Importing surgical change to the nasal tip remains one of the most challenging aspects of rhinoplasty. The surgeon must assess the tip preoperatively and execute the necessary maneuvers to impart the desired change.

Objectives
To assess nasal tip resistance to compression in a cadaveric model before and after specific rhinoplasty maneuvers using a novel method.

Design, Setting, and Materials
Open rhinoplasty maneuvers were performed at an academic tertiary care center on 6 fresh-thawed cadaver heads. Assessment of tip support was performed with a motorized, computer-controlled test stand equipped with a digital load cell. Tip support was assessed by compression to a depth of 2.5 mm from contact both preoperatively and after each surgical maneuver. All force data were recorded in pound-force and converted to newtons (N) following analysis.

Main Outcomes and Measures
Nasal tip support, measured as resistance to compression, before and after various rhinoplasty maneuvers.

Results
Following the elevation of the skin–soft-tissue envelope with septrhaphy, resistance to compression (1.82 N) was not significantly different from the preoperative assessment (1.60 N for all specimens). Tip support following placement of a caudal extension graft was significantly different from all other conditions (3.16 N; P < .01), showing support increased by more than 66% from preoperative assessment. Placement of columnar strut (1.28 N) did not show significant increase in tip support. Tip support was decreased slightly after placement of intradomal sutures, which was significant (1.22 N; P < .01).

Conclusions and Relevance
This study demonstrates the use of materials testing equipment to assess and quantify change in tip support after several rhinoplasty maneuvers. Minor supporting maneuvers that rely on healing and scar do not significantly alter tip support in a cadaveric model. Caudal extension graft is an important maneuver imparting significant effect on nasal tip support.

Level of Evidence
NA.

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Others have sought to more accurately and reliably quantify tip support and changes after surgical maneuvers. Beaty et al.\(^6\) were able to quantify changes in the support of the tip before and after surgery using a custom-designed instrument to measure deflection of the tip in multiple vectors. Nasal deformation was observed as increasing weight was applied to the nose. In addition, Gassner and colleagues\(^7\) used a novel device to construct a force-deformation curve by measuring resistance to compressive force at 5 anatomic locations with an electronic force transducer. Both studies used grams (g) to measure force applied and measured the degree to which various structures were altered on compression. Dobratz and colleagues\(^8\) later used a tip compression device weighted in 5-g increments measuring displacement at each increment. Their work demonstrated fewer millimeters of displacement per weight increment with caudal extension grafting or tongue-in-groove technique than either columellar strut grafting or suture technique.

In the present study, the goal was to demonstrate the feasibility of tip support testing using materials testing machinery and to quantify change in nasal tip support following commonly performed rhinoplasty maneuvers.

**Methods**

Approval for this study was granted by the San Antonio Military Medical Center (SAMMC) institutional review board. A grant supplied by SAMMC Department of Clinical Investigations was used to purchase supplies.

Six fresh-thawed adult cadaver heads were used as subjects. Nasal structures were deemed usable for the study prior to inclusion, and none of the specimens had undergone prior surgery. Each subject served as its own control for the study undergoing the following procedures in succession: elevation of the skin–soft-tissue envelope (S-STE) and septoplasty via hemitransfixion incision, dome sutures after anterior septal angle exposure, floating columellar strut graft, and batten-style caudal extension graft secured to the medial crura in a tongue-in-groove fashion.

Each subject supplied autologous cartilage for grafting. Grafts were sutured into position with 5-0 Prolene suture (Ethicon Inc), and the cadaveric S-STE was closed with 6-0 Prolene suture prior to taking force measurements following each procedure. Preoperatively and after each procedure, the nasal tips were compressed in a single vector. Force data were collected on a Lloyd LRX computer-driven motorized test stand (Figure 1) equipped with a 50-newton (N) load cell (Lloyd Materials Testing) to a fixed depth of 2.5 mm from the point of first contact (as detected by the load cell). The subject heads were oriented as shown in Figure 2. Assessment of each condition was completed in triplicate.

A custom cradle was used to ensure that the head orientation remained stable during compression. Force data were collected in pound-force units. Data were grouped at preselected compression intervals of 0.5 mm, 1.0 mm, 1.5 mm, 2.0 mm, and 2.5 mm. Consolidated data were subjected to 2-factor analysis of variance using SPSS software, version 22 (IBM). Post hoc Hyunh-Feldt epsilon testing was performed. Final data were converted to newtons for ease of discussion and comparison.

**Results**

Following the elevation of the S-STE with septoplasty (median force, 1.82 N), there was no significant difference from
Tip support following placement of a caudal extension graft was significantly different from all other conditions (median force, 3.16 N; \( P < .01 \)), giving a mean 66.7% increase in resistance to compression vs preoperative assessment.

Placement of a columellar strut via caudal pocket placement, as opposed to anterior septal angle approach, did not show significant change in tip support compared with preoperative assessment (median postoperative force, 1.28 N). The careful creation of a caudal pocket for the columellar strut does not disrupt tip-supporting structures, in contrast to the anterior septal angle approach.

Tip support was decreased slightly but significantly after placement of intradomal sutures (median force, 1.22 N; \( P < .01 \)), showing a mean 24.9% decrease in resistance to compression. Force to compress across subjects for each condition is shown in Figure 3 along with range of values. Figure 4 depicts the force vs deflection curves for each procedure averaged across the subjects.
Discussion

The factors affecting the support of the nasal tip are a complex interplay of the cartilaginous skeleton, bony base, and fibrous attachments. The structure of the cartilaginous skeleton resists forces of compression that converge on it from many vectors. Clinically, the tip seems to function as a sum of its parts in resisting the forces of compression, projecting upward against downward forces. As individual aspects of support become compromised, potential energy of the tripod is lost, as is ability to resist displacing forces. During surgical correction for cosmesis or functional reasons, support compromise should be recognized by the surgeon and corrected.

There have been few reports quantifying nasal tip support in a scientific manner. Those few have used compression devices to obtain measures of distortion with compression at various nasal structures. The present study differs from those previously performed in that the dependent variable measured was the force of resistance to compression. In light of this, a fixed compression depth, clinically similar to gentle finger compression of the tip, was assigned. The Lloyd test stand allowed for precise compression to 2.5 mm measured by the computer-driven arm, with an extension resolution of less than 0.1 μm. The load cell measures the force of resistance to compression and can be resolved to less than 0.1 μm. The load cell could detect contact with the nasal tip by only a small displacement. The device was configured such that the load cell could detect contact with the nasal tip by only a small change in force applied, thus allowing the depth of compression to be very accurate and easily repeatable. This test is similar to the finger compression test in that as compressive force is applied, the physician, or in this case the load cell, assesses the resistance of the tip to gauge the intrinsic supportive strength. In this study a clinical correlate group was not used.

The elevation of the S-STE did not produce a significant reduction in support, which corroborates prior reports. This finding, however, differs from the results reported by Dobratz et al., who found that tip support was lost after S-STE elevation, likely due to division of the interdomal ligament and attachment of the crura to the caudal septum. Based on prior work it is accepted that this fibrous structure, not a true ligament, serves as a minor tip-supporting mechanism, while the medial footplate attachment to the caudal septum serves as a major element of support. The present study design attempted to carry out assessment of the S-STE elevation with little disruption of ligamentous attachments and included an “L-strut” conserving septoplasty, which was performed via a hemitransfixion incision instead of anterior septal angle approach. By preserving these structures intact, we found no significant loss of tip support after the nose was opened. This suggests that careful S-STE elevation without disruption of supporting structures does not significantly alter tip resistance to displacement.

The use of a columellar strut graft is a common method of increasing tip support either in a deficient nose or one where support has been altered, as in the repair of caudal septal abnormality. In the cadaveric model, this technique has not been proven to increase tip support, either in the present or prior studies. The columellar strut is a graft that was originally described positioned above the anterior nasalspine and modified by others to abut it. Placement above the spine can prevent unwanted “clicking” or malpositioning as the graft interacts with the spine. In the present model, mattress sutures were placed to secure the graft to the medial crura. The aim was to disrupt as little of the intercrural liga ment as possible so as not to disrupt the attachment of the lower lateral cartilages from the caudal septum between the anterior and posterior angles. This was achieved by creating a small pocket caudal to the most caudal aspect of the septum that did not completely divide the medial crura. This was preferred over the anterior septal angle approach, which requires disruption of the intercrural attachments, a native supporting mechanism. In spite of this, a 16% decrease in tip support (P = .35) vs the preoperative assessment was noted using this technique. This suggests that even during careful and meticulous dissection, there is likely to be inadvertent disruption of soft-tissue attachments that impart stability to the tip architecture and make up one of the classic major tip-support mechanisms. In addition, the healing fibrosis postoperatively likely contributes substantially to the effectiveness of this graft. This fact is evidenced by previous clinical data showing no appreciable change over time in tip support when a columellar strut graft was used.

The caudal extension graft was found to create the greatest increase in tip support. It recreates a major tip-supporting mechanism normally made up of fibrous tissue with cartilaginous graft and suture. Suture fixation to the caudal septum and the medial crura provides multiple fixation points, which directly contribute to tip support. Logically, a medial crural setback creates a very similar level of support and thus has been used when excellent support is required in the setting of a hanging columella. When the columella is retracted, an extension graft provides the desired cosmesis and the robust support required. The caudal extension graft may be sutured to the periosteum of the maxillary crest to maintain a midline position and stabilize the graft further. Cosmetically, this graft can help to correct asymmetry of the caudal-alar-columellar relationship. Use of a tongue-in-groove technique has been demonstrated to correct alar-columellar disproportion and is a useful tip-supporting maneuver. Careful attention should be directed preoperatively to assess for maxillary cant, malocclusion, and midlines so that an appropriate graft can be selected intraoperatively when the need arises.

In addition, stability of the lateral crura of the lower lateral cartilages contribute both to tip support and external valve support. However, previous work has found that quantifiable tip support is not lost until 80% of the lateral crura has been resected. This suggests inequality in the

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dynamic contribution to overall support of the tip. These structures may be augmented by suture and or grafting techniques to add strength, as in alar turn-in flaps.Interestingly, postoperative increase in the alar support has been noted without a grafting procedure following open rhinoplasty technique.7 The same study also reported no significant difference using their alar grafting technique between treatment group and controls. This suggests a significant fibrotic effect postsurgically that contributes to alar support. This concept is further supported in the work performed by Beaty,6 showing a 35% larger decrease in tip support in those patients undergoing secondary rhinoplasty vs primary after S-STE elevation only.

We acknowledge a few limitations of this study. Owing to financial constraints, only 6 cadaveric heads were procured. To maximize sensitivity, multiple assessments were performed, but nonetheless, the number of subjects is still relatively small. This study did not use clinical correlates owing to the nature of the device used to support this tip. This perhaps weakens the evidence presented in that we are uncertain how the surgical techniques demonstrated herein perform in vivo. Prior research based on static photographic measurements suggests that support of the tip can be maintained with any of the studied techniques.8

Conclusions

Understanding the fundamentals of tip support is a prerequisite to obtaining an excellent functional and aesthetic outcome in rhinoplasty. When support mechanisms are compromised in the course of surgery, the surgeon should have a plan to correct these deficiencies. Preoperatively, assessment of the intrinsic support and makeup of the cartilaginous frame can help anticipate and plan for such situations. Those noses that show strong medial crura will tend to be more resistant to forces that threaten postoperative projection.10 When choosing a support-restoring technique, one should also consider the secondary effects so as to meld the functional and aesthetic outcomes. This is exemplified by the tongue-in-groove technique, which confers tip support and corrects a hanging columella. Compare this with the caudal extension graft, which can correct retracted columella and also provide significant support.8,10 The present study uses a novel method of support assessment that is reproducible and accurate, using digital force assessment in conjunction with a computer-controlled test stand. Under these conditions the caudal extension graft technique provided the greatest support when tested under compressive forces. Use of similar materials testing equipment may prove valuable in the study of surgical procedures in a cadaveric model.