The Cleft Palate–Craniofacial Journal 00(00) pp. 000–000 Month 0000

ORIGINAL ARTICLE

Three-Dimensional Analysis of Nasal Symmetry Following Primary Correction of Unilateral Cleft Lip Nasal Deformity

Olivia E. Linden, B.A., Helena O. Taylor, M.D., Ph.D., Sivabalan Vasudavan, B.D.Sc., M.D.Sc., M.P.H., Margaret E. Byrne, R.N., Curtis K. Deutsch, Ph.D., John B. Mulliken, M.D., Stephen R. Sullivan, M.D., M.P.H.

Objective: **To evaluate nasal symmetry using three-dimensional photogrammetry following primary tip rhinoplasty with or without an internal splint in patients with unilateral complete cleft lip/palate.**

Design: **We captured three-dimensional images of patients with unilateral complete cleft lip/palate who underwent nasolabial repair by rotation-advancement of the lip and primary tip rhinoplasty, either with or without an internal resorbable splint, and normal control subjects. We assessed nasal symmetry by identifying the plane of maximum symmetry and the root-mean-square deviation between native and reflected surfaces.**

Patients/Participants: **We imaged 38 controls and 38 subjects with repaired unilateral complete cleft lip/palate (20 with, 18 without an internal splint).**

Results: **Nasal asymmetry root-mean-square deviation clustered between 0.19 and 0.50 mm (median = 0.24 ± 0.08 mm) for controls; whereas, those with repaired unilateral complete cleft lip/palate ranged from 0.4 to 1.5 mm (median = 0.75 ± 0.40 mm). Although root-mean-square deviation ranges overlapped, patients with repaired unilateral complete cleft lip/palate had significantly greater asymmetry than controls ($P < .001$). We found no difference in asymmetry between patients with or without an internal splint ($P = .5$).**

Conclusions: **Three-dimensional photogrammetry was used to successfully compare symmetry among different patient and control groups. Although "normal" nasal symmetry was attained in some patients following cleft lip/nasal repair, most had persistent asymmetry compared with normal controls. Placement of a resorbable internal splint did not improve symmetry in patients with unilateral complete cleft lip/palate.**

KEY WORDS: *3D, nasal symmetry, unilateral cleft lip/palate*

Nasolabial symmetry is the goal of repair of a unilateral cleft lip. Traditionally, symmetry has been assessed postoperatively by two-dimensional (**2D**) anthropometric measurements or photographs, which are limited to linear distances and angles (Farkas et al., 1985). More recently, three-dimensional (**3D**) imaging has been utilized to assess the complexity of the cleft nasal deformity, particularly the soft tissue contour (Al-Omari et al., 2005; Okawachi et al., 2011; van Loon et al., 2011). Benefits of 3D imaging include the speed, reproducibility, and reliability of capturing images and achieving a quantitative analysis (Bourne et al., 2001; Honrado and Larrabee, 2004; Hajeer et al., 2005; Wong et al., 2008; Mulliken and Sullivan, 2009; Taylor et al., 2014).

An internal resorbable splint has been used as an adjunct to protect the affected lower lateral cartilage during primary correction of unilateral cleft lip-nasal deformity (Wong et al., 2002). The rationale is that the internal splint will shield the repositioned cartilage from deformational forces, such as wound contraction, during soft tissue healing and scarring.

Our purpose is to use 3D photogrammetry to assess nasal symmetry following primary repair of unilateral complete cleft lip/palate (**UCCLP**) and the associated nasal deformity and to compare symmetry between those

Ms. Linden is medical student, Warren Alpert Medical School of Brown University, Providence, Rhode Island. Dr. Taylor is Attending Surgeon, Division of Plastic Surgery, Mount Auburn Hospital, Cambridge, Massachusetts. Dr. Vasudavan is Visiting Faculty, Department of Dentistry, Children's Hospital Boston and Department of Developmental Biology, Harvard School of Dental Medicine, Boston, Massachusetts. Ms. Byrne is Registered Nurse, Department of Plastic Surgery, Rhode Island Hospital and Hasbro Children's Hospital, Providence, Rhode Island. Dr. Deutsch is Associate Professor, Psychobiology Program, Eunice Kennedy Shriver Center, University of Massachusetts Medical School, Worcester, Massachusetts. Dr. Mulliken is Professor, Department of Plastic and Oral Surgery, Boston Children's Hospital and Harvard Medical School, Boston, Massachusetts. Dr. Sullivan is Attending Surgeon, Division of Plastic Surgery, Mount Auburn Hospital, Cambridge, Massachusetts.

This project has previously been presented at the 20th Annual Lifespan Hospital Research Celebration in Providence, Rhode Island, on October 11, 2012, and at the American Association of Plastic Surgeons 93rd Annual Meeting in Miami Beach, Florida, on April 4 to 8, 2014.

Submitted March 2016; Revised May 2016; Accepted May 2016.

Address correspondence to: Stephen R. Sullivan, M.D. M.P.H., Division of Plastic and Reconstructive Surgery, Mount Auburn Hospital, 300 Mount Auburn Street, Suite 304, Cambridge, MA 02138. E-mail srsulliv@mah.harvard.edu.

DOI: 10.1597/16-073

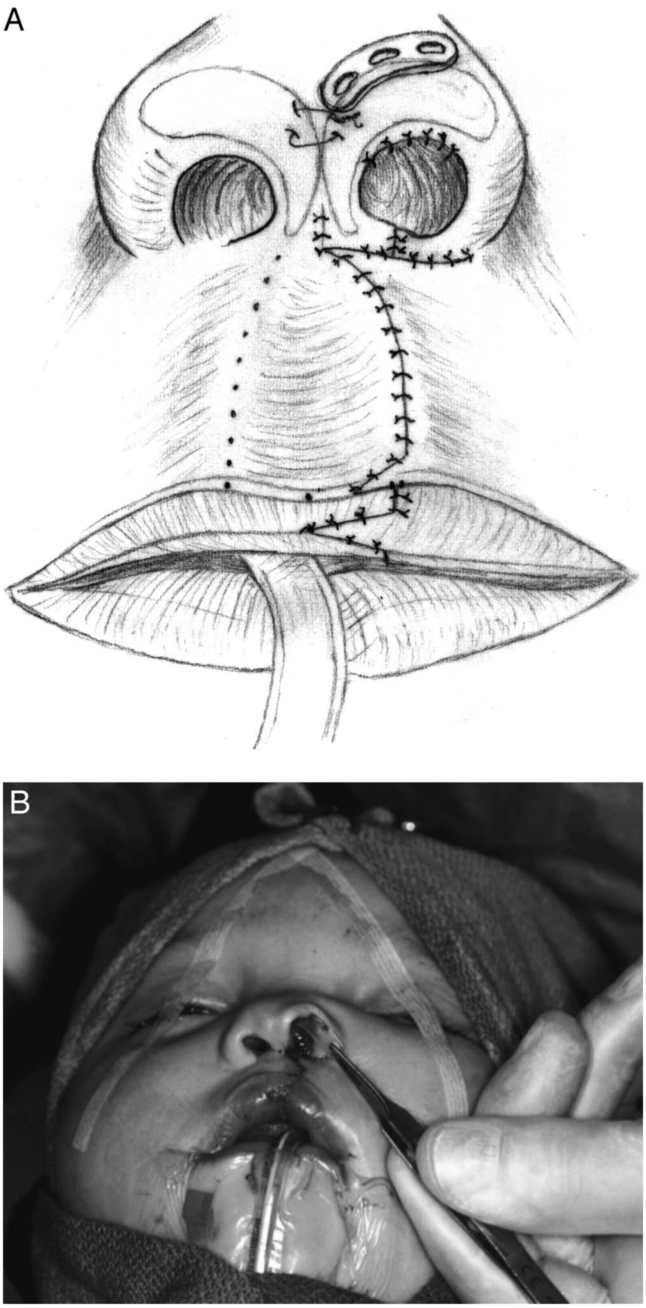

FIGURE 1 A: Illustration and B: intraoperative photograph depicting the surgical technique and placement of an internal resorbable splint during primary correction of the unilateral cleft lip-nasal deformity. The splint is placed through a rim incision into a subcutaneous pocket above the lower lateral cartilage. Intraoperative photo reprinted with permission from Wong et al. (2002, p. 387).

treated, with and without an internal splint, and age-matched controls without the cleft deformity.

Methods

Following institutional review board approval, we prospectively imaged consecutive patients presenting to clinic with UCCLP repaired in infancy with rotation-advancement and primary nasal correction. We included patients treated with and without an internal splint placed at the time of the nasal repair. The same semiopen technique was used on all patients. The nasal tip was dissected through a rim incision, followed by elevating and securing the lower lateral cartilage with absorbable suture to the ipsilateral upper lateral cartilage and an interdomal mattress suture to appose the splayed genua. Beginning in 1997, the surgeon's protocol was amended to include insertion of a resorbable internal splint as an adjunct to primary correction of the unilateral cleft lip-nasal deformity. The splint was cut from a 25 × 25-mm polyglycolic acid/polylactic acid plate (Lactosorb, W. Lorenz, Biomet, Inc., Jacksonville, FL) to a smaller strip measuring approximately 5 × 15 mm. The splint was heated in a water bath and molded to the curvature of the noncleft nostril dome, extending from the area of the accessory alar cartilages over the contralateral genu. The splint was inserted through the rim incision and placed just above the lower lateral cartilage in a subcutaneous pocket (Fig. 1). The total time required for splint placement was approximately 3 minutes. Patients who had secondary nasal revision were excluded.

We also imaged, for comparison, age-matched control subjects with no history of facial trauma, facial operations, or a craniofacial diagnosis. Patients with varying severities of unrepaired cleft lip were also imaged to depict the range of nasal asymmetry seen in patients with cleft lip.

All facial surface scans were captured using the Canfield VECTRA stereophotogrammetry system (Canfield Imaging Systems, Fairfield, NJ) (Lane and Harrell, 2008). Demographic data, including gender and age at 3D imaging, were collected. The nasal form was isolated from each facial scan, as defined superiorly from the midnasal dorsal ridge, laterally to the ala lateralis, and inferiorly to include the columellar base. We assessed nasal symmetry by identifying the unique plane of maximum symmetry. The root-mean-square deviation (**RMSD**), measured in millimeters, was calculated between native and reflected nasal surfaces in the sagittal plane. *Root-mean-square deviation* is defined as

$$x_{\text{rms}} = \sqrt{\frac{1}{N}\sum_{i=1}^{N} x_i^2} = \sqrt{\frac{x_1^2 + x_2^2 + \cdots + x_N^2}{N}}$$

This method has been previously described and has a high interobserver correlation when measuring facial asymmetry (Taylor et al., 2014).

Patient characteristics and descriptive statistics were summarized. Continuous data were compared using the Wilcoxon rank sum test for independent samples. Continuous data are presented as median ± SD and range. All calculated P values are two-tailed and considered significant for values of $P < .05$. Analyses were performed using Stata SE version 12.1 (StataCorp, College Station, TX).

TABLE 1 Patient Characteristics

Patient Data	*Controls*	*UCCLP With Splint**	*UCCLP Without Splint*	*P Value*
N	38	20	18	
Age (y)				
Median ± SD	6.9 ± 3.6	5.3 ± 2.2	8.5 ± 3.8	.001
Range	2.5–20.8	2.4–9.9	4.7–19.7	
Sex				
M:F	19:19	15:5	12:6	.16
RMSD (mm)				
Median ± SD	0.24 ± 0.08	0.75 ± 0.19	0.77 ± 0.2	<.001
Range	0.19–0.50	0.38–1.07	0.51–1.45	

* UCCLP = unilateral complete cleft lip/palate; RMSD = root-mean-square deviation.

Results

We imaged 38 subjects with repaired UCCLP: primary tip rhinoplasty with the addition of a resorbable internal splint (n = 20) and primary tip rhinoplasty without a splint (n = 18). Normal age-matched controls (n = 38) were also imaged. Demographic data for subjects and controls are shown in Table 1.

To depict the range of nasal asymmetry seen in unrepaired cleft lip, we also imaged eight patients with unrepaired cleft lip of varying severities: microform cleft lip (n = 1), unilateral incomplete cleft (n = 2), complete unilateral cleft lip (n = 3), and bilateral cleft lip (n = 2).

There was no difference in average age at imaging for repaired UCCLP (7.5 ± 3.6 years) when compared with controls (7.5 ± 3.5 years) ($z = -0.05$, $P = .96$). Patients with UCCLP without a splint were significantly older at imaging than UCCLP with a splint ($z = 3.16$, $P = .002$), reflecting the surgeon's change in technique to include the use of internal nasal splinting. Nasal symmetry, as measured by RMSD, clustered between 0.19 and 0.50 mm (median = 0.24 ± 0.08 mm) for controls; whereas, those with repaired UCCLP ranged from 0.4 to 1.5 mm (median = 0.75 ± 0.40 mm) (Fig. 2). Although the ranges of symmetry overlapped, patients treated for UCCLP had significantly more nasal asymmetry than controls despite primary tip rhinoplasty ($z = 7.45$, $P < .001$) (Fig. 3). We found no difference in nasal symmetry between patients treated with or without an internal splint (median RMSD = 0.75 ± 0.19 and 0.77 ± 0.25, respectively, $z = 0.67$, $P = .5$). The gradation of RMSDs in nasal symmetry of controls and patients with varying severities of cleft lip can be visually demonstrated on an "asymmetry hierarchy" (Fig. 4).

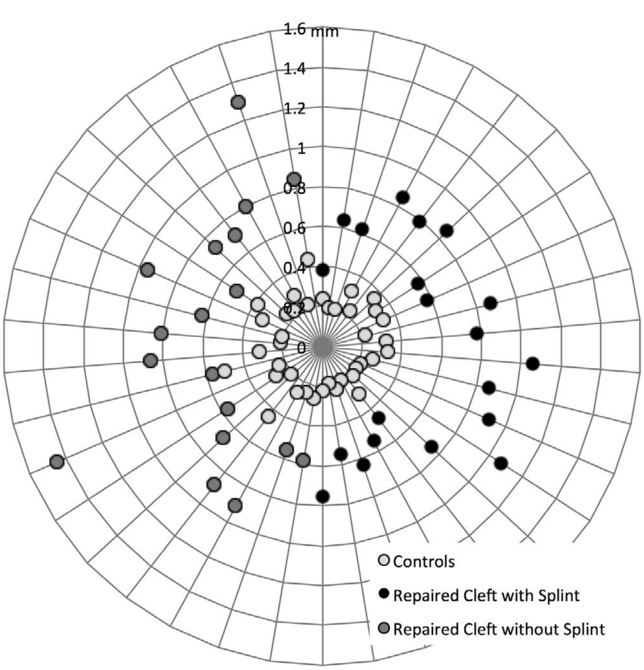

FIGURE 2 Nasal asymmetry as measured by root-mean-square deviation (RMSD). A value of 0 or "bull's-eye" indicates perfect symmetry. Asymmetry is present among nasal images but is greater in children following repair of unilateral complete cleft lip (with or without splint) compared with controls.

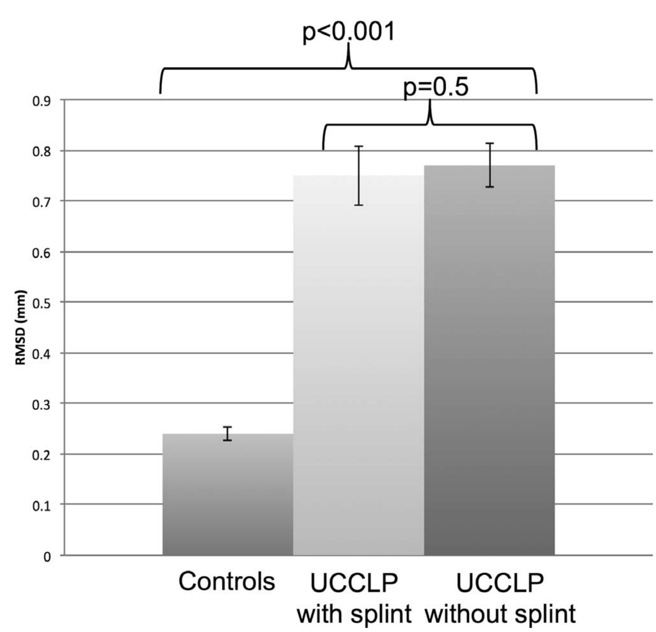

FIGURE 3 Median nasal symmetry as measured by RMSD (mm) in controls, in patients with unilateral complete cleft lip repaired with primary tip rhinoplasty and internal resorbable splint, and in those with labial repairs including primary tip rhinoplasty without a splint. There were significant differences in nasal symmetry among groups; controls had the best symmetry, $P < .001$. There was no difference in symmetry between the groups treated with or without an internal splint, $P = .5$.

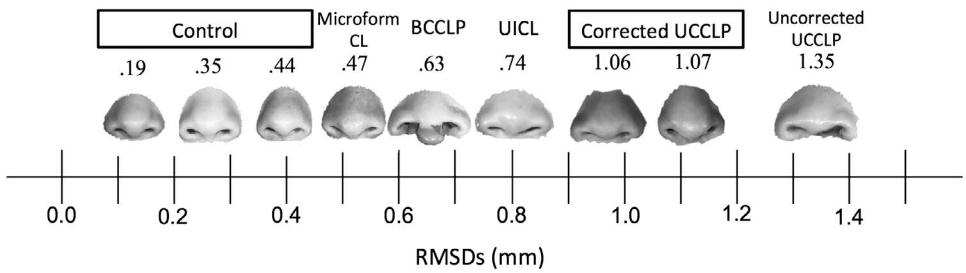

FIGURE 4 The RMSD calculation allows stratification of individuals in an "asymmetry hierarchy." Higher RMSD values indicate more asymmetry. Microform CL = microform cleft lip, BCCLP = bilateral complete cleft lip/palate, UICL = unilateral incomplete cleft lip, UCCLP = unilateral complete cleft lip/palate.

Conclusion

Discussion

We quantitatively evaluated nasal symmetry using 3D photogrammetry in patients with repaired UCCLP as well as control subjects. Nasal asymmetry was ubiquitous, with control noses showing a range of mild asymmetry (range: 0.19 to 0.50 mm). We also found that unrepaired UCCLP had a wide range of nasal RMSDs (range: 0.47 to 1.39 mm). Although the range of nasal symmetry following primary correction of unilateral cleft lip-nasal deformity overlapped with normal controls, most patients, regardless of treatment with or without a resorbable internal splint, had significantly more nasal asymmetry compared with normal controls. Furthermore, patients treated with a resorbable splint were no more symmetric than those who were not treated with a resorbable splint.

In the preliminary papers, the use of an internal splint was found to increase nasal symmetry after primary nasal repair (Wong et al., 2002). This assessment used the old method of submental 2D images to make right-left linear distance and area comparisons to grade symmetry. Other studies have also used limited anthropometric measurements, such as width, angle, and 2D distances to quantitatively evaluate asymmetry and surgical outcomes of the cleft lip-nasal deformity (Wong et al., 2002; Fisher et al., 2008; Boorer et al., 2011; Bell et al., 2014). Three-dimensional photogrammetry, however, provides quantitative data on the symmetry of the entire soft tissue contour of the nose and does so with one measurement. This value, the calculated RMSD, includes all perspectives rather than a single 2D submental view. When the entire nasal soft tissue contour is considered, the 3D imaging failed to show any significant difference in nasal asymmetry, whether an internal splint was used or not. The speed and reproducible nature of 3D photogrammetry also makes it an ideal tool for use in young patients who may not hold still for multiple photographs from different perspectives.

Secondary nasal revisions are necessary for the majority of children with UCCLP (Mulliken and Martínez-Pérez, 1999). Although the internal splint fully resorbs, there is more scar after placement, thus making revisional procedures more technically difficult. During a secondary procedure, more time and surgical experience is required for the excision of the increased scarring to expose the undamaged perichondrial surface of the lower lateral cartilage for repositioning and fixation. The added cost of the internal splint is approximately $384.00. Therefore, we no longer recommend use of an internal resorbable splint during primary correction of cleft nasal deformity.

One limitation of our paper is that many of the operations were performed before we had 3D imaging capabilities and, therefore, we did not have preoperative 3D images with which to assess the severity of the nasal deformity. It may be that the more severely deformed the nose preoperatively, the higher the degree of asymmetry postoperatively (Fisher et al., 2008). Ideally, we would quantitatively evaluate a net change in 3D symmetry following operative repair.

Conclusions

In conclusion, 3D photogrammetry was used to quantitatively assess nasal asymmetry in a consecutive series of patients with UCCLP, which included patients treated either with or without a resorbable internal alar splint. Compared with controls, patients with UCCLP have persistent and significantly greater nasal asymmetry despite primary tip rhinoplasty. We found no improvement in nasal symmetry with insertion of a splint. In the future, 3D photogrammetry can help in assessing short- and long-term nasal configuration and, thus, help surgeons to modify their primary techniques to ensure the best postoperative outcome.

References

Al-Omari I, Millett DT, Ayoub AF. Methods of assessment of cleft-related facial deformity: a review. *Cleft Palate Craniofac J*. 2005;42:145–156.

Bell A, Lo TR, Brown D, Bowman AW, Siebert JP, Simmons DR, Millett DT, Ayoub AF. Three-dimensional assessment of facial appearance following surgical repair of unilateral cleft lip and palate. *Cleft Palate Craniofac J*. 2014;51:462–471.

Boorer CJ, Cho DC, Vijayasekaran VS, Fisher DM. Presurgical unilateral cleft lip anthropometrics: implications for the choice of repair technique. *Plast Reconstr Surg*. 2011;127:774–780.

Bourne CO, Kerr WJS, Ayoub AF. Development of a three-dimensional imaging system for analysis of facial change. *Clin Orthod Res*. 2001;4:105–111.

Farkas LG, Hreczko TA, Kolar JC, Munro IR. Vertical and horizontal proportions of the face in young adult North American Caucasians: revision of neoclassical canons. *Plast Reconstr Surg*. 1985;75:328–338.

Fisher DM, Tse R, Marcus JR. Objective measurements for grading the primary unilateral cleft lip nasal deformity. *Plast Reconstr Surg*. 2008;122:874–880.

Hajeer MY, Mao Z, Millett DT, Ayoub AF, Siebert JP. A new three-dimensional method of assessing facial volumetric changes after orthognathic treatment. *Cleft Palate Craniofac J*. 2005;42:113–120.

Honrado CP, Larrabee WF. Update in three-dimensional imaging in facial plastic surgery. *Curr Opin Otolaryngol Head Neck Surg*. 2004;12:327–331.

Lane C, Harrell W. Completing the 3-dimensional picture. *Am J Orthod Dentofacial Orthop*. 2008;133:612–620.

Mulliken JB, Martínez-Pérez D. The principle of rotation advancement for repair of unilateral complete cleft lip and nasal deformity: technical variations and analysis of results. *Plast Reconstr Surg*. 1999;104:1247–1260.

Mulliken JB, Sullivan SR. Discussion. Nasoalveolar molding improves long-term nasal symmetry in complete unilateral cleft lip-cleft palate patients. *Plast Reconstr Surg*. 2009;123:1007–1009.

Okawachi T, Nozoe E, Nishihara K, Nakamura N. 3-dimensional analyses of outcomes following secondary treatment of unilateral cleft lip nose deformity. *J Oral Maxillofac Surg*. 2011;69:322–332.

Taylor HO, Morrison CS, Linden O, Phillips B, Chang J, Byrne ME, Sullivan SR, Forrest CR. Quantitative facial asymmetry: using three-dimensional photogrammetry to measure baseline facial surface symmetry. *J Craniofac Surg*. 2014;25:124–128.

van Loon B, Reddy SG, van Heerbeek N, Ingels KJAO, Maal TJJ, Borstlap WA, Reddy RR, Kuijpers-Jagtman A, Bergé SJ. 3D stereophotogrammetric analysis of lip and nasal symmetry after primary cheiloseptoplasty in complete unilateral cleft lip repair. *Rhinology* 2011;49:546–553.

Wong GB, Burvin R, Mulliken JB. Resorbable internal splint: an adjunct to primary correction of unilateral cleft lip-nasal deformity. *Plast Reconstr Surg*. 2002;110:385–391.

Wong JY, Oh AK, Ohta E, Hunt AT, Rogers GF, Mulliken JB, Deutsch CK. Validity and reliability of craniofacial anthropometric measurement of 3D digital photogrammetric images. *Cleft Palate Craniofac J*. 2008;45:232–239.