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The use of an inferior pennant flap during unilateral cleft lip repair improves lip height symmetry

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Abstract

Background—In order to improve the rotation of Cupid's bow and achieve sufficient vertical lip height, several variations of the Millard rotation-advancement have incorporated a small laterally-based triangular flap above the cutaneous roll. This study uses three-dimensional photogrammetry to evaluate the outcomes of unilateral cleft lip repairs performed with and without pennant flaps.

Methods—Three-dimensional photographs were analyzed to assess postoperative lip height asymmetry in 90 unilateral cleft lip patients (58 complete, 32 incomplete) treated between 2001 and 2012. Cleft lip repairs were performed by 3 pediatric cleft surgeons using different techniques. Thirty-nine of 90 (43%) procedures utilized an inferiorly placed triangular flap. All patients were photographed at least 9 months postoperatively (mean = 4.2 years). Lip height asymmetry was based on the vertical distances from the subnasale to the peaks of Cupid's bow.

Results—Regression analysis revealed that the use of a pennant flap was a significant predictor of postoperative lip height asymmetry ($B = 4.2\%$, $p = 0.015$). The surgeon performing the repair was also a significant factor in patients with complete cleft lips ($B = 3.6\%$, $p = 0.005$). All three surgeons achieved greater lip height symmetry when a pennant flap was performed.

Conclusions—The results of unilateral cleft lip repairs are affected by both the surgeon and the surgical technique. Procedures that utilized a pennant flap showed better philtral height symmetry than non-pennant repairs.

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Aaron Russell: Performed all data collection for this project. Assisted in data analysis. Wrote the manuscript and prepared figures for publication.

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Albert Woo: Developed the concept for the project. Assisted in drafting and revising the manuscript. Had final approval over the version of the manuscript to be published.

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Introduction

The primary goal of unilateral cleft lip repair is to ensure equal lip height between the cleft and non-cleft sides. Vertical deficiency of the cleft-side philtral column results in elevation of the Cupid's bow, a common cause for secondary cleft lip revision (1). In order to obtain adequate height, a number of surgical techniques have been developed (1–10). The most commonly utilized procedure for unilateral cleft lip repair is the Millard rotation-advancement (2, 11). A key feature of this repair, with regard to lip height, is a back-cut that extends caudally from the base of the columella (12). This incision allows greater rotation of the Cupid's bow and can be modified to increase the length of the cleft-side philtral column (13–14). Despite this, the Millard rotation-advancement has a tendency to yield short repairs, particularly in patients with wide complete cleft lips (15–19).

In order to achieve greater lip height and improve the symmetry of the Cupid's bow, many surgeons have advocated the addition of a small unilimb Z-plasty, or pennant flap, just above or at the level of the cutaneous roll (1, 3–5, 7–10). Noordhoff's modification of the rotation-advancement technique utilizes an inferior triangular flap, instead of a back-cut, whenever there is insufficient rotation of the medial lip segment (9). However, this maneuver is primarily reserved for patients with more severe deformities and is not utilized in all cases. Fisher's anatomical subunit repair takes this approach a step further by standardizing the use of a pennant flap for both complete and incomplete clefts (10). The senior author utilizes a similar technique for unilateral cleft lip repair that incorporates a pennant flap just above the vermilion border (Fig. 1). Whether these modifications provide significant benefits over the traditional rotation-advancement is uncertain. The purpose of this retrospective study is to determine whether the inclusion of an inferior pennant flap improves lip height symmetry following unilateral cleft lip repair. The data is also analyzed for surgeon and type of cleft deformity to investigate how these factors influence the postoperative results.

Methods

After obtaining IRB approval, this study examined the records of all patients who underwent unilateral cleft lip repair at St. Louis Children's Hospital between July 2001 and June 2012. Patients from three pediatric cleft surgeons who each utilized both pennant and non-pennant repairs were selected for analysis. All procedures were performed using one of four surgical techniques, as described by Millard (2), Noordhoff (9), Mohler (6), and Fisher (10). For the purposes of this study, procedures were classified according to the presence or absence of an inferior pennant flap, as specified in the operative dictations. Noordhoff repairs had a mixed distribution: approximately 30% incorporated a pennant flap. A minority of cases included preliminary lip adhesions or postoperative steroid injections, but these factors were not considered in our analysis.

Imaging data consisted of three-dimensional (3D) photographs obtained at the Cleft Palate and Craniofacial Institute at St. Louis Children's Hospital using a 4-pod camera system (3DMD, Atlanta, GA). Only patients with 3D photographs taken at least nine months postoperatively were included in this study. Patients with microform cleft lip or coexisting

craniofacial deformities were excluded. Medical records were reviewed to ensure that selected images were photographed prior to secondary cleft lip revision.

Three-dimensional (3D) photographs were analyzed using Vultus software v. 2.2 (3dMD Atlanta, GA). Images were positioned to set the right and left exocanthia at an equal depth and then oriented to the Frankfort horizontal to adjust for pitch. The longitudinal axis was then rotated so that the lateral canthi were even with the horizontal. Once the images were properly aligned, landmarks were placed on the subnasale and the peaks of Cupid's bow. The vertical distance from the Cupid's bow to the subnasale was measured bilaterally (Fig. 2). Lip height asymmetry was defined as the vertical discrepancy between the cleft and non-cleft sides. Absolute values were used in all quantitative analysis. To facilitate comparisons between subjects, differences were normalized to the height of the unaffected side. Percent asymmetry was calculated as: $(\text{lip height discrepancy} \div \text{height of the unaffected side}) \times 100$.

Intra-rater reliability was assessed via repeat analysis of 30 randomly selected photographs. The one way random effects single measure intraclass correlation coefficient (ICC) was calculated to determine the consistency between measurements. Postoperative lip height asymmetry was analyzed using linear regression. Surgeon, type of cleft lip deformity, and the use of an inferior pennant flap were included as covariates. A two-sided Fisher's exact test was utilized to compare the proportions of complete and incomplete clefts as well as the number of revision procedures in the two repair groups. The data was also separated by cleft type and evaluated via linear regression to determine the effects of surgeon and pennant flap on complete and incomplete clefts. All statistical analyses were performed using SPSS statistical software v. 20 (IBM, Chicago, IL).

Results

Out of 184 patients who underwent unilateral cleft lip repair between 2001 and 2012, there were a total 90 subjects with high-quality 3D photographs who met all of the inclusion criteria. Photographs were taken nine months to 11 years post-surgery (mean $\pm$ SD = 4.2 ± 2.3 years). Subjects included 58 children with complete cleft lips and 32 with incomplete cleft lips. Thirty-nine of 90 (43%) procedures utilized an inferior pennant flap. Cleft types were evenly distributed between repair groups ($p = 0.825$), with incomplete clefts forming approximately one-third of each group (Fig. 3). Intra-rater reliability of measurements was excellent (ICC = 0.982).

In patients who underwent pennant flap during reconstruction, the difference in lip height between the cleft and non-cleft sides was 1.0 ± 0.1 mm (mean $\pm$ SEM) with a range of 0 mm to 4.2 mm. When normalized to the height of the unaffected side, the difference was $8.5 \pm 1.1\%$, range: 0% to 36.4%. Lip height asymmetry in patients who did not receive a pennant flap was 1.5 ± 0.1 mm, range: 0 mm to 5.3 mm. The normalized asymmetry was $13.3 \pm 1.2\%$, range: 0% to 46.0%. Procedures that utilized a pennant flap were significantly more likely to yield lips that were longer on the cleft side ($p = 0.019$). This occurred in 9 of 39 (23%) pennant repairs compared to 3 of 51 (6%) non-pennant repairs. These outcomes were equally distributed between complete and incomplete clefts. Pennant repairs that resulted in long lips showed a mean asymmetry of 0.5 ± 0.1 mm with a maximum value of 1.1 mm.

In patients who underwent pennant flap, the mean percent asymmetry was similar for complete (8.4%) and incomplete (8.7%) clefts (Fig. 4). In contrast, the mean asymmetry in non-pennant repairs was 14.9% for complete and 10.6% for incomplete clefts. All three surgeons achieved greater lip height symmetry when a pennant flap was performed (Fig. 5). It was found that 3 of 39 (8%) pennant repairs and 8 of 51 (16%) non-pennant repairs underwent secondary revision procedures. This difference was not statistically significant ($p = 0.328$). Repairs that produced overlengthening of the cleft side philtral column did not result in any revisionary procedures.

Linear regression of all 90 repairs confirmed that the use of a pennant flap was a significant predictor of postoperative lip height asymmetry (Table 1). The regression coefficient of 4.2% (B) translates, on average, to a 0.5 mm reduction in lip height asymmetry when a pennant flap was utilized. In the subset of patients with complete cleft lips ($N = 58$), both the use of a pennant flap and the operating surgeon were significant predictors of lip height asymmetry. The regression coefficient of 4.9% translates to a 0.6 mm improvement in philtral height symmetry when a pennant flap was utilized. In patients with incomplete clefts ($N = 32$), the use of a pennant flap was less consequential with a best-fit improvement of 2.9% (B), or roughly 0.3 mm.

Discussion

The Millard rotation-advancement revolutionized unilateral cleft lip repair in the mid-twentieth century. Since then, a number of techniques and modifications have been developed to try to improve upon Millard's original design. One such modification, popularized by Mohler, uses a more vertical rotation incision in order to position the scar in line with the philtral column (6). Other approaches have aimed to generate additional lip height through the inclusion of an inferior triangular flap. This adjunct was first described in 1958, when Skoog (3) proposed a modified rotation-advancement technique that featured an inferior, triangular flap of Tennison (20). Over the past 50 years, further improvements on this design have given rise to the modern inferior triangle repairs, including the Noordhoff and Fisher techniques, which utilize a small, laterally-based triangular flap above the cutaneous roll to achieve greater balance of the philtral columns.

This study was designed to analyze the influence of inferior pennant flaps on the results of unilateral cleft lip repair. Our data demonstrate that the inclusion of an inferior triangle improves lip height symmetry compared to standard rotation-advancement techniques, such as the Millard and Mohler repairs. We accounted for individual surgical expertise by including three cleft surgeons in our analysis, all of whom performed repairs with and without pennant flaps. All three surgeons achieved improved height of the lip repair when using an inferior triangle. This was particularly notable in the case of surgeon A (Fig. 5) who predominantly used the Noordhoff technique. In this repair, the use of an inferior triangle is reserved for patients with more severe deformities – those that would normally yield worse results. Nevertheless, patients who underwent pennant flap showed better symmetry post-repair.

Among the individual surgeons, the quality of the postoperative results varied, with particular surgeons achieving better lip height symmetry than others. While it is generally accepted that repairs by different surgeons yield different results, direct comparisons are rarely reported. To our knowledge, the only study which directly correlates surgical proficiency to clinical outcomes comes from Birkmeyer et al. (21), who demonstrate that bariatric surgeons with greater technical skill have fewer postoperative complications and lower mortality rates following laparoscopic gastric bypass. Although our study did not assess surgical skill directly, we were able to evaluate surgical proficiency by comparing postoperative results from three cleft surgeons. Our findings suggest that individual surgical technique is an important predictor of postoperative lip height asymmetry. It should be noted that the surgeons' levels of experience varied, and we did not attempt to correlate clinical experience with repair results.

This study also supports the notion that the severity of the cleft lip deformity influences the quality of the surgical repair (22). Although the difference was not statistically significant, we found that incomplete cleft repairs were 0.3 mm ($B = 2.5\%$) more symmetric, on average, than complete cleft repairs. Anatomically, patients with incomplete clefts possess an intact nasal sill (23), and typically present with milder deficiencies in lateral lip height, as measured from the alar base to the peak of Cupid's bow (24). These factors likely contribute to the improved results obtained in these patients. In fact, lip height asymmetry in unilateral incomplete cleft lip patients has been shown to approach that of non-cleft individuals at around one year post-repair (25). In our study, lip height asymmetry in patients with incomplete clefts was not significantly affected by either the surgeon or the surgical technique, although a trend in that direction was noted. It might be that the choice of procedure is relatively unimportant in patients with mild cleft lip deformities. Alternatively, this result may be due to the small number ($N = 32$) of patients with incomplete clefts. It is unclear whether greater power to the study may have yielded significance.

In contrast, both the surgeon and the surgical technique had a significant impact in patients with complete cleft lips. Indeed, when a pennant flap was utilized, postoperative lip height asymmetry was similar for complete and incomplete clefts (Fig 3). It is important to consider the preoperative anatomy when managing patients with unilateral cleft lip. In children with more severe deformities, pennant flap repairs provide a clinical advantage because they allow the surgeon to obtain vertical height without sacrificing lateral lip length (24). Operating on wide complete cleft lips also requires a greater degree of technical proficiency. This could explain why the surgeon performing the repair was a significant factor in complete cleft lips but was less important in incomplete cleft lip repair.

Inferior triangle repairs are designed to create additional lip height. However, if the flap is inappropriately sized, this can result in lips that are vertically long. In our study, procedures that utilized a pennant flap were significantly more likely than non-pennant repairs to produce lips that were longer on the cleft side. This occurred in 9 of 39 pennant flap repairs, with no predilection for complete or incomplete clefts. One of the consequences of long repairs involves the surgical approach to secondary revisions. When the cleft side is vertically long, corrections may be more complex because they require a complete incision through the whole cutaneous lip. In contrast, short lips can often be revised by placing

another pennant above the cutaneous roll (26). In this study, pennant repairs that resulted in long lips were still relatively symmetric (mean asymmetry = 0.5 ± 0.1 mm) and did not result in additional revisionary procedures. Furthermore, pennant repairs showed greater lip height symmetry overall. Therefore, it is unclear whether the increased frequency of long repairs has any clinical significance.

The accuracy and precision of three-dimensional imaging systems in evaluating facial soft tissue structures have been well-documented (27, 28), though the precision may vary depending on the landmarks selected. The anatomic points identified in this study – the exocanthia, cristae philtri, and subnasale – are some of the most reliable craniofacial landmarks reported in the literature, with error levels of a fraction of a millimeter (29). Even so, in some patients scar tissue may obscure the vermilion-cutaneous junction on the cleft side, making the peak of Cupid's bow less easy to identify. This is a potential source of inaccuracy that we could not account for due to the imperfect resolution of our 3D photographs. However, it did not significantly impact the precision of our data, as evidenced by our excellent measures of intra-rater reliability.

The advent of 3D imaging techniques opens new avenues for the objective evaluation of craniofacial morphology. In addition to improving the accuracy and reliability of standard anthropometric measurements, 3D technology may permit more sophisticated approaches, such as volumetric analysis, for assessing the facial soft tissues. However, validated methods for evaluating 3D photo data are limited. As an initial application of 3D photographic technology, our study focused on a single linear measurement of lip height asymmetry. In doing so, we overlooked other anatomical features, such as lateral lip length or alar symmetry, which may influence the overall aesthetic impression. Several other studies have looked at vertical lip height following unilateral cleft lip repair (25, 30–31). While complete lip symmetry is the ultimate goal for cleft surgeons, one of the critical components of lip symmetry is the height of the philtral tubercles. This is also the primary parameter that the surgeon attempts to modify with the placement of an inferior triangle. For these reasons, we intentionally focused our investigation on philtral height symmetry.

In addition to the factors already discussed, there are many others which may influence lip height symmetry following unilateral cleft lip repair. Although we did not identify them directly, the r^2 for our linear regression model was 0.134, which means that only a small percentage of the total variation was due to differences in surgeon, cleft type, or pennant flap. For example, initial cleft width has previously been correlated with postoperative outcomes (32–33). In addition, this study did not control for time post-surgery.

While there was a statistically significant difference in philtral height symmetry between the two repair groups, there is little data in the current literature to suggest whether this difference is visibly noticeable. The classic teaching is that a mismatch of even 1 mm of the vermilion-cutaneous border is visible at conversational distance (34). Indeed, Millard argues that a 1 mm difference in lip height is far more noticeable to the eye than a 2 to 3 mm difference in horizontal lip length (35). In this study, there was an average improvement of 4.8%, or roughly 0.5 mm, in lip height symmetry when a pennant flap was performed during primary lip reconstruction. It is difficult to speculate whether this difference is clinically

detectable. A worthwhile direction for future research would be to quantify the degree of lip asymmetry that is visible to the casual observer.

Conclusions

Lip height asymmetry following unilateral cleft lip repair is affected by the surgeon, type of cleft deformity, and the use of an inferior pennant flap. On average, patients with incomplete cleft lips demonstrated better results than those with complete cleft lips. However, when a pennant flap was used during reconstruction, postoperative asymmetry was equivalent between complete and incomplete clefts. Overall, inferior triangle repairs achieved greater lip height symmetry than traditional rotation-advancement techniques, particularly in patients with complete cleft lip deformities. The surgeon performing the repair was also an important determinant of lip height symmetry, but only in patients with complete cleft lips.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.

(*Top left*) Calipers are used to measure the disparity in vertical length between the medial lip element and the non-cleft philtral tubercle. This difference determines the size of the inferior pennant flap. (*Top right*) The pennant is marked on the lateral lip element just above the vermilion border. (*Bottom left*) The small triangular flap of skin from the lateral lip is inset into a back cut within the medial lip element. (*Bottom right*) Immediate postoperative results demonstrate equal height of the philtral tubercles between the cleft and non-cleft sides.

Figure 2.
Vertical lip height measured from the subnasale to the peak of Cupid's bow. A: cleft side. B:
non-cleft side. Percent asymmetry = $(B - A)/B \times 100$.

Figure 3.
Distribution of subjects with complete and incomplete cleft lips.

Figure 4.
Mean postoperative lip height asymmetry in patients with complete and incomplete clefts.

Figure 5.

Mean postoperative lip height asymmetry in pennant and non-pennant repairs. A, B, and C represent repairs performed by three individual cleft surgeons. Combined results are shown on the far right.

Table 1

Pennant Flap, Surgeon, and Cleft Type as Predictors of Postoperative Lip Height Asymmetry: Results of Linear Regression Analysis.

	r^2	B (percent asymmetry)	p	95% CI for B	
				Lower Bound	Upper Bound
All Patients (N = 90)	0.134				
Pennant Flap		4.2	0.015	0.8	7.6
Surgeon		1.6	0.099	-0.3	3.5
Cleft Type		2.5	0.156	-1.0	5.9
Complete Only (N = 58)	0.249				
Pennant Flap		4.9	0.028	0.5	9.3
Surgeon		3.6	0.005	1.2	6.1
Incomplete Only (N = 32)	0.122				
Pennant Flap		2.9	0.200	-1.6	7.5
Surgeon		2.3	0.083	-0.3	4.9

r^2 : coefficient of determination, B: regression coefficient, CI: confidence interval.