated on for cleft lip and palate.[6]

Different surgical approaches and intrinsic differences among patients (ethnic group, cohort) may partly explain these contrasting results. In particular, the continuous evolution of the surgical techniques used to repair the soft and hard tissues in patients with cleft lip and palate seems particularly important.[6,34] Moreover, both the current study and those by Farkas and Lindsay (as cited by Vegter and Hage[6]) were three-dimensional, whereas Smahel et al.[1] and Smahel and Mullerova[3] used two-dimensional radiographic projections for their measurements. The different image techniques may also explain the variations between the present values of upper lip height and those reported by Heliovaara et al.[5] and by Smahel and Mullerova.[3]

In conclusion, the upper lip of the current adult patients operated on for cleft lip and palate differed from that of healthy controls of the same age, sex, and ethnic group. In the patients, surgical correction of cleft lip and palate failed to provide a completely normal appearance. The deviations from the reference were larger in the bilateral cleft patients, and the analysis pointed out those parts of the lips and mouth (in particular, the vermilion part of the upper lip) that differed the most from the norm. The method may be used to indicate to the surgeon and patient where additional procedures might be performed to approximate the anthropometric and aesthetic characteristics of a reference population. Also, these data could provide suggestions about the technical and chronological details of the most useful surgical procedures. Nevertheless, the surgical approach must be as noninvasive as possible to avoid additional, unnecessary repairs.

Further analyses of larger groups of patients are needed, along with longitudinal assessments of the patterns of craniofacial growth and development.

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