The Quantification of Surgical Changes in Nasal Tip Support

Mark M. Beaty, MD; Wallace K. Dyer II, MD; Matthew W. Shawl, MD

Objectives: To quantify the changes in the strength of nasal tip support associated with various surgical modifications and to identify the procedures that best maintain or augment tip support.

Design: Case study in 2 phases. Phase 1 included 10 patients undergoing primary rhinoplasty, 5 undergoing secondary rhinoplasty, and 5 control patients. Fresh cadavers were used in phase 2. A purpose-built instrument (Beaty Tensegrometer; G. M. Tooling, Chamblee, Ga) was used to measure nasal tip support before and after surgical modifications.

Results: In the patients who underwent primary rhinoplasty, there was a 25% decrease in tip support when the ligamentous attachments between the lateral crura were divided. Reconstruction of these attachments increased tip support over baseline by 35%. With a columellar strut and ligament reconstruction, tip support was increased by 44%. In the secondary rhinoplasty group, reconstruction with the dynamic adjustable rotation tip-tensioning technique increased nasal tip support over baseline by 70%. In cadavers, intercartilaginous incisions and delivery of the lower lateral cartilages caused a loss of tip support, while raising the skin–soft tissue envelope with the open technique did not. Extensive resection of the lower lateral cartilages caused a loss of tip support.

Conclusions: This study demonstrates that nasal tip support can be reliably quantified in a reproducible manner. Use of the open approach, reconstruction of the attachments between the lateral crura, conservative resection of the lower lateral cartilages, and the dynamic adjustable rotation tip-tensioning technique for secondary rhinoplasty best preserve nasal tip support.

Arch Facial Plast Surg. 2002;4:82-91

Surgical Modification

SURGICAL MODIFICATION of the complex architecture of the nasal tip is the most challenging aspect of rhinoplasty. Numerous clinical descriptions of nasal tip support and surgical methods for tip modification have been proposed. Surgical modifications that reshape the nasal tip affect the strength of its architecture. Maintenance or augmentation of the architectural strength of the nasal tip is necessary to achieve desired aesthetic and functional results.

Clinical evaluation of nasal tip support by finger palpation of its resistance to deformation is a routine part of the diagnostic workup for rhinoplasty. In Rhinoplasty: The Art and the Science, Tardy states that “pressure applied to the tip with the index finger will be helpful in determining the resistance to tip retrodisplacement and the degree of recoil and forward thrust of which that particular tip is capable.” Surgeons may subjectively evaluate preoperative and postoperative nasal tip support with finger palpation. However, to our knowledge, objective changes in nasal tip support after surgical modification have never been quantified in the literature.

Our goal was to quantify changes in nasal tip support before and after common rhinoplasty modifications. Objective quantification of these changes will provide valuable information to guide modification of the nasal tip.

Nasal Tip Support

Tardy described nasal tip support mechanisms in major and minor groups (Table 1). These designations were determined by clinical experience and are currently accepted as the determinants of nasal tip support. Surgical alteration of these tip support mechanisms produces changes in the shape and function of the nasal tip. Selection of the appropriate surgical modification is determined by the desired effect, such as a change in tip rotation, projection, or width.
MATERIALS AND METHODS

One of us (M.M.B.) designed a device (Beaty Tensegrometer; G. M. Tooling, Chamblee, Ga) that is capable of measuring the resistance of the nasal tip to deformation in multiple vectors (Figure 2). This measure of resistance to deformity is a quantification of the subjective finger palpation that was advocated by Tardy. Instrument calibration was performed at 1-month intervals to ensure that no fatiguing of the springs had occurred. No significant changes in calibration were found during the study period. During calibration trials, each data point was independently measured 3 different times to evaluate the projected intertrial error of the device. Interttrial variation in these measurements was less than 3%.

Tightening of the thumbscrew at the crown of the gantry increased compression on a spring, applying pressure to the nasal tip along the chosen vector. Deflection of the tip was measured in millimeters along the attached scale at the side of the gantry. The compression necessary (in grams) to deflect the nasal tip by 1, 2, or 3 mm in each vector was recorded (Table 2). Compression of the tip beyond 3 mm resulted in the crural architecture pushing against the nasal septum, with further measurement reflecting resistance of the septal cartilage.

The device was stabilized on the upper lip and malar eminence, with the measurement gantry centered over the nasal tip. The measurement gantry was oriented along the vector to be evaluated. Three vectors were evaluated: (1) along the columella, (2) along the nasal dorsum, and (3) along the plane of the lateral crura. Measurements were taken before, during, and immediately after surgery.

The study comprised 2 phases. In phase 1, tip support was measured in live patients; in phase 2, cadavers were studied. The results were statistically analyzed with a commercially available software package (Excel; Microsoft Corp, Redmond, Wash) by comparing group means using 1-way analysis of variance or paired t test, as appropriate.

PHASE 1

The first phase of the study included 5 nonsurgical control patients and 15 surgical patients. Of the 15 surgical patients, 10 underwent primary nasal surgery and 5 underwent secondary rhinoplasty. All tip modifications were performed through an open approach.

During phase 1, measurements were taken before and after the following procedures: surgical incisions (marginal and transcolumellar), opening of the skin–soft tissue envelope (S-STE), placement of a columellar strut, reconstitution of the intercrural ligament, and performance of the DARTT technique. Preoperative and postoperative measurements were taken with the S-STE intact, and intraoperative measurements were taken directly on the cartilaginous framework.

PHASE 2

In the second phase of the investigation, 15 fresh cadavers were studied. Each cadaver was inspected to ensure that no significant nasal damage was present. They were divided into groups of 5 for evaluation of different surgical modifications. Cadavers were used for more than 1 evaluation when appropriate. For example, noses used to measure the effects of open technique exposure were also used to evaluate the effect of suture reconstitution of the intercrural ligament.

During phase 2, measurements were taken before and after the following procedures: surgical incisions (intercartilaginous, transfixion, marginal, and transcolumellar), opening of the S-STE, crural modifications, placement of a columellar strut, and reconstitution of the intercrural ligament.

Differences between the open and closed approaches to the nasal tip were analyzed for changes in support. Two different methods for lateral crural modification were evaluated. First, cephalic strips of crural cartilage were resected from medial to lateral (Figure 3). Second, cartilage was resected from lateral to medial, progressively truncating the crus (Figure 4). Twenty percent of the volume of the lateral crus was resected at a time before each measurement. Data were recorded on the effect of suture reconstitution of the midline intercrural ligament (Figure 5). Effects of each surgical modification were measured along the 3 vectors previously described.

Anderson3 compared the nasal tip architecture to a tripod in 1969. According to his analogy, the medial crura of the lower lateral cartilages (LLCs) together form the central limb of the tripod. Each lateral crus independently forms a lateral limb. Anderson’s description of nasal tip support mechanisms emphasizes the importance of the extensive ligamentous attachments between the crural cartilages. Tardy’s description emphasizes the importance of the interdomal portion of these ligamentous attachments.

NASAL TIP MODIFICATION

Anderson and Ries5 described nasal tip modification by altering the components of the tripod: “Tip projection can be decreased by destroying the supports of the tripod or by shortening its legs. The main supports are destroyed by interrupting the ‘ligaments’ connecting the medial ends of the lateral crura, by lowering the projection of the septal dorsum, and by excising cartilage from the region of the inferior septal angle.” Anderson3 also believed that reconstitution of the ligamentous attachments between the lateral and intermediate crura was necessary to restore the strength of the nasal architecture.

<table>
<thead>
<tr>
<th>Major Group</th>
<th>Minor Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size, shape, and resilience of the lower lateral cartilages</td>
<td>Dorsal septum</td>
</tr>
<tr>
<td>Attachment of the medial crural footplate to the caudal septum</td>
<td>Interdomal ligaments</td>
</tr>
<tr>
<td>Scrolled attachment of the cephalic margins of the lower lateral cartilages to the caudal margin of the upper lateral cartilages</td>
<td>Membranous septum</td>
</tr>
<tr>
<td>Attachment of the lower lateral cartilages to the skin–soft tissue envelope</td>
<td>Anterior nasal spine</td>
</tr>
<tr>
<td>Lateral crural attachment to the pyriform aperture</td>
<td>Attachment of the lower lateral cartilages</td>
</tr>
</tbody>
</table>

Table 1. Nasal Tip Support Mechanisms

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Many surgeons prudently believe that conservative surgery is essential to successful modification of the nasal tip. The open rhinoplasty approach, popularized by Anderson and Johnson and Toriumi, advocates wide exposure of the nasal tip architecture, with minimal violation of tip support mechanisms. This approach contrasts with the closed or delivery approach, in which exposure of the cartilage framework is limited and incisions violate significant tip support mechanisms.

Conservative methods of LLC modification using the open approach have been described. Kridel and Konior introduced the lateral crural overlay to achieve cephalic rotation of the tip without permanent division of the lateral crus. They also advocated conservative removal of cephalic strips to narrow and cephalically rotate the nasal tip. Kridel and Konior described the “lateral crural steal” for management of the underprojected nasal tip and the “domal truncation procedure” for management of the overprojected tip. Suture support of the domes has also been advocated by Tardy, McCollough and English, Tebbets, Baker, and Perkins et al. The common thread of their techniques is conservation of nasal tip support.

Johnson and Toriumi emphasize both surgical conservation and augmentation of nasal tip support in Open Structure Rhinoplasty. They advocate placing a columellar strut between the medial crura for increased nasal tip projection and support. This strut is routinely fashioned from septal cartilage and is often combined with a shieldlike tip graft to project and refine the nasal tip.

We also advocate the concepts of conservatism and augmentation of support for tip rhinoplasty. In cases of primary rhinoplasty, we use the open approach to obtain maximal exposure and minimal interruption of tip support. Refinement of the nasal supratip is accom-
plished by excising conservative cephalic strips and reconstituting the ligamentous attachments between the medial and lateral crura (the intercrural ligament)\textsuperscript{14} (Figure 1). Reestablishment of the intercrural ligament significantly augments nasal tip support. If additional tip projection or support is necessary, a columellar strut is placed.

The cartilage and supportive ligaments of patients undergoing secondary rhinoplasty have often been severely weakened. The lateral crura and scrolls are frequently overresected or absent, and the domes are often malpositioned by scar contracture. This type of injury typically results in decreased tip projection, cephalic over-rotation, and associated nasal valve collapse. This triad of findings has been termed a porcine deformity\textsuperscript{15} and presents a significant reconstructive challenge. Dyer and Yune\textsuperscript{15} describe the dynamic, adjustable, rotation tip-tensioning (DARTT) technique, a method of nasal reconstruction that reestablishes tensile support of the damaged nasal architecture. The DARTT technique allows precise selection of nasal tip projection, rotation, and correction of nasal valve collapse.

### RESULTS

#### PHASE 1

Fifteen patients who underwent rhinoplasty (10 primary, 5 secondary) were evaluated for nasal tip support before, during, and immediately after surgery. Each procedure was tailored to the needs of that specific patient and performed through an open approach. Three vectors were evaluated: (1) along the columella, (2) along the nasal dorsum, and (3) along the plane of the lateral crura. The vector along the plane of the lateral crura was chosen as the representative measure of tip support because it combines components of both projection and rotation. The following results are based on measurements that were taken along that vector, except where noted.

**Preoperative Measurements**

Measurements of nasal tip support in 5 control patients compared with preoperative patients undergoing primary or secondary rhinoplasty revealed no significant differences in any vector. In all groups, there was slightly greater tip support in the vector along the columella, compared with the other 2 vectors. This finding may indicate that there was slightly greater support along the vector of the paired medial crura. Mean values for each group are summarized in Table 2.

<table>
<thead>
<tr>
<th>Vector</th>
<th>Group</th>
<th>1 mm</th>
<th>2 mm</th>
<th>3 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lateral crura</td>
<td>Control</td>
<td>33.32</td>
<td>56.26</td>
<td>77.24</td>
</tr>
<tr>
<td></td>
<td>Primary rhinoplasty</td>
<td>30.80</td>
<td>53.69</td>
<td>79.93</td>
</tr>
<tr>
<td></td>
<td>Secondary rhinoplasty</td>
<td>27.26</td>
<td>46.72</td>
<td>68.70</td>
</tr>
<tr>
<td>Columella</td>
<td>Control</td>
<td>35.54</td>
<td>61.24</td>
<td>89.40</td>
</tr>
<tr>
<td></td>
<td>Primary rhinoplasty</td>
<td>36.53</td>
<td>61.80</td>
<td>86.33</td>
</tr>
<tr>
<td></td>
<td>Secondary rhinoplasty</td>
<td>30.13</td>
<td>54.57</td>
<td>81.67</td>
</tr>
<tr>
<td>Dorsum</td>
<td>Control</td>
<td>29.42</td>
<td>50.70</td>
<td>70.92</td>
</tr>
<tr>
<td></td>
<td>Primary rhinoplasty</td>
<td>31.94</td>
<td>53.14</td>
<td>74.79</td>
</tr>
<tr>
<td></td>
<td>Secondary rhinoplasty</td>
<td>28.56</td>
<td>44.54</td>
<td>62.24</td>
</tr>
</tbody>
</table>

Figure 3. Technique of cephalic strip resection.

Figure 4. Technique of lateral crural truncation.
Elevating the S-STE

In all cases, elevating the S-STE reduced tip support. Paired t tests showed significant differences in nasal tip support before and after elevation of the S-STE in both primary and secondary rhinoplasty groups (P<.05).

In patients undergoing primary open rhinoplasty, the mean nasal tip support was reduced by 20%, 26%, and 20% at 1, 2, and 3 mm of deflection, respectively, by elevating the S-STE (P<.05). Patients undergoing secondary open rhinoplasty had even greater losses in tip support when the S-STE was opened, with mean reductions of 64%, 61%, and 52% at 1, 2, and 3 mm of deflection, respectively (P<.05).

Reconstructing the Intercrural Ligament

In primary open rhinoplasty, elevating the S-STE in a bloodless plane above the crural cartilages disrupted the intercrural ligament from the domes to the septal angle (25% loss of support). Reconstituting the intercrural ligament (Figure 5) provided an increase in tip support over baseline of 35%, 24%, and 24% at 1, 2, and 3 mm of deflection, respectively (P<.05).

Columellar Strut

Patients in the primary open rhinoplasty group were evaluated for changes in tip support after columellar strut placement. Placement of a columellar strut alone provided a 40% increase in nasal tip support in the vector along the columna (P<.05). In the vectors along the nasal dorsum and along the plane of the lateral crura, however, no significant difference was found (P = .15). Also, when intercrural fixation sutures were used in combination with a columellar strut (4 patients), the increase in support was even more pronounced (27%, 42%, and 44%, respectively) (P<.05).

DARTT Technique

Reconstruction in patients undergoing secondary rhinoplasty was performed using the DARTT technique described by Dyer and Yune15 (Figure 6). These patients had a statistically significant increase in the strength of the cartilaginous nasal tip architecture after reconstruction (P<.01). Mean increases of 364%, 208%, and 213% were seen at 1, 2, and 3 mm of deflection, respectively. These measurements were taken intraoperatively, directly on the cartilaginous architecture before the S-STE was redraped.

Postoperative Measurements

Finally, all patients were evaluated for changes in tip support from the preoperative to the immediate postoperative state with the S-STE replaced. In the primary rhinoplasty group, nasal tip support was increased 30% over baseline in all 3 vectors. In the secondary rhinoplasty group, the tip support was increased 70% over baseline in all 3 vectors. All these changes were statistically significant (P<.05). A summary of preoperative vs postoperative tip support is provided in Table 3.

PHASE 2

Elevating the S-STE

The effect of the open rhinoplasty technique on tip support was measured on cadavers. Tip support was measured after marginal and transcolumellar incisions were made and the S-STE was elevated. During phase 2, care was taken to preserve the intercrural ligament as the S-STE was elevated. Support measurements were taken with the S-STE elevated and the intercrural ligament intact. Elevation of the S-STE caused no significant change in tip support (P = .11).
Closed Approach Incisions

The effect of the closed (transnostril) approach on tip support in cadavers was then evaluated. Placement of marginal and transfixion incisions had no effect on tip support. After intercartilaginous incisions, tip support decreased 25% in all 3 vectors. The LLCs were delivered and then replaced in their native position with no further modification. Delivery of the LLCs resulted in a 10% further loss of tip support (35% total) in vectors along the plane of the lateral crura and along the columella. A 42% loss of support was seen in the vector along the nasal dorsum. All these differences were statistically significant (P < .05) and are summarized in Table 4.

Intercrural Ligament Reconstruction

In 5 noses, after the closed technique with delivery of the LLCs was used (alone resulting in a 35% loss in tip support), a transcolumnellar incision was made and the S-STE

Table 3. Percentage Increase in Nasal Tip Support After Procedure*

<table>
<thead>
<tr>
<th>Group</th>
<th>Vector</th>
<th>1 mm</th>
<th>2 mm</th>
<th>3 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>LC</td>
<td>40</td>
<td>26</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Columella</td>
<td>31</td>
<td>38</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td>Dorsum</td>
<td>31</td>
<td>29</td>
<td>29</td>
</tr>
<tr>
<td>DARTT</td>
<td>LC</td>
<td>84</td>
<td>73</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td>Columella</td>
<td>109</td>
<td>68</td>
<td>60†</td>
</tr>
<tr>
<td></td>
<td>Dorsum</td>
<td>64</td>
<td>74</td>
<td>71</td>
</tr>
</tbody>
</table>

*DARTT indicates dynamic adjustable rotation tip-tensioning technique; LC, lateral crura.
†Not statistically significant.

Table 4. Percentage Decrease in Nasal Tip Support After Procedure*

<table>
<thead>
<tr>
<th>Maneuver</th>
<th>Vector</th>
<th>LC</th>
<th>Columella</th>
<th>Dorsum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open S-STE</td>
<td>−3</td>
<td>−3</td>
<td>−5</td>
<td></td>
</tr>
<tr>
<td>IC incision</td>
<td>−27</td>
<td>−20</td>
<td>−26</td>
<td></td>
</tr>
<tr>
<td>Delivery of LLC</td>
<td>−34</td>
<td>−33</td>
<td>−42</td>
<td></td>
</tr>
</tbody>
</table>

*S-STE indicates skin–soft tissue envelope; IC, intercartilaginous; LLC, lower lateral cartilage; and LC, lateral crura.
was elevated. This effectively converted the procedure into a “standard” open rhinoplasty approach. The intercrural ligament was then reconstructed with sutures, and tip support was measured. Tip support increased 25% in the vector along the plane of the lateral crura compared with preoperative measurements (P<.05). Tip support was equivalent to the preoperative levels in the vectors along the columella and nasal dorsum.

Crural Modifications

Cephalic strips were taken from medial to lateral in 5 noses through a closed approach. Serial measurements were taken after resection of increments of 20% from the total width of the lateral crus. Tip support did not change beyond that imposed by delivery of the crura (35% loss) until 80% of the lateral crus width was resected (Figure 3). With 80% of the LLC resected, a further 35% loss of tip support was seen in all 3 vectors.

Progressive resections of LLC were taken in 5 additional noses in a lateral to medial direction (Figure 4). In these specimens, an open approach was used, and the intercrural ligament was preserved. There was no significant change in nasal tip support until 80% of the width of the LLC was resected (P>.60). At 80% or greater resection, a 25% loss of tip support in all vectors was measured.

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Figure 7. Preoperative (A, C, and E) and postoperative (B, D, and F) photographs of a patient who underwent primary rhinoplasty with intercrural fixation.
PHASE 2

Cadavers were used to evaluate surgical techniques that are not generally used in our practice, many of which are associated with the closed approach to the nasal tip. Marginal and transfixion incisions had no significant effect on nasal tip support. These findings are in agreement with the conclusion of Tebbetts\textsuperscript{11} that "soft tissue incisions were the scapegoat for the real culprit—destructive tip shaping techniques." Placement of intercartilaginous incisions produced a 25% loss in tip support in all vectors. These incisions divide the scrolled attachment of the lower lateral and upper lateral cartilages as well as transecting the intercrural ligament from the septal angle to the dome. Delivery of the LLCs completes the division of the ligamentous binding between the domes and medial crura and further weakens the nasal tip (total, 35%).

In contrast to the outcome in live surgical patients, in cadavers the ligamentous attachments between the LLCs were preserved when the S-STE was elevated. Freeing the S-STE, while preserving the intercrural ligament, was shown to have no significant effect on support of the na-
sal tip. The intercrural ligament is a major tip support mechanism, and its division significantly weakens tip support. When the intercrural ligament is reconstructed, nasal tip support returns to preoperative levels or greater.

Resection of portions of the LLCs had no significant effect on nasal tip support until 80% of the cartilage had been excised. This held true whether cephalic strips were taken from medial to lateral or whether crural truncation was performed from lateral to medial. These surprising findings suggest that the maintenance of the intercrural ligament may be more critical to nasal tip support than the bulk of the lateral crural cartilage itself. Although the intercrural ligament is a major tip support mechanism, large resections of the LLC can still produce significant nasal tip deformities and functional compromise owing to the inevitability of scar contracture.

This study demonstrates that nasal tip support can be reliably quantified in a reproducible manner. Based on the findings of this study, the intercrural ligament (ligamentous attachments between the lateral, domal, and medial crura) is a major tip support mechanism. When the intercrural ligament alone is completely divided, nasal tip support decreases by 35%. Therefore, a full one third of the support of the nasal tip is attributable to the midline binding of the intercrural ligament. During rhinoplasty, suture reconstitution of the intercrural ligament increases tip support by 35% over peroperative measurements. The open approach to rhinoplasty is less damaging to nasal tip support than the closed approach. This observation was confirmed by measuring tip support before and after each approach.

We advocate the concepts of surgical conservatism and augmentation of nasal tip support during rhinoplasty. After nasal tip rhinoplasty, a well-supported nasal tip is better able to withstand the compressive forces of the inherent weight of the S-STE and the inevitability of scar contracture.

In primary rhinoplasty, we use the open approach to obtain maximal exposure and minimal interruption of tip support. Refinement of the nasal supratip is accomplished by excising conservative cephalic strips and reconstituting the intercrural ligament. If additional tip projection or support is necessary, a columellar strut is placed. Using these guidelines, nasal tip support will increase between 35% and 44% over baseline (Figure 7). In secondary rhinoplasty, we advocate an open approach and the DARTT technique, which increases tip support by an average of 70% (Figure 8).

Although the quantification of nasal tip support is in its infancy, it has great potential to guide facial plastic surgeons toward predictable and structurally stable results. Selecting the methods of tip modification that best preserve or augment the architectural integrity of the nasal tip will ultimately benefit all our patients.

Accepted for publication August 15, 2001.

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CONCLUSIONS

REFERENCES