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Three-dimensional laser scanner evaluation of facial soft tissue changes after LeFort I advancement and rhinoplasty surgery: patients with cleft lip and palate vs patients with noncleftedmaxillary retrognathic dysplasia (control group)

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Objective. The aim of this study was to analyze the differences in facial soft tissue changes, despite the same extent of upper jaw forward movement, between patients with unilateral cleft lip and palate (uCLP) and those without, after LeFort I osteotomy and secondary rhinoplasty.
Study Design. Twelve patients with maxillary retrognathic dysplasia and nose deformity were divided in 2 groups, A (uCLP) and B (control), and compared on the basis of the same maxillary advancement. Cephalometry and 3D mean facial model of groups A and B were obtained before and after surgery. Linear and angular measurements were calculated.
Results. Upper vermilion and alar base remained unchanged in group A but increased in group B. In both groups, symmetry of the nasal base was improved, and an increase of the sagittal projection of the lips was observed.
Conclusions. 3D analysis showed that surgical procedures for uCLP can provide a satisfactory aesthetic outcome, but some differences are evident in comparison with the control group. (Oral Surg Oral Med Oral Pathol Oral Radiol 2014;117:416-423)

Improvement of facial aesthetics is one of the primary objectives of modern orthognathic surgery; attractiveness is a major component of the self-concept. The appearance of the face has been found to influence the social acceptance and psychological well-being of the individual. In the literature, it has been reported that symmetrical body shape is a central cue for attractiveness.[1-3] Thus, patients with cleft lip and palate (CLP) are at potential disadvantage.[3,4]

The cleft malformation shows a variety of interindividual shapes. Even in those who received surgery followed by therapeutic rehabilitation early in infancy, adult patients with CLP often show secondary deformities in the maxillary and nasal regions. These deformities may consist of defects that are unrepaired in primary surgery and distortions that develop through growth or are caused by residual scars. Clinical examination usually finds upper lip scars from previous corrective plastic surgery, maxillary hypoplasia, difference in lip length, and nasal deformities, which can vary from almost invisible to catastrophic, mostly dependent on the severity and type of cleft[5] and on the ability of the cleft-repairing surgeon. Nose distortions include a deviated columella, a depressed and deviated nasal tip, dislocation of the alar cartilage, webbing at the alar rim, flat and V-shaped nostrils, and scarring or fistulas of the nostril floor. These abnormalities are involved in all components of the nose, such as the facial skeleton, cartilage, muscle, skin, subcutaneous tissue, and mucosal lining.[6-9]

There are many well-established surgical techniques to repair residual maxillary, lip, and nose deformities in adult patients with CLP. In all cases, the aim of the therapy is to reach normal anatomy with symmetrical relations between the cleft and noncleft sides.

Several cephalometric studies in cleft patients after surgery were conducted. The results of soft tissue changes have so far been interpreted with the aid of lateral cephalograms.[10] However, in the lateral view, structural comparison is limited in the medial plane, and the asymmetries were not quantified.[11] Analytical and objective 3-dimensional (3D) laser scanner evaluation could help to quantify the postoperative soft tissue changes.

To the authors' knowledge, no 3D laser scanner studies have been performed on the volumetric 3D soft tissue changes after LeFort I osteotomy and secondary rhinoplasty surgery (RSP) in patients with unilateral

Statement of Clinical Relevance

3D analysis showed that surgical procedures in adult patients with uCLP can provide a symmetric nasal base and a satisfactory facial profile, but some differences remain in the postoperative frontal and profile views in patients with uCLP, in comparison with the control group, indicating further technical requirement.

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CLP (uCLP) compared with a control group (patients with noncleftcd maxillary retrognathic dysplasia).

The aim of this study was therefore to analyze the differences in facial soft tissue changes in patients with uCLP who underwent LeFort I osteotomy and secondary RSP surgery compared with patients without CLP who underwent the same extent of upper jaw forward movement and secondary RSP surgery.

PATIENTS AND METHODS

From January 2010 to December 2011, 53 adult white patients with maxillary retrognathic dysplasia and varying degrees of nasal deformity underwent LeFort I osteotomy and secondary RSP at the Division of Maxillofacial Surgery, San Giovanni Battista Hospital, University of Turin, Turin, Italy.

The criteria for inclusion in the present study were as follows: white men or women, adult age (>18 years), skeletal class III status (with maxillary retrognathic dysplasia, SNA [sella/nasion/A point angle] $< 82° \pm 2°$), and nasal deformity. All the patients underwent a similar surgical procedure, by the same surgeon, consisting of a maxillary advancement (standardized surgical treatment consisting of a LeFort I osteotomy) and RSP with or without grafts. After maxillary stabilization, a resorbable (2.0 Vicryl) oblique suture, performed intraorally with 2 symmetrical tension stitches between levator labii superioris alaeque nasi (LLSAN) of the right side and LLSAN of the left side, allowed a good control of alar flaring.

Patients with congenital syndromes or previous facial injuries, those with incomplete clinical and radiologic records, and those who had not completed their postoperative follow-up were excluded from the study.

Twelve patients fulfilled inclusion criteria for the study and were divided in 2 groups (Table I). Variables examined included age, sex, and deformity of the nose.

Group A included 6 adult patients (4 women, 2 men) with complete uCLP (with no other associated malformations or distinctive features in the face, such as piercing or tattoos; mean age, 28.5 years; range, 18-39 years). Three patients had a uCLP on the right side; the others (1 woman, 2 men) had a uCLP on the left side. Cheilorhinoplasty was conducted between the ages of 6 and 9 months. Closure of the hard and soft palates was done between the ages of 12 and 18 months. Three patients received a secondary alveolar bone graft between ages 10 and 13 years. In all patients, a fixed orthodontic appliance was placed to align the permanent teeth.

Group B (control) included 6 patients (4 women, 2 men; mean age, 28 years; range, 22-45 years). The patients of this group were selected on the basis of the same maxillary advancement of the patients in group A. None had distinctive features in the face, such as piercing or tattoos. In all patients, a fixed orthodontic appliance was placed to align the permanent teeth; 1 out of 6 also underwent mandibular setback to correct progenism.

Preoperative patients' features and descriptions of the surgical procedures are given in Table I. The costal and auricular cartilage grafts were used to support the nasal tip projection. The quadrangular cartilage graft was used in patient 6 to reconstruct the left nasal alae.

Lateral (L) cephalometry and 3D facial surface data were obtained before surgery (T0) and 1 year after surgery (T1).

Informed consent was obtained from all participants. This study was performed in agreement with the local institutional review board. We followed the Helsinki Declaration guidelines.

Cephalometric measurements

Lateral cephalograms were traced by 1 examiner using the software Dolphin 11.0 Premium (Dolphin Imaging, Chatsworth, CA, USA). Only SNA measurements were obtained to assess sagittal skeletal movements.

A subsample of 20 randomly selected radiographs were retraced and digitized 1 month later to calculate the systematic errors. All the measurements were compared between the 2 time sets by the paired *t* test. All the measurements presented no significant difference at retracing.

Facial scan and data processing

3D images of all participants were obtained at T0 and at T1. Surface data were acquired using a head and face color 3D scanner (3030RGB; Cyberware Inc, Monterey, CA, USA). Participants were registered with the head in natural position, the eyes closed, and the teeth in occlusion. The acquired data were transferred to a graphics workstation for viewing and elaboration with Cyberware Echo software (Cyberware Inc, Monterey, CA, USA). The scanning method and the detailed protocol regarding how to reduce the artifacts were previously described.[12]

Scanned data arrays of the facial area were first restricted and then reduced from around 160 000 to 30 000 points. Facial surface reconstruction, multiple scan alignment, and measurements were carried out using Rapid Form 2004 software (INUS Technologies Inc, Seoul, South Korea).

Facial scans at T0 and T1 were pooled together by electronic surface averaging to obtain the mean facial model of patients with uCLP (A) and control group participants (B), before (T0) and after treatment (T1); the rater was L.V. (Figure 1). The 3D average surfaces were constructed using the software Morphostudio

Table I. Patients involved in the study

A (uCLP)						
					Surgery	
Patient	*CLP side*	*Sex*	*Age (y)*	*Deformity of the nose**	*LeFort I (advancement, mm)*	*RSP*‖
1	Right	F	18	b, c	5	B§
2	Right	F	35	a, d, e	5	C, E
3	Right	F	18	c, e	6	B, D
4	Left	F	39	d	7	‡
5	Left	M	20	b, d	7	†
6	Left	M	21	b, d, e	8	A, B, C, E

B (control)						
					Surgery	
Patient	*Angle*	*Sex*	*Age (y)*	*Deformity of the nose*	*LeFort I (advancement, mm)*	*RSP*
1	III	F	24	b, e	5	A, C, E
2	III	F	22	e	5	A, C§
3	III	F	22	c, e	6	C, E
4	III	F	45	e	7	C, E
5	III	M	23	e	7	C, D
6	III	M	32	e	8	A, C, E

CLP, cleft lip and palate; *uCLP*, unilateral cleft lip and palate; *RSP*, rhinoplasty surgery.
*Deformity of the nose. *a*, deviated columella; *b*, depressed or deviated nasal tip; *c*, wide nasal ala; *d*, flat and v-shaped nostril; *e*, hump.
†Costal cartilage graft.
‡Auricular cartilage graft.
§Quadrangular cartilage graft.
‖*A*, symmetrizing of alar cartilages; *B*, basal osteotomy; *C*, hump; *D*, septum; *E*, tip of the nose (upward rotation).

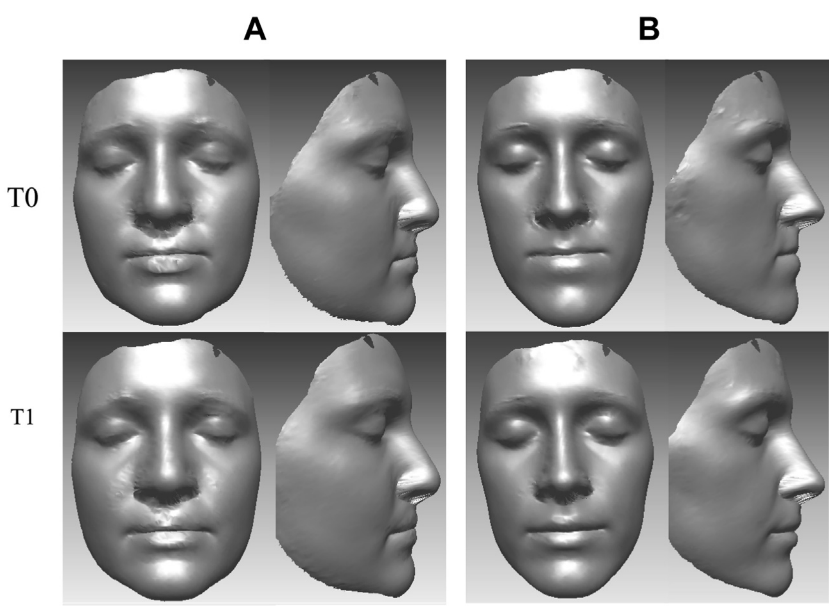

Fig. 1. Mean facial model of patients with unilateral cleft lip and palate (A) and control group participants (B) at T0 and at T1.

(Biomodelling Solutions, UK) and a mesh framework algorithm based on 9 anatomic landmarks.

Reference vertical planes (Y, midline through glabella; Y1, vertical plane through left endocanthion and perpendicular to X) and horizontal planes (X, through the right and left endocanthion) were constructed on models.

Different linear and angular measurements of the mean faces were calculated for comparison of the T0 and T1 models using 10 landmarks taken from classical anthropometry. The landmarks were as follows (Figure 2; Table II): (1) enr, right endocanthion; (2) enl, left endocanthion; (3) alr, right alar crest point; (4) all, left alar crest point; (5) prn, tip of nose; (6) sn,

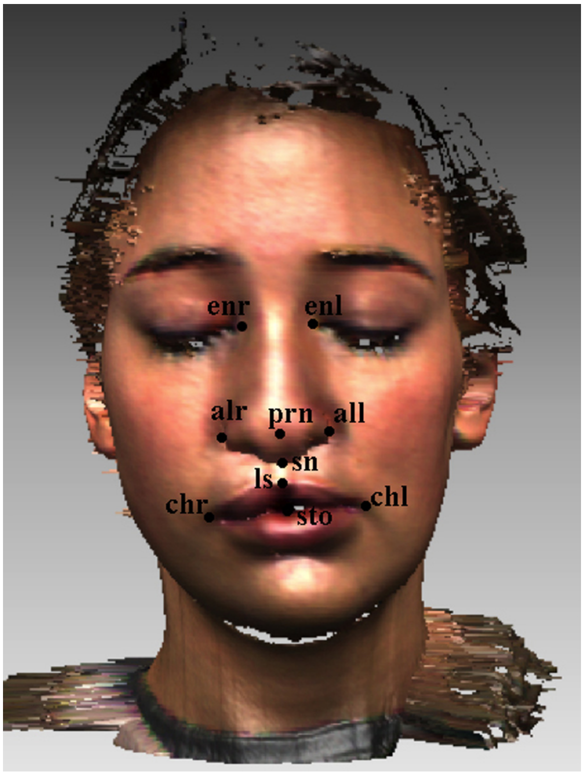

Fig. 2. Demonstration of 10 facial landmarks taken from classical anthropometry employing 3D analyses. (*enr*, right endocanthion; *enl*, left endocanthion; *alr*, right alar crest point; *all*, left alar crest point; *prn*, tip of nose; *sn*, subnasale; *chr*, right cheilion; *chl*, left cheilion; *ls*, labialis superior; *sto*, stomation.)

subnasale; (7) chr, right cheilion; (8) chl, left cheilion; (9) ls, labialis superior; and (10) sto, stomation. Differences of linear measurement greater than 1 millimeter and angular measurements superior to 3 grades were considered significant.

Axial cross sections through prn, sn, and ls and sagittal cross sections were also obtained (Figures 3 and 4).

RESULTS

Cephalometric measurements

The L Cephalometric measurements showed a maxillary advancement between 5 to 8 mm (mean, 6.33 mm) in each group (see Table I).

Facial scan and data processing

The comparison between A and B found that patients with uCLP had a shorter and more round face than participants without CLP, in both T0 and T1 (see Figure 1).

In frontal view, a vertical increase of the upper vermilion and increase of the alar base width were evident in B. At T0, the alar base width in A was bigger than in B and was unchanged at T1; in A the upper vermilion also remained unchanged. In both groups, symmetry of the alar forms were improved at T1 (see Figure 1).

In profile view, both in A and B, an improvement of the orbito-maxillary-zygomatic sulcus and increase of the sagittal projection of the lips were observed; at T1, a successfully projected nasal tip was noticed more in B than in A (see Figure 1).

Table II showed different linear and angular measurements of the mean faces at T0 and T1. Measurements at T0 and T1 documented that the major postoperative changes in A and B were in the upper lip and nose. At T0, al_r-al_l in A was greater than in B; at T1 this measurement significantly decreased in A. Normalization of the nasal alae was evident in B; reduced but still noticeable asymmetry of the alae was observed in A ($al_{r\text{-}l}$-prn). At T0, the al point of the 2 sides demonstrated vertical asymmetry, significantly improved at T1; $al_{r\text{-}l}$-X was greater in B than in A, at both T0 and T1. In A, prn-Y showed that surgery allowed an improvement of deviation of the tip of the nose on the symmetry axis. After treatment, the distance of the ls from sto was increased in B, demonstrating lengthening of the upper vermilion.

In A, prn-sn-ls° significantly increased and was larger than in B either at T0 or T1. The distance between prn and the horizontal axis (prn-X) is longer in B than in A and was unchanged at T1.

Increase of the sagittal projection of the lips was also evident, in particular in B, with lengthening of the ls-Y_1.

Axial cross sections through prn, sn, and ls clearly demonstrated a postoperative displacement of facial soft tissue in B greater than in A; reduced, but still noticeable deviation of the tip of the nose on the symmetry axis (Y) was observed in A (see Figure 3). Sagittal sections illustrated a refinement of the nasolabial sulcus in A and increase the sagittal projection of the upper lip in B (see Figure 4).

DISCUSSION

The impairment of maxillary growth resulting in retrusion of the maxilla is a frequent finding in adult patients with CLP. To correct these dentofacial deformities, orthognathic surgery may therefore be indicated.[13]

A maxillary advancement with a LeFort I osteotomy is the most common orthognathic procedure. In the literature, the frequency of indications for a LeFort I osteotomy in patients with uCLP varies from 22% to 48.3%.[14-17] Children with CLP often have midfacial growth deficiency, with a characteristic concave profile. This generally increases during adolescence.[18] A few authors view these growth disturbances as intrinsic to the cleft itself, because they have been observed in

Table II. Point-to-point distances of the landmarks considered

		A	*B*
Frontal view			
al_r-al_l	T0	35.22	31.10
	T1	**33.62**	32.06
al_r-prn	T0	24.19	25.30
	T1	**22.32**	**23.19**
al_l-prn	T0	27.53	22.09
	T1	**25.90**	22.18
al_r-X	T0	36.53	40.21
	T1	37.02	**44.69**
al_l-X	T0	38.11	44.27
	T1	37.10	**45.57**
prn-Y	T0	1.60	0.97
	T1	**0.53**	0.87
sn-ls	T0	11.08	12.39
	T1	11.92	12.24
ch_r-ch_l	T0	51.20	52.89
	T1	50.38	53.01
ls-sto	T0	3.18	5.64
	T1	3.27	**7.39**
Lateral view			
prn-sn-ls°	T0	134.05	133.05
	T1	**137.54**	133.47
prn-X	T0	32.98	37.64
	T1	32.10	37.23
ls-Y_1	T0	38.64	38.56
	T1	39.52	**40.08**

The values are in millimeters (or degrees for angles). (Differences of linear measurement major of 1 mm and angular measurements superior to 3 grades were considered significant and highlighted in bold). *A*, patients with uCLP; *B*, control group participants; *X*, horizontal reference plane; *Y*, vertical reference plane through glabella; *Y1*, vertical plane through left endocanthion and perpendicular to X; *r*, right; *l*, left; *alr*, right alar crest point; *all*, left alar crest point; *prn*, tip of nose; *sn*, subnasale; *chr*, right cheilion; *chl*, left cheilion; *ls*, labialis superior; *sto*, stomation.

children who were never operated on for their cleft.[19-21] But many authors consider maxillary growth deficiency to be mainly iatrogenic in nature and a consequence of the primary surgical repair of the palate.[22-23] Adults with CLP can also show secondary nasal deformities.

Recently, primary rhinoplasty has been highlighted for the management of patients with uCLP, and these techniques have been found to clearly improve the results of the nasal deformity and overall symmetry.[24-26] However, definitive rhinoplasty may still be necessary as the child grows.

The goal of the secondary treatment of uCLP deformities is to achieve naturally balanced nasal forms with an adequately projected nasal tip and a repositioning of the retrognathic maxilla. Because a uCLP involved more or less inherent tissue deformities in the lip and nose, the secondary correction does not always achieve the level of the healthy frontal/profile configuration. Many rating systems for nasal deformity have been established and used worldwide.[27,28]

Recent developments in computer technology have facilitated the more accurate and objective 3D characterization of facial forms of patients with CLP.[29,30] Laser surface scanning has been reported as a reliable and accurate method for identifying craniofacial surface landmarks.[12,31,32]

Previous studies have been conducted on the 3D laser scanner analysis of the morphologic changes of the nose and lips after a LeFort I osteotomy in patients without CLP. The authors observed that the labial changes were mainly due to the movements of the jaw. The nasal morphologic changes after a LeFort I osteotomy consist mainly of widening of the nasal alae caused by the release of the muscle insertion and their retraction. This change was not influenced by the direction of the maxillary movement.[33]

To date, very limited evaluation of facial morphology changes after orthognathic surgery in adult patients with CLP, in comparison with participants without CLP, was performed with 3D analysis.[10,11] McCance et al.[10] measured the 3D soft tissue changes in a group of adult patients with various forms of clefts after orthognathic surgery to correct jaw disproportion. The cleft groups were also compared with a control group of normal adults with skeletal and occlusal class I relationships and average facial heights, before and after surgery. A previous 3D soft tissue evaluation of facial morphologic changes after rapid maxillary expansion and Delaire facemask use, with children with CLP and patients with class III malocclusion among the groups, has been described.[11]

The present study attempted to determine the soft tissue changes in adult patients with uCLP who underwent LeFort I advancement and RSP, by comparing the 3D mean facial model (A) at T0 and T1 and also comparing A with a 3D mean facial model B (control group without CLP) who underwent the same bone displacement. Although the results of our 3D analyses should be interpreted with caution because of the relatively small sample size, several conclusions from our data seem to be warranted, as explored in the following paragraphs.

It is well known that the morphology of the soft tissues, such as the nose and lips, as well as that of the maxilla, changes after a LeFort I osteotomy. The changes have been reported as a flattening and thinning of the upper lip, expansion of the nose, and anterosuperior movement of the nasal tip.[34,35]

Baek et al.[36] compared the treatment outcomes and relapse between maxillary advancement surgery with LeFort I osteotomy (group 1) and maxillary distraction osteogenesis (group 2) in 25 patients with cleft lip and palate with maxillary hypoplasia. They founded that the nasolabial angle increased more in group 2 than in group 1. In addition, the forward movement of the upper lip and nasal tip was significantly greater in group

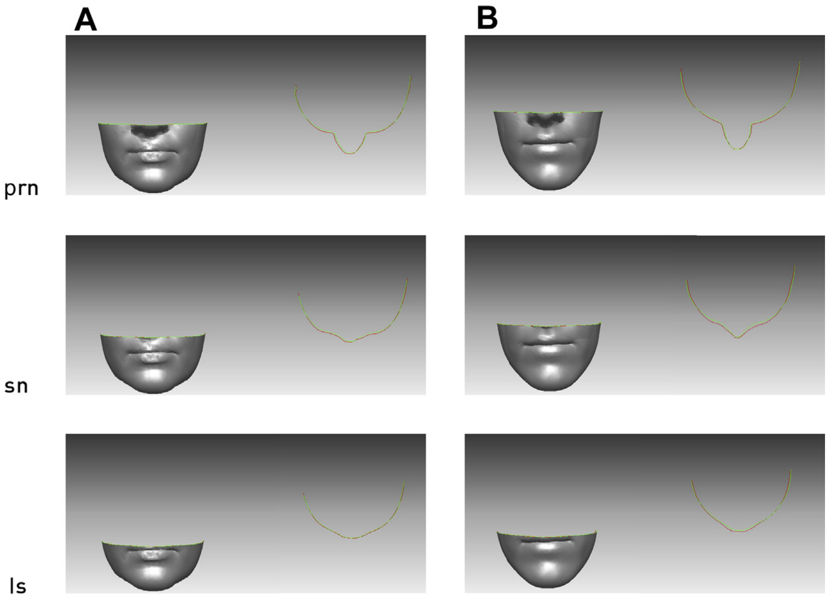

Fig. 3. Axial sections of the 2 superimposed shells (T0, green; T1, red) at different levels passing through prn, sn, ls. A, Mean facial model of patients with unilateral cleft lip and palate. B, Mean facial model of control group participants. (*prn*, tip of nose; *sn*, subnasale; *ls*, labialis superior.)

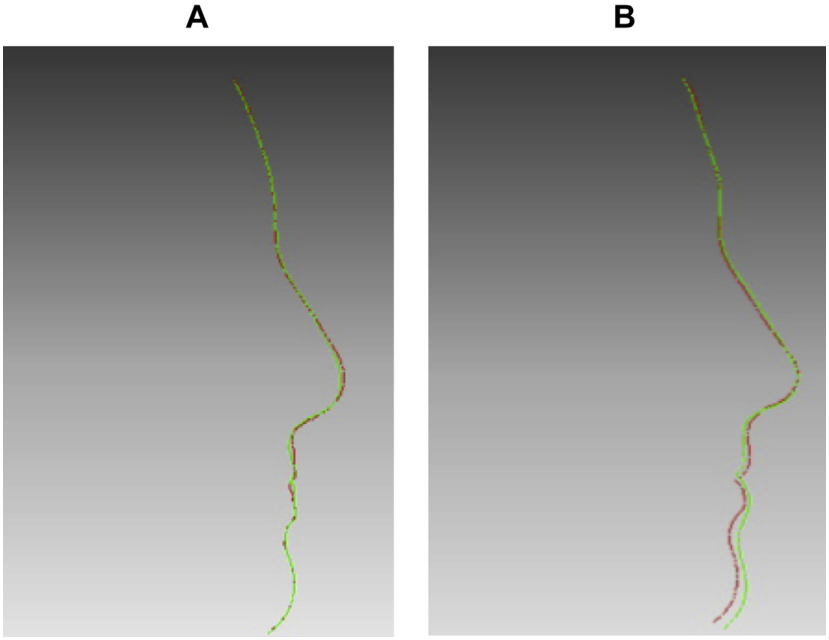

Fig. 4. Sagittal sections of superimposed shells (T0, green; T1, red). A, Mean facial model of patients with unilateral cleft lip and palate. B, Mean facial model of control group participants.

2. These findings agreed with those of Chua and Cheung.[37] However, there are few reports that evaluated the form of these soft tissues 3-dimensionally.

In our study, the alar base width in CLP was wider and vertically increased compared with the control preoperatively and was reduced at T1 (see Figure 1; see Table II). This finding is consistent with previous results in the literature.[7,38] In contrast, the upper vermilion remained unchanged. This is probably because it is more difficult to detach tissues when there are previous scars.

Otherwise, increase of the alar base width and a vertical increase of the upper vermilion were evident in B (see Figure 1; see Table II). The vertical increase of the upper lip in B is positive and probably due to the V-Y closure. The nasal alar widening seems to be due to the release of the soft tissue attachment and muscle insertion. Once released from the bone, muscles including the zygomaticus major, levator labii superioris, levator labii superioris alaeque nasi, and nasalis give rise to lateral retraction, thus resulting in alar widening.

To prevent nasal alar widening and labial flattening after the maxillary osteotomy, alar cinch suture and V-Y closure are conceptually good procedures. However, although these procedures were performed, some reports, as well as this study, state that several millimeters of widening of the nasal alae were still observed.[7] The reasons may include insufficient sutures under general anesthesia with nasal intubation and the short duration of tensile strength of the threads. For the aim of tightening up the nasal alae, some tools such as an external fixator may be effective. Subspinal LeFort I osteotomy may be another solution for this problem.[39]

An improvement of symmetry of the alar forms, both vertically and horizontally, were observed in both groups. A normalization of the position of the tip of nose in the center of the face was observed in A (see Table II). These effects may be attributed to the closed rhinoplasty, which allowed the reshaping of the alar cartilage, columella, and nasal dorsum.

In profile views, an increased support of the lips was shown to a greater degree in B than in A (see Figures 1 to 4). Although a significant normalization of soft tissue profiles was generally observed in A, residual deformities were documented in the postoperative upper lip and tip of nose projection (see Figure 1). This may be because patients with CLP had scar contractures, which prevented the correct soft tissue countering. In addition, in some of the patients with CLP, 1 or 2 anterior teeth were missing at the cleft side, and this absence may contribute to reduced upper lip support.

The main limitation of this study is the small sample size. More experience and further long-term follow-up studies are needed to evaluate a much larger patient population, with better control over the variables.

In conclusion, the 3D analysis performed in this study showed quantitative outcomes on the secondary treatment of uCLP nose/lip/maxilla deformities. Our surgical procedures can provide a symmetric nasal base and a satisfactory facial profile, but some differences remain in the postoperative frontal and profile views in patients with uCLP, in comparison with the control group.

Precise correction of secondary deformities in adult patients with CLP is still a challenging task in maxillofacial surgery, and further technical improvements are still possible.

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