Original Investigation

Lower Lateral Cartilage Repositioning
Objective Analysis Using 3-Dimensional Imaging

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IMPORTANCE In recent years, with the advent of 3-dimensional (3D) imaging techniques, it has become possible to objectively measure rhinoplasty results. However, few studies have used 3D imaging software to assess postoperative rhinoplasty results of the nasal tip.

OBJECTIVE To analyze nasal tip volumes of patients with bulbous tips and measure postoperative nasal tip volume changes in patients who have undergone lower lateral cartilage (LLC) repositioning.

DESIGN, SETTING, AND PARTICIPANTS A prospective study of patients with a preoperative diagnosis of bulbous nasal tip and cephalically oriented LLC as measured intraoperatively (with angles less than 30 degrees from the midline) who underwent rhinoplasty by a single surgeon and preoperative and postoperative 3dMD imaging at a university hospital.

INTERVENTIONS Rhinoplasty with LLC repositioning and preoperative and postoperative 3dMD system imaging. We also used 3dMD Vultus software for the analysis of nasal tip volume changes.

MAIN OUTCOMES AND MEASURES Changes in nasal tip volume and LLC angle.

RESULTS Thirty-one patients met the inclusion criteria (25 women and 6 men; mean age, 33 years). Among these, there were 16 primary and 15 revision cases with a follow-up range of 1 to 19 months. Statistical tests included a paired *t* test on volume and angle changes as well as correlative and exploratory analyses to gain further insight into the analysis population over time. The change in the LLC angle after repositioning was found to be statistically significant. The mean decrease in volume on the right was 0.0254 mL, and the mean decrease on the left was 0.0249 mL. The mean total volume change was a decrease of 0.0503 mL. An exploratory analysis suggested that subjects with longer follow-up displayed a greater reduction in volume. Using 5 months as a cutoff, we found that the subgroup with longer follow-up displayed a mean total bilateral volume change of −0.07 mL compared with −0.03 mL in the subgroup with shorter follow-up.

CONCLUSIONS AND RELEVANCE We found that LLC repositioning when used to address bulbous nasal tips and cephalically oriented LLCs leads to significant increase (preoperative to postoperative) in the angle of the LLC (to a more caudal orientation). We also found an overall trend of decreasing nasal tip volume throughout follow-up. Although not statistically significant, the overall decrease in volume is clinically meaningful when paired with favorable positioning of the LLC. Exploratory analyses suggest that treatment effect is consistent across sexes and that greater decrease in total volume might be found with longer follow-up.

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The objective assessment of rhinoplasty poses inherent difficulties. Measurements including angles and distances such as tip rotation and projection have been used with the aid of 2-dimensional (2D) photography.[1] Although validated surveys have also been used to assess patient satisfaction, assessment of results has been mostly via subjective physician opinion. Today, the advent of 3-dimensional (3D) measurement software has made it possible to introduce yet another variable, which has only recently begun to be measured—volume changes following rhinoplasty. There are few studies in the literature that have evaluated 3D imaging techniques in the assessment of rhinoplasty results. Use of 3D imaging software has now made it possible to objectively analyze rhinoplasty results with accuracy values that range from 0.2 to 1.0 mm.[2] Several studies have shown the accuracy and reproducibility of the technique to measure both facial appearance and rhinoplasty results.[3-5] In the present study, the 3dMD system (3dMD Inc) was used to help quantify postoperative volumetric changes within the nasal tip complex. Previous studies using 3dMD in assessing rhinoplasty results have shown this software to have an accuracy of 0.5 mm.[4]

Cephalically positioned lower lateral cartilages (LLCs) were described by Sheen and Sheen[6] as a "parentheses" deformity contributing to the bulbous-appearing nasal tip. Cephalically positioned LLCs cross from the nasal tip complex to the nasal sidewall and supratip region, thus blunting the demarcation between the subunits and creating excess vertical supratip fullness. The blunting of the boundaries between the nasal tip/supratip and nasal sidewall gives the tip a bulbous appearance. In the aesthetic nasal tip, there exists a shadow in the supratip region.[7] The cephalic orientation of the LLCs ideally is identified and addressed when tip refinements are made during rhinoplasty.

The lateral crural strut graft was described by Gunter and Friedman[8] as a tool for nasal tip reshaping whereby cartilage grafts are placed on the underside of the LLCs above the vestibular skin (**Figure 1**). Lateral crural strut grafts can be used to reshape the nasal tip by flattening the LLCs thereby eliminating the bulbous shape.[8] If the lateral crura are cephalically oriented, they can be flattened as well as repositioned to a more caudal position. Cephalically oriented LLCs are repositioned by elevating them off the underlying vestibular skin, placing lateral crural strut grafts, and repositioning them into a more caudal orientation. Additionally, LLC repositioning allows the cartilages to be rotated along its long axis into a more favorable orientation, whereby the caudal margin of the LLC rests at a point level to or more superficial than the cephalic margin.[7] **Figure 2** contrasts the differences between the LLC in an unfavorable orientation (Figure 2A) with the LLC in a favorable orientation (Figure 2B); in unfavorable orientation, the cephalic edge rests superficial to the caudal edge.

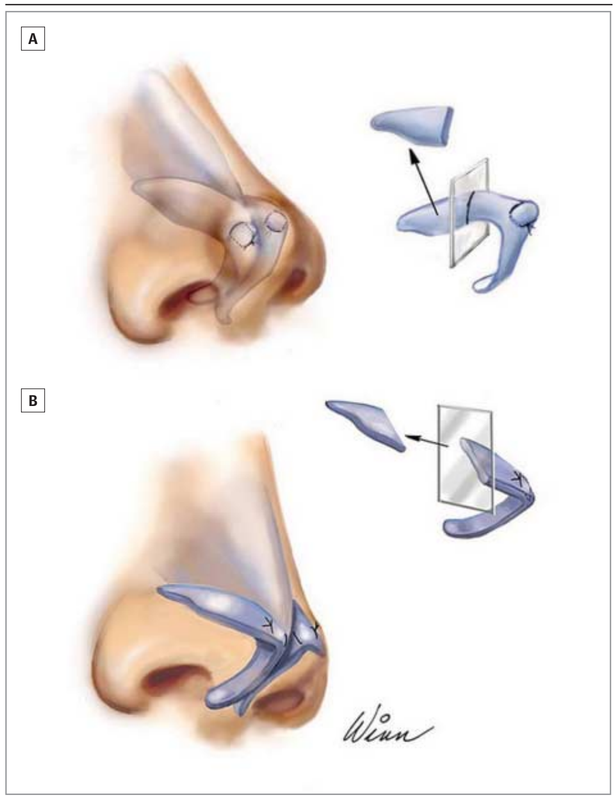
The repositioning of the LLCs removes volume created in the nasal sidewall/supratip regions leading to better tip refinement. **Figure 3**A and B are preoperative and intraoperative photographs of cephalically malpositioned LLCs. Figure 3C shows the intraoperative view of the nasal tip complex after the LLCs have been repositioned. **Figure 4** is a view of the same nasal tip immediately after cartilage repositioning, showing reduction in the fullness previously caused by the cephalic malpositioned cartilages (compare with Figure 3A).

Given these observations after repositioning, we hypothesize that there is a reduction in volume in the area corresponding to the previously cephalically malpositioned LLCs. We tested our hypothesis by using the 3dMD system to objec-

Figure 1. Intraoperative View of Lateral Crural Strut Grafts

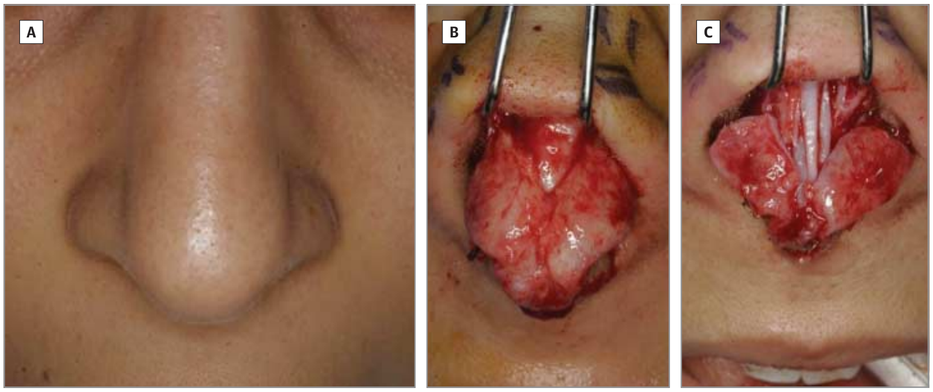
The lateral crural strut grafts are shown being sutured to the underside of the lower lateral cartilages after they have been elevated off the vestibular skin.

Figure 2. Graphic Representation of Different Orientations of Lower Lateral Cartilages (LLCs)



A, Unfavorable LLC orientation. B, Favorable LLC orientation.

Figure 3. Preoperative and Intraoperative Images of Patient With a Bulbous Nose Tip

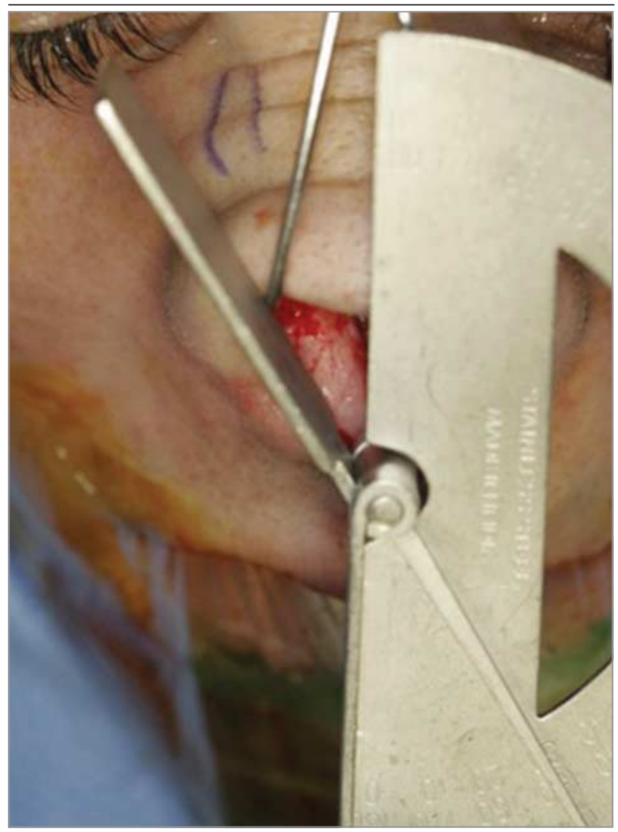


A. Preoperative view. B, Intraoperative view of the same patient, showing cephalic malpositioned lower lateral cartilages (LLCs). C, View of the LLCs after they have been repositioned to a more caudal orientation.

Figure 4. Postoperative View

Immediate postoperative appearance after cartilage repositioning.

Figure 5. Lower Lateral Cartilage (LLC) Angle Measurement



A finger goniometer was used to measure the angles of the LLCs with respect to the midline.

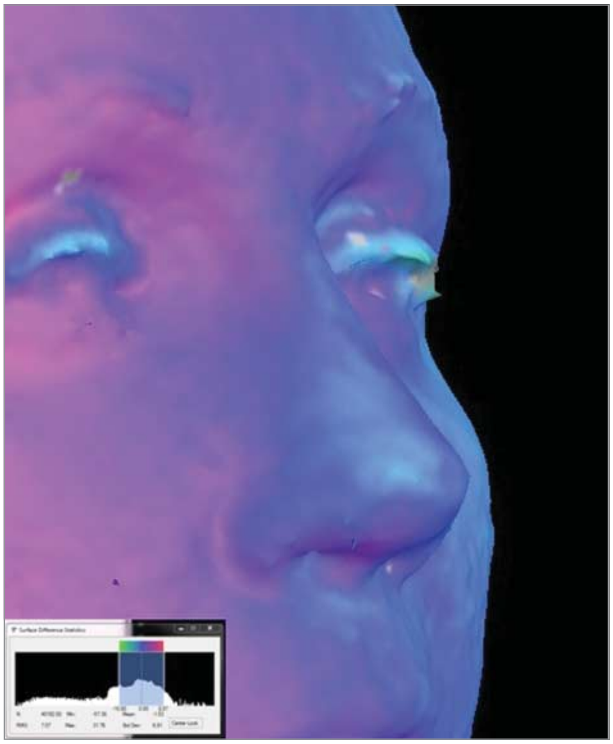
tively assess whether volume reduction occurred in specific regions of the nasal tip in patients who had undergone LLC repositioning.

Methods

All patients provided written informed consent, and we received University of Illinois institutional review board approval for this prospective study of patients who had undergone rhinoplasty performed by the senior author (D.M.T.). The data set included 31 participants (25 women and 6 men) who met the inclusion criteria. The analysis set consisted of measured change from preoperative to postoperative supra-alar volume and LLC angle. Statistical tests included a paired *t* test on volume and angle changes to test each measurement and correlative and exploratory analyses to gain further insight into the analysis population.

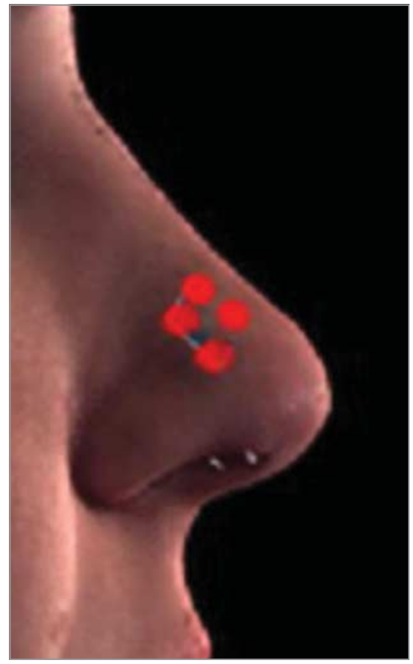
Information collected included preoperative diagnosis of bulbous tip as determined by the senior author (D.M.T.) and intraoperative LLC angles measured from the midline. A finger goniometer was used to measure LLC angles intraoperatively (**Figure 5**). A Neivert knife guard retractor was used to retract the skin and soft-tissue envelope to expose the LLCs. We were cognizant of the possibility that retraction on the skin could slightly alter the angles; therefore, care was taken to not alter the native angles of the cartilages with skin retraction.

Figure 6. Example of the Histogram Resulting When Preoperative and Postoperative Images Are Superimposed



The aqua-shaded areas represent the areas of volume decrease.

Figure 7. Demonstration of the Overlay Technique in Which the Preoperative and Postoperative Images Are Superimposed



The postoperative image was converted into a mesh pattern, as seen in this image in the lateral view.

The angles were then measured by aligning one arm of the goniometer with the midline and the other arm with the caudal edge of the LLC.

Participants in the study were limited to those patients whose LLC angle was more acute than 30 degrees from the midline, an experience-based cutoff angle determined by the senior author (D.M.T.) to represent cephalically malpositioned lateral cartilages. All patients included in the study were those who had undergone repositioning of their LLCs. The LLCs were elevated off the underlying vestibular skin, cephalic resections were performed, and lateral crural strut grafts were sutured to the underside. The lateral crura were then repositioned into more caudally positioned pockets. After the LLCs were repositioned, the resulting new angles were measured in the same manner.

Patients included in the study had a preoperative image and at least 1 postoperative image taken with the 3dMD system. Overall, the inclusion criteria for the study were as follows: (1) preoperative diagnosis of bulbous nasal tip; (2) cephalically oriented LLC as measured intraoperatively with angles less than 30 degrees from the midline; (3) LLC repositioning performed; and (4) 3dMD imaging performed preoperatively and at a postoperative visit. In the case where multiple 3D images were taken, the image from the last postoperative visit was used.

Preoperative and postoperative 3D stereophotogrammetric images were imported into 3dMD Vultus software (3dMD Software). The 2 images were superimposed on each other, and alignment precision measured by registering images and calculating the root mean square (RMS). Prior to registration, alignment precision is assessed by increasing the preoperative image transparency to visualize and correct regions of misalignment. The RMS values are calculated by highlighting areas demonstrating minimal postoperative soft-tissue volume change: right and left cheek and radix. As the RMS value approaches 0, the accuracy of preoperative and postoperative alignment increases. An RMS value of 0.5 or less is required. If the RMS is not less than 0.5, the images are realigned, and the RMS recalculated.

Once an RMS value of less than 0.5 is achieved, a topographic image is created that uses a color histogram to represent the relative volume change between the preoperative and postoperative image. Although we used 0.5 as a cutoff for the RMS, we found that the mean RMS value from our study was 0.18, thus showing that we pushed this method to its limits. The more pink-shaded regions in the histogram represent areas of volume increase, and the more aqua-shaded regions in the histogram represent areas of volume decrease (**Figure 6**).

To measure the precise difference in volume change between the preoperative and postoperative images of the bilateral supratip/nasal sidewall junction region, we converted the postoperative image to wire mesh format, and data points were manually selected to cover the perimeter of the region. The high level of precision was achieved by overlaying the preoperative and postoperative images, thus ensuring the highest possible degree of exact reproducibility. A single region of interest (ROI) was selected preoperatively and then compared directly with the precisely corresponding postoperative ROI. **Figure 7** demonstrates this overlay technique.

Table 1. Summary of Results

Case No.	RMS	Right Angle, °		Right VC, mL	Left Angle, °		Left VC, mL	Bilateral VC, mL	Rotation	Projection
		Pre	Post		Pre	Post				
1	.208	30	43	−0.01	32	42	−0.007	−0.017	Increased	Decreased
2	.1126	26	39	−0.002	34	40	−0.003	−0.005	Increased	Increased
3	.12	21	49	−0.002	33	50	−0.004	−0.006	Increased	Decreased
4	.2859	28	36	−0.003	28	36	−0.001	−0.004	Increased	Same
5	.1499	30	41	−0.003	24	34	−0.003	−0.006	Increased	Same
6	.1629	34	47	0.015	35	50	0.031	0.046	Increased	Increased
7	.0901	34	47	−0.002	35	50	−0.002	−0.004	Increased	Deceased
8	.2842	26	34	0.005	26	45	0.008	0.013	Increased	Same
9	.3439	30	38	−0.021	34	48	−0.02	−0.041	Increased	Same
10	.1249	16	30	−0.017	21	39	−0.027	−0.044	Increased	Decreased
11	.3678	20	42	−0.001	29	35	−0.004	−0.005	Increased	Same
12	.1407	34	40	−0.001	31	35	−0.001	−0.002	Increased	Increased
13	.1251	21	42	−0.01	15	43	−0.002	−0.012	Increased	Increased
14	.1354	22	40	−0.003	26	40	−0.015	−0.018	Increased	Same
15	.2456	29	36	−0.003	34	36	−0.004	−0.007	Increased	Decreased
16	.2223	26	42	−0.026	29	44	−0.026	−0.052	Increased	Increased
17	.1729	20	40	0.003	27	36	0.004	0.007	Increased	Decreased
18	.2006	32	42	−0.001	33	38	−0.003	−0.004	Increased	Same
19	.179	19	35	0.011	25	30	0.02	0.031	Increased	Same
20	.1282	30	49	−0.012	28	38	−0.011	−0.023	Decreased	Decreased
21	.0726	32	43	−0.004	32	46	−0.002	−0.006	Increased	Decreased
22	.1787	32	42	−0.002	29	35	−0.011	−0.013	Increased	Decreased
23	.2718	28	35	−0.019	30	36	−0.025	−0.044	Increased	Increased
24	.2026	26	45	−0.213	27	41	−0.213	−0.426	Increased	Decreased
25	.1959	26	35	−0.001	30	40	0.003	0.002	Increased	Decreased
26	.2574	29	41	0.006	24	49	.005	0.011	Increased	Same
27	.2699	20	60	0.002	22	50	0.006	0.008	Decreased	Same
28	.1104	28	30	−0.013	26	30	0.001	−0.012	Same	Increased
29	.1147	26	41	0.004	28	42	0.0005	0.009	Increased	Decreased
30	.2038	29	40	−0.001	28	39	−0.002	−0.003	Decreased	Increased
31	.1537	25	34	−0.462	26	34	−0.462	−0.924	Increased	Same

Abbreviation: Post, postoperative measurement; Pre, preoperative measurement; RMS, root mean square; VC, volume change.

An important limitation is that the RMS is the difference of the entire face, not just the ROI. So if a patient also received a chin implant, the RMS cutoff of 0.5 would be harder to reach. We were able to bypass this problem by using other bony landmarks such as the malar prominence or orbital rims. The volume differences of the selected areas in the study region were then calculated.

To assure the greatest precision, we trimmed the ROI prior to overlaying the images. This allowed us to obtain consistent results because the selected ROI was always the same. The procedure is reproducible because with histogram-based Vultus software, a patch is generated for base reference. This patch is then applied to the postoperative surface for selection. Therefore, the measuring procedure is consistent and reproducible, since we are using the same patch that was overlaid. As further confirmation that the measurements were reproducible, we took each measurement 3 times and reported the average of the 3 measurements. The precision of 3dMD Vultus volume assessment has been established by previous studies and is accepted to be accurate to the 0.01 mL.[9] The 3 averaged measurements were then reported, rounding to 0.0001 mL. The greater number of decimal places in the reported results, 2 more than the accepted degree of accuracy, are an effect of averaging such data.

Results

A detailed summary of the data collected for each patient can be found in **Table 1**. The *t* test analysis of volume change and angle change are summarized in **Table 2** and **Table 3**, respectively. A *t* test analysis was chosen because, although we have a small sample size, the data were approximately normally distributed, and our goal was to determine if these sets of data were significantly different from each other.

The change in the LLC angle after repositioning was found to be statistically significant on both the right and left. The preoperative angle on the right changed from a mean of 25 degrees to 38 degrees after repositioning (increase of 13 degrees). The mean preoperative angle on the left changed from a 26 degrees to 38 degrees after repositioning (increase of 12 degrees). The mean RMS value was 0.18, showing very little variation in the alignment of the preoperative and postoperative images. The changes in the nose itself from the rhinoplasty would also contribute to the variability between the images, adding slightly to the RMS value.

We used 3D histograms to analyze where along the nasal tip volume changes occurred. In all cases, volume reduction occurred along the studied region. The mean decrease in volume on the right was 0.0254 mL, and the mean decrease on the left was 0.0249 mL. The mean total volume change was a decrease of 0.0503 mL. One patient had a large and symmetric volume change of 0.462 mL on each side. He had a porous polyethylene implant from his primary rhinoplasty, and this implant was removed and replaced with costal cartilage during the procedure. This replacement might have contributed to the large volume change as well as the marked symmetry obtained postoperatively.

An exploratory analysis suggested that subjects with longer follow-up displayed a greater reduction in volume. A 1-way analysis of variance was performed to test the duration of follow-up as a factor in volume and angle change. To evaluate volume change as a function of follow-up time, we split the analysis data set into 2 categories: subjects with less than 5 months' follow-up (17 patients) and subjects with follow-up of 5 months or longer (14 patients). Five months was used to determine the categories because a cutoff at this follow-up time most evenly distributed the data set for analysis. The subgroup with longer follow-up displayed a mean total bilateral volume change of −0.070 mL compared with −0.030 mL in the shorter follow-up subgroup. Although not statistically significant, the overall decrease in volume is clinically meaningful when paired with favorable positioning of the LLC.

Table 2. Summary of paired *t* Test Analysis of Volume Change

Measurement Site	Volume Change, mL[a]	*P* Value
Right side (n = 31)	−0.025 (0.090) [−0.058 to 0.008]	.13
Median (range)	−0.002 (−0.462 to 0.015)	
Left Side (n = 31)	−0.025 (−0.090) [−0.058 to 0.008]	.13
Median (range)	−0.003 (−0.462 to 0.031)	
Total (n = 31)	−0.050 (− 0.180) [−0.116 to 0.016]	.13
Median (range)	−0.006 (−0.924 to 0.046)	

[a] Unless otherwise noted, data in this column are reported as mean (SD) [95% CI]; one subject was excluded from the volume change analysis given the outlying nature of the data observed.

Discussion

Use of 3D imaging software technology has advanced our ability to analyze postoperative results in facial plastic surgery over 2D photographic technology, which limits the evaluation of rhinoplasty results to angles and distance assessments. Some of the more attainable measurements with 2D photography include those pertaining to nasal tip projection and nasolabial angle. However, 2D photography introduces inaccuracies between preoperative and postoperative measurements (lack of standardization of photography, changes in magnification from setting to setting, variability in head position, and others). Use of 3D imaging has now allowed for volumetric analysis of rhinoplasty results without the problems associated with variability in 2D photography. To our knowledge, this is the first study that has used 3D imaging software to analyze the changes in nasal tip volume after rhinoplasty. Specifically, we used this software to analyze the changes that take place after the LLCs are repositioned secondary to cephalic malpositioning.

The malpositioning of LLCs has been reported to contribute to the bulbous nasal tip.[6,10] The extension of the cartilages from the nasal tip complex to the supratip and nasal sidewall causes a blunting of these boundaries and the resulting appearance of tip bulbosity. If cephalic malpositioning of the LLCs is not recognized at the time of the rhinoplasty, the patient may have persistent fullness in this area. In cases where it is not recognized and the domes are brought together to achieve narrowing of the tip, the patient may have persistent bulbosity in the nasal tip or other tip deformities. Repositioning of the LLCs is one technique that allows for the correction of this deformity. The senior author (D.M.T.) performs LLC repositioning using lateral crural strut grafts and repositioning them in a more caudal orientation.[7] In this study, we analyzed patients with bulbous nasal tips secondary in part to cephalic malpositioning. Preoperative analysis included the diagnosis of bulbous nasal tip, while intraoperative measurements were taken of the angles of the LLCs relative to the midline.

Table 3. Summary of Paired *t* Test Analysis of LLC Angle Change

	LLC Angle, °			
Measurement Site	Preoperative	Postoperative	Change	*P* Value
Right Side (n = 32)				
Mean (SD)	25.19 (5.68)	38.19 (7.27)	13.00 (8.73)	<.001
Median (range) 95% CI	26.00 (15.00 to 34.00) NA	40.00 (28.00 to 60.00) NA	12.00 (−3.00 to 40.00) 9.85 to 16.15	
Left Side (n = 32)				
Mean (SD)	26.41 (5.78)	38.44 (6.16)	12.03 (7.84)	<.001
Median (range) 95% CI	26.00 (14.00 to 40.00) NA	38.50 (30.00 to 50.00) NA	12.00 (−6.00 to 29.00) 9.21 to 14.88	

Abbreviation: NA, not applicable; LLC, lower lateral cartilage.

Postoperatively, it was obvious to the surgeon (D.M.T.) that there was a volume reduction in the supratip/nasal sidewall junction after patients underwent cartilage repositioning. In some cases, repositioning of the lateral cartilages was performed in conjunction with other tip-altering procedures such as changing tip rotation and projection. Although these factors may have confounded our measurements of volume changes, we attempted to minimize these possible confounding factors by limiting our region of interest to a very specific area. It was hypothesized that this bulk in the area studied corresponded to the underlying malpositioned LLCs, and thus the repositioning of these cartilages would translate into reduction of volume in this specific area. Our attempt in this study was to ascertain if a reduction in volume resulted from LLC repositioning.

Subjectively, we saw greater tip refinement, so we used the 3dMD system to confirm our subjective findings. And, indeed, the volume metrics showed a trend toward volume reduction. Owing in part to the small patient population and in part to wide variance in volume calculations, there was no statistical significance to the volume changes, but the changes were clinically meaningful. In conjunction with a more caudal angle change of the LLC, the volume reductions resulted in refinement of the nasal tip. The surgery described herein is partially a volume-reduction procedure and partially a volume-repositioning procedure. The significant change in angle of the LLC allows for a more refined tip via volume repositioning. It is this volume repositioning in conjunction with the volume reduction of the specific anatomic region of interest (supratip/nasal sidewall junction) that results in a more refined nasal tip.

Our study was limited to a relatively small number of patients and limited follow-up time owing to the novelty of 3D imaging. Despite the short follow-up time, volume loss was evident. Our exploratory analyses suggested that treatment effect is consistent across sexes and that longer follow-up appears to be associated with greater decrease in total volume. This finding likely results from a decrease in postoperative swelling and skin contracture over time. Additionally, it would be beneficial to compare the repositioning technique for cephalic malpositioning with other techniques for this deformity using 3D imaging software.

Conclusions

This study supports our hypothesis that repositioning of the LLCs results in volume loss in the expected areas of the supratip and nasal sidewall junction. There is volume loss and likely volume repositioning involved in this process. Volume repositioning is accomplished by repositioning the LLC to a more favorable and caudal position. Although a larger patient population and longer follow-up are needed for future studies, statistical significance was found within the present study sample. Subjective analysis showed that when cephalically malpositioned cartilages were repositioned in a more caudal direction, tip refinement was improved. Use of 3D imaging in this case was able to lend support for this subjective finding by objectively demonstrating volumetric nasal tip changes.

ARTICLE INFORMATION

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Author Contributions: Dr Toriumi had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
Study concept and design: Bared, Toriumi.
Acquisition of data: Bared, Rashan, Caughlin, Toriumi.
Analysis and interpretation of data: Rashan, Caughlin, Toriumi.
Drafting of the manuscript: Bared, Rashan, Caughlin, Toriumi.
Critical revision of the manuscript for important intellectual content: Bared, Rashan, Caughlin, Toriumi.
Statistical analysis: Rashan, Caughlin, Toriumi.
Administrative, technical, and material support:
Study supervision: Toriumi.

Conflict of Interest Disclosures: Dr Toriumi is a consultant for the 3dMD software and is helping to develop software to be used for rhinoplasty analysis but has no monetary interest in sales. No other conflicts were reported.

Previous Presentation: This research was presented as an oral presentation at the American Academy of Facial Plastic and Reconstructive Surgery Annual Fall Meeting; September 5-8, 2012; Washington, DC.

Additional Information: Dr Bared is currently in private practice at the Foundation for Plastic Surgery, Miami, Florida.

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