ORIGINAL ARTICLE

Intraoperative Suction-Assisted Evaluation of the Nasal Valve in Rhinoplasty

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Objective: To introduce and analyze suction-assisted analysis of nasal valve strength in functional septorhinoplasty. This is a novel method for helping the surgeon analyze the integrity of a patient's airway during surgery.

Methods: In this prospective study, 20 patients who underwent functional septorhinoplasty were analyzed. Negative pressure using suction tubing was placed at the nasal sill, and measurements of the amount of maximal depression of the nasal valve were performed in the operating room immediately before incision and immediately after closure of the incisions.

Results: All 20 patients had an immediate decrease in the deviation of the weakest point of the valve, with a mean change of 2.14 mm. The change on both sides was statistically significant (paired *t* test, $P < .001$). This novel method helped the surgeons decide which grafts provided the most immediate structural benefit.

Conclusions: Structure-based septorhinoplasty can immediately improve the strength of the nasal valve. Suction-assisted analysis of the nasal valve can be a useful "real-time" tool for determining which maneuvers improve the strength of the nasal valve.

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NASAL VALVE COLLAPSE IS A type of anatomic obstruction that can have a significant impact on a person's quality of life. Because of its implications on the functional and aesthetic outcome of nasal reconstruction, it has been the subject of numerous studies.[1-4] The nasal valve is differentiated into the internal and external valves. The internal nasal valve is where the upper lateral cartilage meets the septum. Patients may have isolated internal nasal valve insufficiency, which is evidenced by a dynamic depression at the nasal sidewall when the patient breathes in. An endonasal view shows the upper lateral cartilage being pulled in toward the septum, decreasing the angle between the upper lateral cartilage and the septum. In white patients, this angle is normally 10° to 15°.[5] The external nasal valve is composed of the alar lobule laterally, the nasal sill inferiorly, and the columella medially. With this type of weakness, one will see the ala and supra-alar crease collapse on deep nasal inspiration. Increased negative pressure by deep inspiration can affect the internal or external nasal valve or both.

Videos available online at www.archfacial.com

The effect of different grafts on nasal valve function has not yet been fully established. Surgeons vary in their opinions on which grafts are best for helping improve valve weakness.[6] The alar batten graft may be the most commonly used grafting technique to help improve valve strength.[7,8] Its effects have been studied, and it has been found to be a versatile and consistent method to strengthen the internal and external nasal valve.[1,9] We use this graft in nearly all functional rhinoplasty procedures to improve the integrity of the valve.

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A successful result in functional septorhinoplasty relies partly on the ability of the nasal valves to have enough integrity to withstand the forces of negative pressure. During an operation, surgeons have few tools to assess whether the maneuvers they use are providing enough strength for the nasal valve. Objective tools to determine airway dimensions include acoustic rhinometry, manomanometry, and 3-dimensional computed tomographic scans.[10-13] Subjective studies can also be performed.[7] However, none of these

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evaluations can be performed in the operating room to judge, in real time, whether specific surgical maneuvers provide an actual improvement. To our knowledge, objective and live intraoperative analysis of whether septorhinoplasty is helping improve nasal airway dynamics has never been described.

We sought to develop and validate a method of objectively analyzing nasal valve strength. To accomplish this, the senior author (C.S.M.) created a method of analysis that would be easy for surgeons to perform and uses equipment available to all surgeons. Above all, we wanted this method to be simple and reproducible in every surgery. The method uses suction tubing attached to its usual negative pressure source. This creates negative pressure that resembles deep nasal inspiration. Suction tubing with its negative pressure flow to determine the strength of the nasal valve in vivo before, during, and after surgery can be used in all rhinoplasty operations. In this study, we sought to validate this tool and used it to determine whether we are gaining improvement in the strength of the nose by creating a negative pressure similar to deep inspiration.

METHODS

This is an institutional review board–approved prospective study on 20 consecutive functional septorhinoplasties performed from November 2010 to April 2011. Inclusion criteria were that all patients have complaints of difficulty breathing and evidence of external nasal valve collapse on deep active inspiration preoperatively. This is seen when a patient has dynamic depression with deep inspiration at the ala and supra-alar crease. They were enrolled consecutively and with no respect to age or sex, except for children (age <18 years). Immediately before surgery, the patient was asked to breathe in deeply through his or her nose, and the point of deepest external depression was marked with a surgical marking pen. Once in the operating room, and before incision, suction tubing was held to the end of the nose and confirmed that suction will cause the deepest depression at the area marked preoperatively. The distance of maximal depression before totally occluding the nostril was measured with calipers and recorded. This was done on both sides. The distance of deviation was recorded in millimeters. The measurement zero was recorded when the valve maintained its integrity until the suction totally occluded the nostril. Surgery was performed using a variety of techniques, and the details of maneuvers used were recorded and are described herein.

Video 1 and video 2 (http://www.archfacial.com) show the technique being performed intraoperatively on a patient immediately before incision and at the end of the surgery. This patient had complaints of nasal obstruction and had obvious weakness of the nasal valve on preoperative assessment. She underwent septoplasty, submucous turbinate reduction, and an endonasal approach to insertion of alar batten grafts composed of septal cartilage. The blue surgical pen marks define the points of maximal depression on preoperative analysis. One can define the area of maximal weakness using standard suction tubing near the nose, the same as having a patient inspire deeply through the nose. The surgeon must be careful to see how much the valve collapses with maximal suction, just short of totally occluding the nose with the suction tip. In both videos, the left side of the screen shows the calipers used to measure the preoperative deviation of the point of maximal depression, which was marked with a blue surgical marking pen before incision. On the caliper, the measurement of maximal deviation before incision was 3 mm. The right side of each video shows the same patient's nose in the operating room immediately after surgery was completed, and the skin envelope was closed with a simple 6-0 polypropylene suture at the columella. New suction tubing was used. On both sides (left and right), there is an obvious difference in deviation of the same point, which is demonstrated in the videos. The calipers showed only a 0.5-mm deviation postoperatively. Compared with the preoperative depression, there was a 2.5-mm difference in deviation of the same point on both sides.

We performed bilateral measurements on each patient to determine whether the maneuvers improved the strength of the nasal valve. The surgical center in which the operations were performed has a meter that displays the amount of negative pressure for each room's suction. The operating rooms used for the study were set to have a flow rate of 50 L/min and a minimum negative pressure of –80 kPa. The sensors for the operating rooms reflected these numbers consistently throughout the study. In addition, if there was significant build-up of blood in the suction tubing, it was irrigated with saline to clear it of debris, or it was replaced before the posttreatment measurements. This ensured that the amount of suction flow was not affected by material in the suction tubing.

RESULTS

From November 2010 to May 2011, 20 patients met inclusion criteria and underwent measurements during surgery. Fifteen were female and 5 were male. Ages ranged from 20 to 66 years, with a mean of 41 years. Fourteen were primary and 6 were revision surgical procedures. Nineteen were performed with external approach and 1 was performed with an endonasal approach. The **Table** shows the maneuvers used for each patient in the study. Because some terms used in the table may be unfamiliar to the reader, we will elaborate:

Auto-spreader flap: Redundant dorsal portion of the upper lateral cartilage can be used as its own "auto-spreader" flap by turning in the dorsal portion into the area normally used for the spreader graft.[14,15] This provides the effect of a spreader graft without the need for cartilage grafting.

Cephalic turn-in flap: This uses the cephalic portion of the lower lateral cartilage to strengthen the lateral crura by rotating it into a position between the lateral crura and the vestibular mucosa. This simultaneously strengthens the lateral crura, helps ameliorate convexities and/or concavities, and provides a cephalic trim for cosmetic purposes.[16,17]

Alar batten grafts, which are the most widely used grafts for strengthening the nasal valve, were used in all but 2 patients. These were placed either superficial to the lateral crura or, more commonly, superficial and cephalad to the lateral crura, with differing degrees of overlap based on where the greatest weakness was evidenced by suction. The placement of alar batten grafts was usually the final maneuver before closure of incisions in all patients. Suction-assisted analysis before placement of these grafts revealed that the valve had enough integrity without alar batten grafts. In these 2 patients (patients 4 and 16), this graft was not inserted.

In all patients the most maximally displaced point with suction was somewhere near the supra-alar crease. **Figure 1** and **Figure 2** show the results of a typical patient in the study. This is a different patient from the videos. One can see a noticeable difference in the deviation of the maximal point of depression before and after surgery.

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Table. The Specific Maneuvers Used for Each Patient[a]

Patient No.	L Pre-op (mm)	L Post-op (mm)	R Pre-op (mm)	R Post-op (mm)	Revision Operation	External Approach	Septoplasty
1	2.5	0	2	1		X	X
2	2	0	1.5	0	X	X	X
3	3	1	3	2		X	X
4	2	0	3	1		X	X
5	3	0	3	1		X	X
6	6	1.5	3	0.5	X	X	X
7	3	0.5	3	0.5			X
8	4	2	3	0		X	X
9	2	2	3	1		X	X
10	2	1	4	0		X	X
11	1	0	3	1		X	X
12	5	2	3	1		X	X
13	2	0	2	1	X	X	X
14	**2**	**0**	**1.5**	**0**		**X**	**X**
15	1.5	0	1.5	0		X	X
16	**3**	**0.5**	**3**	**0.5**	**X**	**X**	**X**
17	2	0.5	1	0	X	X	X
18	2	0	2	0		X	X
19	3.5	0.5	0	0		X	X
20	4	1	5	2	X	X	X

Patient No.	Turbinate Reduction	Alar Batten Grafts	Spreader Grafts	Cephalic Turn-in Flaps	Lateral Osteotomies	Columellar Strut Grafts	Alar Rim Grafts
1	X	X	X	X	X	X	
2	X	X	X		X	X	X
3	X	X	X	X	X	X	
4	X	X	X	X	X	X	
5	X	X	X	X	X	X	
6	X	X					
7	X	X					
8	X	X	X	X	X	X	
9	X	X	X	X	X		
10	X	X			X		
11	X	X					
12	X	X	X	X	X	X	
13	X	X				X	X
14	**X**		**X**	**X**	**X**	**X**	
15	X	X	X	X	X	X	
16	**X**		**X**	**X**	**X**	**X**	
17	X	X			X	X	
18	X	X		X	X	X	
19	X	X		X	X	X	
20	X	X	X	X	X	X	X

Abbreviations: L, left; Pre-op, preoperation; Post-op, postoperation; R, right; X, procedure was performed; blank cell, procedure was not performed.

[a]The Table details the specific maneuvers used for each patient. The columns titled "L Pre-op," "L Post-op," "R Pre-op," and "R Post-op" are the measurements in millimeters for each side. Patients 14 and 16 (highlighted rows) are the only patients who did not undergo alar batten grafting because the cephalic turn-in flap provided enough strength to decrease the amount of deviation with suction.

The analysis of all patients showed statistically significant results. On the left side for all patients, the mean preoperative deviation of the maximally displaced point with suction before total occlusion was 2.75 mm. Postoperatively, the amount of deviation of this point decreased to a mean of 0.70 mm. The mean amount of change on the left was 2.07 mm. This was a statistically significant amount of change (paired *t* test, $P < .001$). On the right side, the mean preoperative deviation of the maximally displaced point with suction before total occlusion was 2.45 mm. Postoperatively, the amount of deviation of this point decreased to a mean of 0.60 mm. The mean amount of change on the right was 1.83 mm. Overall, the range of improvement was 0 to 4.5 mm. Only 1 side of 1 patient did not improve from a deviation of 2 mm. Besides this 1 side on 1 patient, all patients showed improvement in their deviation on the both sides, with an overall mean change of 2.14 mm. This was a statistically significant amount of change (paired *t* test, $P < .001$).

COMMENT

Since we starting using suction-assisted analysis, it has become an excellent tool for ensuring nasal valve strength. Intraoperatively, our goal is to maintain the shape of the

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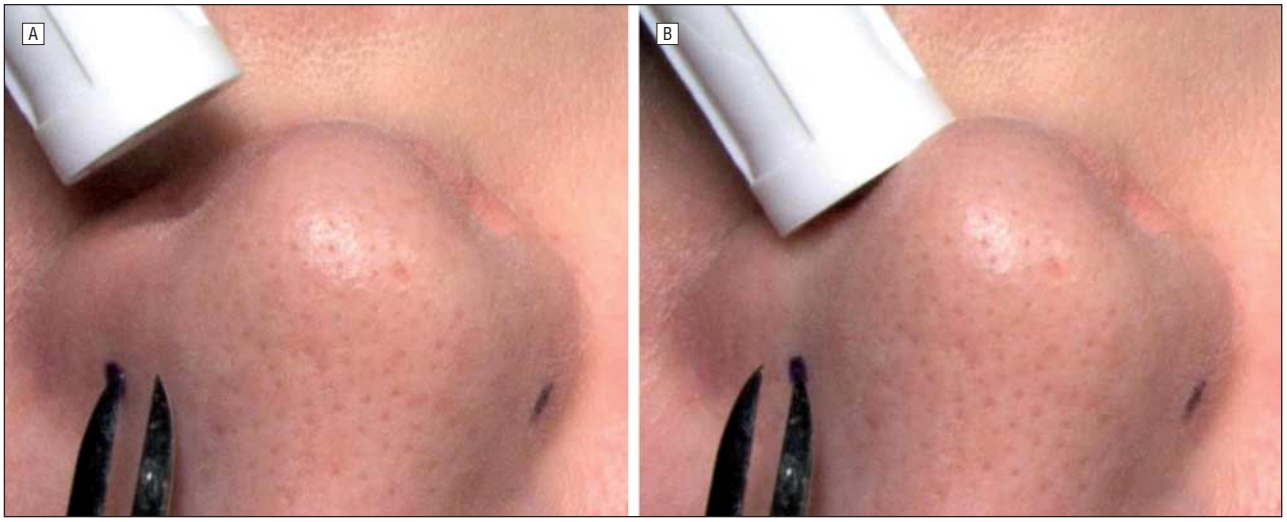

Figure 1. A patient who underwent external approach for septorhinoplasty (patient 19 in the Table). A, Preoperative location of the point of maximal depression without suction. B, Preoperative location of the point of maximal depression with suction applied. The deviation measured 3.5 mm using the calipers seen in the image.

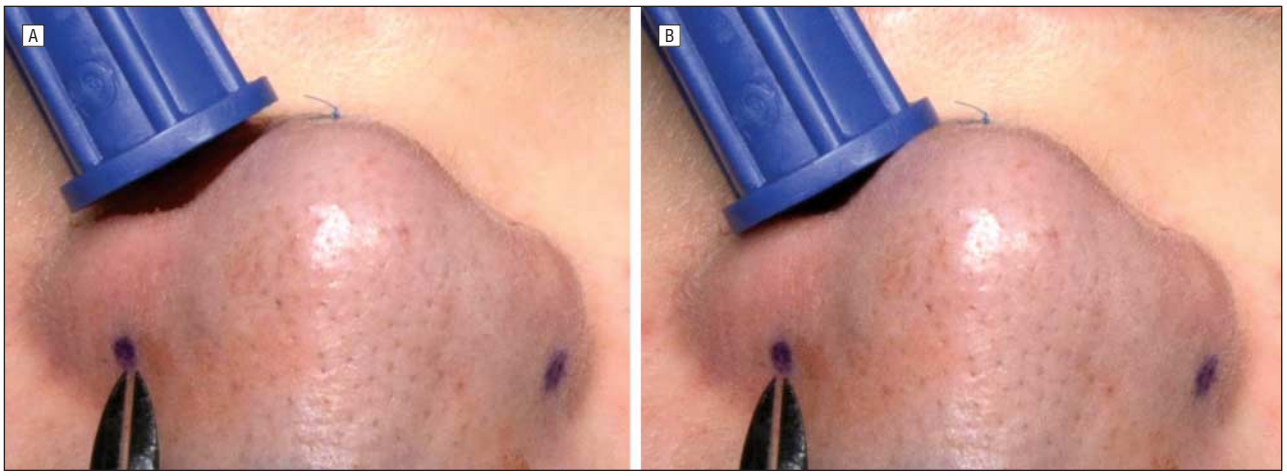

Figure 2. Same patient as in Figure 1 (patient 19). A, Postoperative image of the postoperative location of the point of maximal depression without suction. This is an intraoperative photograph using the same amount of negative pressure and new suction tubing. B, Postoperative location of the point of maximal depression with suction applied (patient 19). The deviation measured 0.5 mm using the calipers seen in the image.

nasal valve even with the closest application of the suction tubing before total circumferential contact. Having used this dynamic analysis during the year (2010-2011), we noted that properly placed alar batten grafts achieve the largest attenuation of the nasal valve collapse. These grafts are versatile for strengthening the nasal valve. The lateral edge should approximate the pyriform aperture to stent the airway. Other than that, the suction-assisted analysis will guide the surgeon as to where the body of the graft should lie, which is under the point of maximal depression. This makes placement easier for those with less experience with placement of this graft. The effect of the graft placement on the amount of depression was instantaneous, suggesting that alar batten grafts make the biggest difference in dynamic flow. When patients went from having a significant depression with suction to decreased or absence of deviation until circumferential contact with the suction tubing, we felt comfortable that the surgery would provide adequate support in the dynamic function of the internal nasal valve.

In 2 cases, as mentioned in the "Results" section (patients 14 and 16), we noted that just before alar batten graft placement, the integrity of the valve was markedly improved after performing cephalic turn-in flaps. We determined that the improvement was sufficient without alar batten grafts. These 2 cases demonstrated that the cephalic turn-in flap may provide enough support in some patients. We find that these patients typically have larger and thicker lateral crura, which create the optimal conditions for this type of flap having enough strength. Without the suction-assisted analysis, we may have not been able to objectively assess the strength of the internal valve and been confident in our choice to omit alar batten grafting. The suction assisted analysis is useful throughout the surgery to assess which maneuvers are providing strength and whether enough has been done to strengthen the valve.

This tool can also be helpful in the event that the surgeon did not assess the maximal point of deviation or lost his or her markings. During the surgery, the

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nose is wiped continuously, and these marks can be lost. The suction-assisted determination of point of maximal depression can solve this problem by providing an instantaneously available reminder of where the weakness lies.

It is important to note that there are inherent weaknesses in this study. The direction of airflow in the analysis is the reverse of natural inspiration. Nonetheless, when the suction is applied, the motion seen is identical to the effect of deep nasal inspiration seen in the same patients in the office. Therefore, we believe that the mechanical depression seen with the suction exhibits weaknesses that exist on deep inspiration. We also cannot know whether the negative pressure of the suction tubing is of physiologic magnitude and whether the amount of negative pressure correlates with actual inspiratory negative pressure. Another issue is that the nose is a 3-dimensional structure, and the maximal point of deviation does not occur in the coronal plane only. For longer noses with less sagittally oriented supra-alar crease, the degree of deviation is more than the amount measured in the coronal plane. In addition, septorhinoplasty changes the overall shape of the nose in a 3-dimensional fashion so that the valve position and orientation changes. In a twisted or deviated nose that has been straightened, the amount of deviation change may not be accurate. Furthermore, with septorhinoplasty and turbinate reduction, there is a change in the minimal cross-sectional area of the nose that changes the amount of pressure and thus movement, based on the Bernoulli principle. We cannot determine if the changes in movement are due to increased intrinsic nasal integrity or a change in cross-sectional diameter caused by maneuvers such as septoplasty. Future studies may help clarify how significant these potential confounding factors are.

However, while we measured deviation in the coronal plane using calipers for the study, intraoperative decisions were not based on these measurements taken in this 2-dimensional plane. The measurements were performed for the purpose of the study. The benefit of using this technique is being able to sense the amount of weakness using negative pressure and getting a feeling for how much integrity is gained with each maneuver. With the external technique, we would periodically place 1 central columellar suture to close the nose and observe the degree of deviation with negative pressure. This would give us a sense of its strength. We would then take this suture out and continue to work until we got a significant improvement in the strength of the valve witnessed by the suction technique.

In conclusion, we find suction-assisted analysis of the nasal valve to be an invaluable tool to help determine whether the techniques we use during surgery are actually helping improve the integrity of the nasal valve. This study found that maneuvers we used during septorhinoplasty had immediate effects on the integrity of the nasal valve. Further studies can help elucidate whether these maneuvers improve the strength of the nose in the long-term and should seek to correlate these findings with subjective long-term breathing function.

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Author Contributions: Dr Zoumalan had full access to all 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:* Zoumalan, Larrabee, and Murakami. *Acquisition of data:* Zoumalan and Murakami. *Analysis and interpretation of data:* Zoumalan. *Drafting of the manuscript:* Zoumalan and Murakami. *Critical revision of the manuscript for important intellectual content:* Zoumalan and Larrabee. *Statistical analysis:* Zoumalan. *Obtained funding:* Zoumalan. *Administrative, technical, and material support:* Zoumalan and Murakami. *Study supervision:* Zoumalan and Murakami.
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