

Anatomical Comparison of Minimally Invasive Nasal Valve Procedures

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Objective: To determine the quantitative effects of Z-plasty vs spreader grafts on nasal valve surface area.

Methods: Eight fresh cadaver heads were used that provided 16 total nasal valve procedures. Surgical sides were randomized, and Z-plasty was performed on 8 valves and endonasal spreader grafts were performed on 8 valves. The minimal cross-sectional area at the level of the nasal valve was measured preoperatively and postoperatively using acoustic rhinometry. We then compared Z-plasty and spreader grafts using a Wilcoxon signed rank test.

Results: The mean nasal surface area at the nasal valve before Z-plasty was 1.37 cm² (range, 0.39-2.25 cm²) and

after Z-plasty was 1.95 cm² (range, 1.08-2.62 cm²). The mean surface area at the nasal valve before spreader grafts was 1.15 cm² (range, 0.75-1.48 cm²) and after spreader grafts was 1.48 cm² (0.95-1.95 cm²). This correlates with a mean increase in the nasal valve surface area of 65% when Z-plasty was performed (95% CI, 28%-88%; $P = .007$) and 31% when a spreader graft was performed (95% CI, 15%-54%; $P = .01$).

Conclusions: Z-plasty and spreader grafts were shown to increase nasal valve surface area. Z-plasty seems to increase nasal valve surface area more than spreader grafts.

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IN THE EARLY 1920S, P. J. MINK BECAME the first physician to formally describe an anatomical region of intranasal narrowing in the nasal vestibule.¹ He termed this region the *nasal valve* and hypothesized it to be important in the regulation of airflow and turbulence through the nasal cavity. Since its discovery, continual efforts have been made to define the role of the nasal valve not only in normal nasal physiologic conditions but also in intranasal pathologic conditions. What Mink had previously described as a unified anatomical entity is widely accepted to be subdivided into 2 separate components: the internal nasal valve (INV) and the external nasal valve. The INV is contained in an area bounded by the upper lateral cartilage, the septum, the nasal floor, and the anterior head of the inferior turbinate. In this architecture exists a potential plane created between the septum and the caudal border of the upper lateral cartilage. The angle of this plane should be maintained at a minimum of 10° to 15° for optimal internal nasal patency.²

The INV region is the narrowest anatomical point in the nasal vestibule and, thus, presents the area of highest resistance. In fact, almost two-thirds of nasal airway resistance occurs in the INV. Nasal resistance, according to Poiseuille's law, is inversely proportional to the fourth power of the radius of the nasal passages. In turn, even small changes in the size of the nasal valve can have expo-

ponential effects on airflow resistance. During inspiration, negative pressure generated from pulmonary expansion is transmitted throughout the respiratory tract, including the INV. In healthy individuals, the rigid lateral walls of the nasal valve provide adequate intranasal integrity to maintain patency and prevent nasal valve collapse.³ However, some individuals experience ingression of the INV with inspiratory effort. In these patients, intranasal patency is lost, and varying degrees of nasal obstruction ensue. Collapse of the nasal valve is best explained by the Bernoulli principle that states that at the narrowest portion of a cylindrical tube, the velocity of flow is highest and the pressure is lowest. Thus, in compromised anatomical integrity, decreasing pressure gradients in the INV can cause ingression and collapse.⁴

It has been estimated that up to 13% of the population experiences some degree of nasal valve collapse.^{5,6} The structural integrity of the INV is maintained by a variety of different structures, including the aponeurotic system, muscle, cartilage, and the inferior turbinate.³ Disruption of any of these structures can lead to ingression and subsequent obstruction. Two separate surgical options exist for correcting INV collapse. One technique attempts to increase the nasal valve potential space. This can be done by nasal septal reconstruction and inferior turbinate surgery. The second surgical option aims to improve or restore the appropriate nasal valve angle. Techniques, such as spreader grafts,

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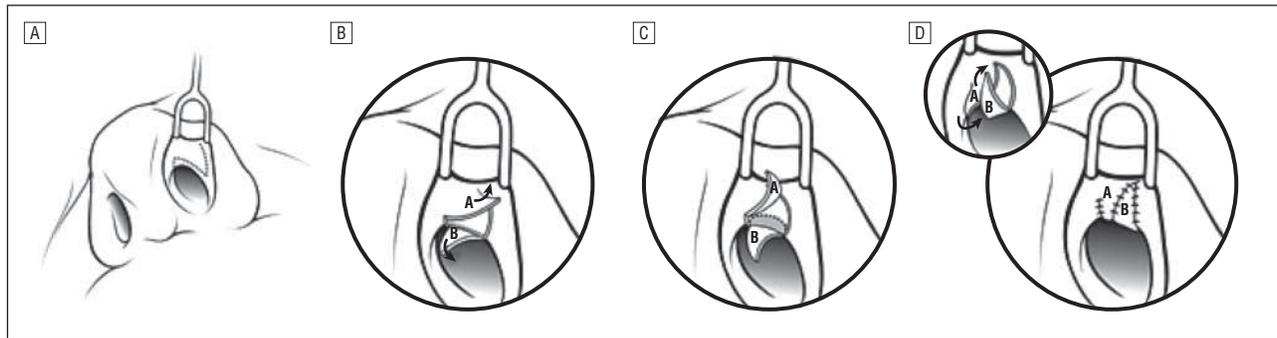


Figure 1. Intranasal Z-plasty procedure. A, The incisions are created such that the central incision is an intercartilaginous incision, and the side incisions are positioned such that the anterior flap will be medially based and the posterior flap will be laterally based. B, Triangular flaps A and B are then elevated. Note the underlying caudal border of the upper lateral cartilage. C, The caudal border of the upper lateral cartilage (shaded area) is then removed to make room for mobilization of flaps A and B. D, The flaps are then interdigitated and sutured into position.

Table 1. Intranasal Minimum Cross-sectional Surface Area Before and After the Z-plasty and Spreader Graft Procedures

Head	Surface Area, cm ²	
	Before	After
	Z-plasty	
1	0.39	1.08
2	2.25	2.48
3	1.99	2.13
4	1.40	1.82
5	1.74	2.62
6	0.98	1.76
7	1.11	2.11
8	1.06	1.59
Mean	1.37	1.95
	Spreader Graft	
1	0.75	0.95
2	1.50	1.60
3	1.23	1.43
4	1.48	1.71
5	1.09	1.95
6	0.87	1.01
7	1.20	1.62
8	1.06	1.60
Mean	1.15	1.48

Table 2. Percentage Change in Minimum Cross-sectional Surface Area Before and After the Z-plasty and Spreader Graft Procedures

Head	Change in Surface Area, %	
	After Z-plasty	After Spreader Graft
1	176	26
2	10	6
3	6	16
4	30	15
5	86	79
6	79	16
7	90	35
8	50	51
Mean (95% CI)	65 (28-88)	31 (15-54)
P value	.007	.01

first study, to our knowledge, to evaluate the effect of Z-plasty on the nasal valve surface area. This is also the first study to objectively compare Z-plasty with spreader grafts.

METHODS

CADAVERIC SPECIMENS

This study qualified for exempt status by the Rush University institutional review board under the Federal Regulations 45 CFR 46.102(f) definition of "Human Subjects." In conjunction with the Anatomical Gift Association of Illinois, the Rush University Department of Pathology provided 8 fresh, adult cadaver heads for this study. Before surgery, each cadaveric specimen underwent endoscopic examination of both sinus cavities. No evidence of previous procedures was noted in any of the specimens, and any preexisting septal deviation was corrected by submucous resection of deviated cartilage and bone.

SURGICAL TECHNIQUE

Preoperatively, cross-sectional surface area of the nasal valve was measured bilaterally in all 8 heads using acoustic rhinometry (Eccovision; Sleep Group Solutions Inc). The nasal cavities of each cadaveric head were then randomized, with one nasal cavity undergoing spreader graft and the contralateral nasal cavity undergoing Z-plasty.

The nasal valve procedures were performed by one of us (J.M.D.). The spreader graft technique used was first de-

flaring sutures, titanium-expanded polytetrafluoroethylene butterfly grafts, orbital suspension sutures, lateral battens, lateral crus pull-up, and alar expansion and reinforcement, have all been described as having a role in INV repair.⁷⁻¹² Of these options, spreader grafts have evolved to become the most accepted technique to improve the nasal valve angle. Not only have spreader grafts been shown to improve patient symptoms, but they have been documented, through cadaver studies, to objectively increase nasal surface area.^{13,14}

Recently, Z-plasty has been proposed as an alternative surgical technique for correction of nasal valve collapse. Z-plasty has been well described in the literature for scar revision and palatoplasty; however, it has only recently been documented as a method to assist patients in nasal valve collapse. It was recently shown that Z-plasty can subjectively improve patients' obstructive symptoms when used as an operative repair for nasal valve collapse.¹⁵ Despite this subjective improvement, no studies have objectively quantified the effect of Z-plasty on the nasal surface area. This is the

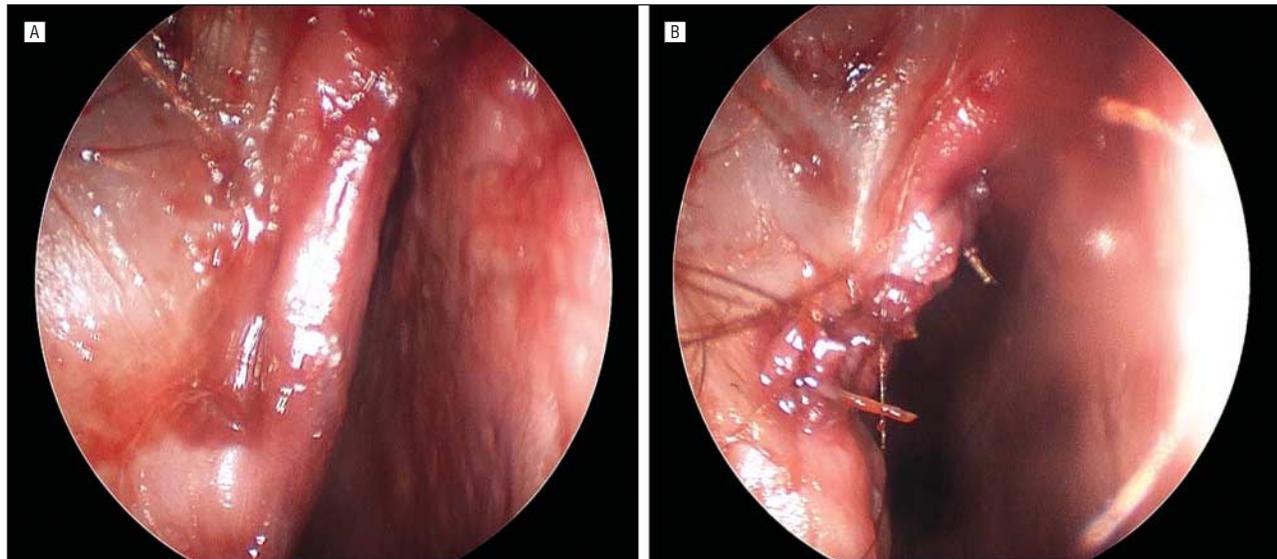


Figure 2. Endoscopic images of a nasal valve specimen before (A) and after (B) Z-plasty.

scribed by Sheen.¹⁶ Cartilage was harvested from the septum and was trimmed to measure $20 \times 2 \times 2$ mm. An incision was performed at the anterosuperior epithelium of the nasal cavity. A submucosal plane was dissected to the rhinion using iris scissors. The cartilage graft was placed in a submucosal plane between the upper lateral cartilage and the nasal dorsum, and 5-0 chromic sutures were used to approximate the incision.

The Z-plasty technique was performed as described by Dutton and Neidich.¹⁵ An intercartilaginous incision was made in the scroll region (the ridge formed where the caudal border of the upper lateral cartilage is overlapped by the lateral crus of the lower lateral cartilage). The Z-plasty incisions were then completed such that the anterior flap was medially based and the posterior flap was laterally based. The soft-tissue flaps were subsequently elevated. The caudal border of the upper lateral cartilage was identified and removed to make room to mobilize the Z-plasty flaps. The flaps were interdigitated and sutured into position using 4-0 chromic sutures (**Figure 1**). The apex of the anterior flap can be technically difficult to suture into the posterior flap donor site. This was addressed by passing a 6-0 nylon suture through the apex of the anterior flap and then passing it through the final destination (posterior flap donor site) before being passed through an external bolster. The suture was then passed back internally through the posterior flap donor site before being tightened. The postoperative cross-sectional surface area of the nasal valve was then measured bilaterally in all 8 heads using acoustic rhinometry.

STATISTICAL ANALYSIS

The Wilcoxon signed rank test was used to compare nasal valve cross-sectional areas for preoperative and postoperative values of spreader grafts and Z-plasty.

RESULTS

The mean surface area at the nasal valve before Z-plasty was 1.37 cm^2 (range, $0.39\text{-}2.25 \text{ cm}^2$) and after Z-plasty was 1.95 cm^2 (range, $1.08\text{-}2.62 \text{ cm}^2$). The mean surface area at the nasal valve before spreader graft placement was 1.15 cm^2 (range, $0.75\text{-}1.48 \text{ cm}^2$) and after spreader graft placement was 1.48 cm^2 (range, $0.95\text{-}1.95 \text{ cm}^2$)

(**Table 1**). A mean increase was noted in the nasal valve surface area of 65% when Z-plasty was performed (95% CI, 28%-88%; $P = .007$) and of 31% when a spreader graft was performed (95% CI, 15%-54%; $P = .01$) (**Table 2**).

A selection of before and after endoscopic images is provided for a subjective appreciation of Z-plasty's ability to improve nasal patency. Two separate specimens are presented (**Figure 2** and **Figure 3**).

COMMENT

The nasal valve is believed to be the narrowest portion of the human nose. Its size is approximately 1 to 2 cm^2 and is located 1 cm from the opening of the nasal cavity. When functioning correctly, the nasal valve is the primary regulator of airflow and gives the sensation of a patent nasal airway. However, given a variety of different physiologic and pathologic scenarios, the nasal valve can be obstructed, stenosed, or collapsible in certain situations. In such situations, surgical therapy has been shown to provide improved intranasal patency and increased minimum cross-sectional area. A consensus has not been reached regarding the exact surgical method that provides the greatest benefit to the patient. In turn, numerous cadaveric and clinical trials have occurred in the past, each hoping to better quantify the efficacy of each surgical approach.

In this study, we compared the Z-plasty and spreader graft techniques using a cadaveric model with an end-outcome measure of intranasal cross-sectional area. Comparisons of intranasal cross-sectional areas before and after the surgical procedure were statistically significant for both techniques. As given in Table 2, the change in mean cross-sectional area was more than 2 times greater using Z-plasty compared with using spreader grafts (65% vs 31%). This study suggests that in appropriate patients, Z-plasty provides a comparable, if not superior, alternative to spreader graft surgery for the treatment of INV collapse.

This study is not without limitations, most of which are inherent to the cadaveric experimental design. Given this

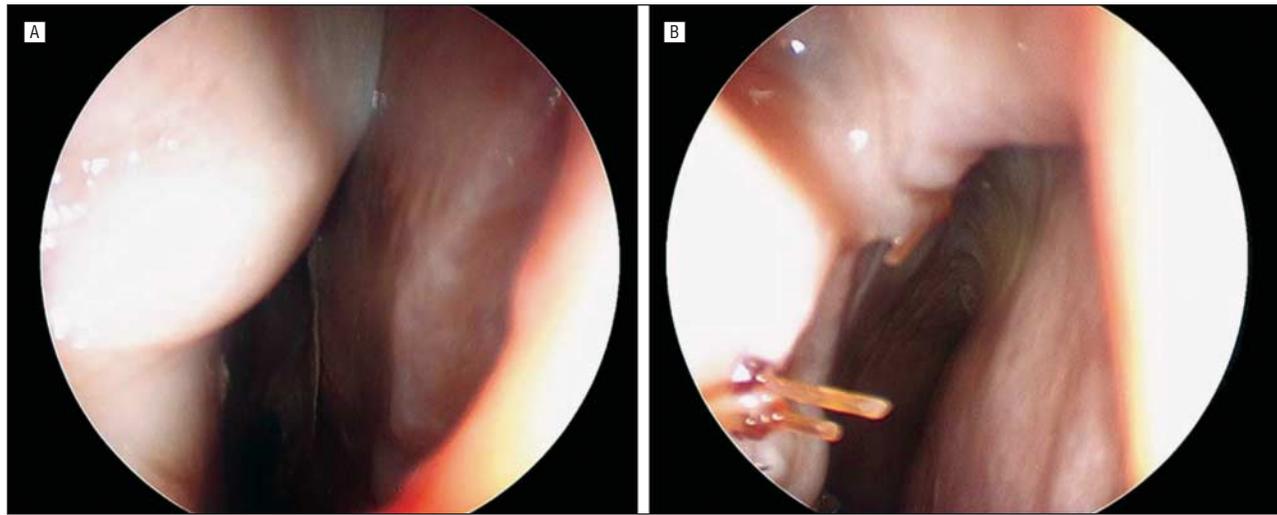


Figure 3. Endoscopic images of a nasal valve specimen before (A) and after (B) Z-plasty.

design, subjective clinical measures of success (nasal patency scores, aesthetics, and surgical complications) could not be evaluated. Furthermore, it is uncertain whether increased intranasal minimum cross-sectional area correlates with subjective improvement in nasal patency. Also, the preexisting level of nasal patency in each cadaver specimen is used only to calculate a percentage of overall change. In turn, both surgical techniques were performed on individuals who may or may not have had varying gradients of nasal valve collapse. Nevertheless, this study demonstrates the efficacy of Z-plasty in increasing nasal cross-sectional area. As mentioned previously, nasal valve collapse is a multifactorial problem with static and dynamic influences on INV structural integrity. Although these surgical approaches both addressed the static component of the pathologic disorder, the dynamic component can be neither assessed nor addressed owing to the cadaveric design of the research model.

With the study limitations in mind, we believe that the Z-plasty technique warrants not only future experimental explorations but also increased surgical implementation in the appropriate patient population. In the future, cadaveric studies will be performed comparing Z-plasty with alternative surgical therapies, such as suspending sutures. Such studies will provide greater insight into the advantages and limitations of the Z-plasty technique. At the moment, however, the present study provides data indicating that Z-plasty is a viable alternative for the surgical correction of nasal valve collapse.

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script: Weeks, Walker, and Dutton. *Critical revision of the manuscript for important intellectual content:* Weeks and Dutton. *Administrative, technical, and material support:* Weeks and Dutton. *Study supervision:* Weeks and Dutton. **Financial Disclosure:** Dr Dutton has been a consultant for Acclarent and GlaxoSmithKline.

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