Preface

Nasal Trauma

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Nasal trauma plays a role in the practice of most facial plastic and reconstructive surgeons. Whether it be the initial management in acute traumatic nasal injuries, or the treatment of established secondary nasal deformities, most of us are faced with both evaluation and treatment challenges of such traumatized noses on almost a daily basis.

For this issue of Facial Plastic Surgery, we have invited renowned facial plastic surgeons who are known for their contributions in the areas of nasal trauma, posttraumatic rhinoplasty, and related deformities. The issue starts with the excellent perspectives by Drs. Hoffman, Ries, and Davis on topics dealing with the initial management of acute nasal bony and soft tissue trauma. This is followed by demonstration of different approaches to the deviated and posttraumatic nasal deformity by Drs. Wang, Fedok, Park, Kriet, and Farrior. Finally, I will discuss my own experience with the difficult problem of perinasal posttraumatic deformities, focusing on the malpositioned medial canthus.

I am confident that you will enjoy this issue of Facial Plastic Surgery and learn as much as I have from reading these excellent personal reviews.

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An Algorithm for the Initial Management of Nasal Trauma

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Abstract

Nasal fractures are the most common of all facial skeletal injuries. Untreated, these fractures frequently lead to functional and aesthetic problems. Careful history and physical assessment are critical to determine the extent of injury and to determine proper management. Critical aspects of assessment are discussed, as is the role of imaging in management. The unique aspects of pediatric nasal fractures and their management are reviewed. Fractures are classified based on the degree of injury and the involvement of the septum. A simple treatment algorithm is provided to help guide the selection of optimal treatment techniques. A review of instrumentation and treatment techniques is provided. The goal of treatment is to restore the nose to its preinjury shape and function and to minimize the need for secondary seatorhinoplasty.

Keywords

► nasal fractures
► septal trauma
► closed reduction

Evaluation

Unlike many facial fractures that rely on sophisticated radiographic imaging for accurate diagnosis, isolated nasal fractures are principally diagnosed through history and especially through careful clinical examination. The history will provide clues as to the severity and location of the fractures. A lateral blow to the nose, as might occur when one is elbowed in a basketball game or perhaps punched in an altercation, is likely to result in lateral displacement of the nasal pyramid. A low-energy lateral strike might result in isolated unilateral or bilateral fractures with mild displacement of the dorsum (► Fig. 1). A higher-energy blow might result in comminuted bilateral fractures such that the side that was struck is medialized—or depressed—while the contralateral bone is lateralized and made more prominent (► Fig. 2). The end result is significant movement of the nasal dorsum off the midline. In these instances, displacement of the nasal dorsum is highly suggestive of significant nasal septal dislocation and fracture. Many of these patients will typically complain of significant nasal airway obstruction as well. This is another important clinical clue that suggests significant septal injury.

In contrast, a frontal blow in a fall will commonly fracture the anterior aspect of the nasal bones, nasal tip, and septum (► Fig. 3). This may result in frontal depression of the nasal bones without lateral deviation. A more intense frontal blow may lead to impaction of the nasal bones with loss of some
nasal height and splaying of the nasal bones laterally. Anterior trauma also frequently will cause fracture of the caudal septum and perhaps the anterior nasal spine (►Fig. 4).

It is important to inquire whether the patient has undergone septorhinoplasty surgery prior to the trauma. As septorhinoplasty may weaken nasal structures, this may lead to greater instability and posttrauma deformities and airway compromise. These patients are much more likely to need secondary reconstruction after the initial management of their fracture and they should be counseled accordingly.

Plain radiographic imaging offers little clinical benefit in isolated nasal trauma. In fact, sometimes plain film X-rays can be confusing as they may suggest there is no fracture even when the nose is obviously displaced (►Fig. 5). Conversely, plain X-rays may be read as significant fractures even when there is no significant change in the nasal appearance or airway. Plain films also are unable to distinguish between acute and old fractures. Even though there is little clinical utility with plain radiographs, there may be a need for objective documentation of nasal fractures for legal purposes especially in cases of assault or liability claims. However, the author never obtains plain films in cases of isolated nasal trauma for clinical purposes alone. Surprisingly, more often than not, new patients referred with isolated nasal fractures still present after they have had plain films taken elsewhere. The indications for surgical intervention following nasal trauma are solely based on changes in the appearance or function of the nose after injury, and plain film imaging will rarely impact these decisions and may in fact be confusing.

The only time that imaging is definitely indicated following nasal trauma is when one suspects the presence of associated facial injuries. A few clinical questions will quickly identify most of those patients that may have additional facial fractures. Is there any facial numbness? If yes, that could suggest the presence of maxillary or orbital injury involving the infraorbital nerve. Is there any double vision or change in vision? If so, this would suggest orbital trauma. Has there been any change in dental occlusion? If yes, then there may be associated fractures of the maxilla or mandible. Is there significant rhinorrhea? This might suggest a skull base or frontal sinus injury with cerebrospinal fluid (CSF) leakage. A positive response to any of these inquiries would dictate the need for a high-resolution computed tomographic (CT) scan of the face bones with axial, coronal, and sagittal views (►Fig. 6).
Physical Examination

The goal of the physical examination in patients with nasal trauma is to assess the extent and severity of the injury so that one can determine the most appropriate management and counsel the patient accordingly. Nasal trauma commonly results in perinasal edema, ecchymosis, and deformity. The physical examination includes gentle palpation of the dorsum and tip. One should assess the degree of displacement of the bony pyramid and the extent of depression or lateralization of the nasal bones. Palpation of the nasal tip should assess potential loss of caudal septal support. A saddle deformity may indicate significant dislocation or fracture of the septal cartilage (►Fig. 7). One should also gently palpate the nasal bone and upper lateral cartilage junction. On occasion, trauma may result in separation of these structures, resulting in depression and collapse of the middle vault even when the bony pyramid is not displaced (►Fig. 8). As it is difficult to reduce such an injury acutely, many of these patients may benefit from secondary reconstruction with cartilage onlay grafting or other techniques done on an elective basis.

Fig. 2  (A) A 24-year-old man involved in altercation. Significant displacement of the dorsum to the left with associated septal dislocation and nasal airway restriction. (B) CT scan demonstrating significant comminution and septal displacement. (C) Post-op following closed reduction of nasal bone and septal fractures.

Careful anterior rhinoscopy—and endoscopy as needed—should be performed to assess the septum and intranasal structures. One should carefully look for the presence of a septal hematoma. A septal hematoma must be drained and managed as quickly as possible to avoid the development of a septal abscess, which could lead to significant septal cartilage loss and subsequent nasal collapse. One should assess the alignment of the septum and the degree of septal dislocation and fracture. Significant septal deviation has been shown in multiple studies to be a critical predictor of failure of closed nasal fracture reduction and the need for revision surgery after closed reduction. The intranasal examination should assess soft tissue damage to the septal mucosa and look for evidence of watery rhinorrhea, which may suggest a CSF leak. The rest of the facial skeleton should be carefully palpated to identify any associated fractures. An examination of the eyes should at a minimum assess visual acuity, pupillary symmetry, and responses as well as globe position and extraocular movement. Additional imaging or consultation is obtained as indicated by a high suspicion of associated injuries.
Overall the pediatric nose is relatively protected from fractures. This is partly because the nasal dorsum projects less than the adult nose and thus is given protection by the more prominent forehead and supraorbital rim. Furthermore, the pediatric nasal skeleton is more cartilaginous and hence more flexible and less prone to comminution. The pediatric nasal septum is vulnerable to dislocation or distortion, however, and septal hematomas are proportionately more common in children than in adults. Thus, the clinician must be on the lookout for septal hematomas in all cases of pediatric nasal and facial trauma. When present, hematomas must be drained urgently to avoid the possibility of septal abscess.

**Pediatric Nasal Trauma**

Overall the pediatric nose is relatively protected from fractures. This is partly because the nasal dorsum projects less than the adult nose and thus is given protection by the more prominent forehead and supraorbital rim. Furthermore, the pediatric nasal skeleton is more cartilaginous and hence more flexible and less prone to comminution. The pediatric nasal septum is vulnerable to dislocation or distortion, however, and septal hematomas are proportionately more common in children than in adults. Thus, the clinician must be on the lookout for septal hematomas in all cases of pediatric nasal and facial trauma. When present, hematomas must be drained urgently to avoid the possibility of septal abscess.

**Fig. 3** (A, B) A 19-year-old man involved in altercation with predominately frontal trauma with impaction of nasal bones with some loss of dorsal height and airway obstruction. (C) CT scan showing severe comminution and impaction of nasal bones. (D, E) Post-op following disimpaction and limited septal reconstruction with restoration of dorsal height and improvement of airway.
which could lead to substantial septal cartilage loss. As soon as feasible, the hematoma should be evacuated through a limited mucoperichondrial incision. The dead space is then obliterated by placing through and through gut sutures as this might eliminate the need for placement of packing. Antibiotics are typically administered as well.

It is well recognized that prior to adolescence, the nasal septum plays a crucial role as a growth center for the nose and midface. To minimize the impact of trauma on eventual naso-facial development, it is prudent to be conservative in the treatment of nasal fractures in the pediatric population. Thus, the mainstay of treatment is closed reduction of bony fractures and closed reduction of septal dislocation. Open treatment of bony injuries with osteotomies or open septal reconstruction, although advocated by some authors, is rarely indicated except in those cases of severe trauma, which typically would also involve the orbit or midface. As children tend to heal rapidly, closed reduction should ideally be performed within a week of the injury or else adequate reduction may become difficult. It is prudent to advise the parents that trauma at an early age, in spite of timely treatment, may result in nasal airway or appearance problems later in life.

FIG. 4 (A) 53-year-old man who sustained frontal trauma in a fall off a ladder with widening of the dorsum and airway restriction. (B) CT scan showing fracture of anterior nasal spine. (C) CT scan demonstrating severe comminution, impaction and lateral splaying of nasal bones.

FIG. 5 (A) A 13-year-old man who sustained sports-related nasal trauma with obvious displacement of nasal bridge to the left. (B) Plain film radiograph read as “no fractures.”

FIG. 6 (A) A 17-year-old man who sustained nasofacial trauma in an altercation. Obvious nasal displacement and diplopia with up gaze. (B, C) CT scan demonstrating displaced nasal fractures as well as mildly displaced right orbital floor fractures.
Classification of Nasal Fractures and Management Algorithm

Not all nasal fractures require treatment. If the fractured nasal bones remain well aligned and the nasal airway is not significantly changed, observation alone is adequate. If the patient is seen shortly after the injury and the edema is still significant, they should be advised that any external deformity may only become apparent once the edema improves. In these cases, the patient should be reevaluated as soon as the swelling has receded but soon enough to reduce the fractures prior to consolidation of the fracture site.

Several different classification schemes for nasal fractures have been proposed through the years. Typically these have attempted to categorize the trauma based on the degree of injury to the nasal bones and septum. The intent is to then guide management based on the severity of injury. Rohrich and Adams\(^7\) in 2000 proposed a classification scheme and treatment algorithm in an effort to reduce subsequent revision rates. They proposed initial closed reduction of nasal and septal fractures with advancing to limited septal reconstruction as needed. Staffel\(^12\) also proposed a graduated approach as well progressing from simple closed reduction to septal reconstruction, osteotomies, and grafting as indicated. More recently, Ondik et al\(^8\) devised a new classification scheme dividing nasal trauma into five groups. Class I fractures were simple mildly displaced fractures progressing in severity up to class V fractures that were complex injuries with severe, comminuted fractures of the nose and septum including significant soft tissue injury. They then proposed a comprehensive treatment algorithm designed to recommend treatment based on the fracture classification. This was all done in an effort to improve treatment outcome and to reduce the need for secondary surgery, and in their study the overall need for revision surgery was an admirable 6%. Riley and Davison\(^2\) also reviewed their experience in closed and open treatment of nasoseptal fractures. They concluded that those injuries that needed septal reconstruction also greatly benefitted from open treatment of the nasal bone component as closed treatment alone in these cases led to high rates of revision.

In this article, a somewhat simplified classification scheme similar to Ondik et al\(^8\) is presented as well as a basic treatment algorithm (→ Table 1). The first group includes those who have displaced but noncomminuted fractures with minimal septal deviation and only minor displacement of the midline (→ Fig. 1). The second would include those with more...
comminution and mild, but nonobstructive septal deviation and moderate dorsal displacement greater than ½ the width of the dorsum (►Fig. 2). Both groups can typically be managed with simple closed reduction of the nasal bones with external splint stabilization.

A third group would include those with bony comminution and obstructive septal deviation or dislocation along with significant displacement of the midline dorsum (►Fig. 9). In addition to closed reduction of the nasal bones, these patients will also need either closed septal reduction or perhaps limited septoplasty and perhaps limited osteotomies of the nasal bones. Included in this group would be those with comminuted and depressed fractures with associated septal fractures and loss of dorsal support (►Figs. 3 and 9). In most of these cases, intranasal septal splints can be helpful to provide additional support to the weakened septal cartilage and protection of the septal mucosa. Intranasal septal splints may also reduce the incidence of synechia between the septum and the mucosa of the turbinates and nasal sidewall, which is commonly lacerated in this group. Adequate repair of the septum is often cited as the key to a successful outcome and for reduction in the need for secondary surgery. That said, it remains prudent to only use the minimal intervention necessary to allow adequate septal reduction.

The final group includes those with severe comminution and impaction of the nasal bones as well as collapse of the septal support and damage to or loss of external soft tissues (►Fig. 10). Naso-orbital-ethmoid fractures would fall into this category. These cases may require open reduction and internal fixation of the nasal bones with limited osteotomies, septal reconstruction, soft tissue repair, and perhaps bone or cartilage grafting to restore dorsal support and contour.

Any of these groups may ultimately need secondary formal septrhinoplasty at some point in the future. This may be indicated for persistent nasal airway restriction or external deformity. Typically this is performed after 3 to 6 months of healing, which allows for stabilization of the nasal bones and septum as well as time for the external edema to resolve. This allows for more accurate secondary septrhinoplasty at a convenient time. A discussion of secondary surgery for traumatic nasal deformity is beyond the purview of this chapter.

Techniques

The timing of nasal fracture repair is dependent on the degree of injury and amount of soft tissue edema. Commonly, fracture reduction is done within 1 to 2 weeks following the injury. Pediatric patients should be managed within 7 to 10 days given their tendency to heal more rapidly. Ideally, one should allow enough time for a substantial amount of the swelling to resolve but not so much time that the bones have become stable and difficult to disimpact and reduce. If the reduction is done while there is still significant edema, the reduction of the nasal bones may be inaccurate as the bony contours and position are hidden under the thickened soft tissues. Additionally, if an external stabilizing splint or cast is applied too early, it will prematurely become loose and ineffective as the edema resolves. Thus one should attempt to schedule the reduction during the 1 to 2 weeks window of time for maximum accuracy and stability. In cases where there is severe comminution, closed reduction may still be successful up to 3 weeks after the initial trauma as these bony fragments tend to remain mobile longer. Beyond 2 weeks, however, the surgeon should be prepared to perform open

Table 1  Treatment algorithm

<table>
<thead>
<tr>
<th>Comminution and Mild Septal Deviation</th>
<th>Closed Reduction of Nasal Fracture (CRNF)</th>
<th>Formal Septrhinoplasty as Needed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bony Comminution and Obstructive Septal Deviation</td>
<td>Closed Septal Reduction Limited Septoplasty</td>
<td>Limited Osteotomies Limited Septoplasty Bone Grafting</td>
</tr>
<tr>
<td>Severe Comminution Impacted Septal Disruption Stable Deformity</td>
<td>CRNF</td>
<td></td>
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techniques on the septum and nasal bones, and the patient should be prepared for that eventuality.

Simple closed reduction is typically performed as an outpatient procedure. It is the author’s preference to perform this in an ambulatory surgical center under brief general anesthesia. Although this can be done under local and topical anesthesia, it has been our routine to perform these quickly and in a very humane fashion under a brief general anesthesia. Not only does this approach result in little postoperative pain, but it is believed that more complete and accurate reduction can be performed effectively without any limitation or restriction caused by patient discomfort during the procedure. When performed in an efficient ambulatory surgery center, it is also very cost-effective and well received by the patient. A further advantage of general anesthesia is that it is easy to perform more invasive maneuvers such as osteotomies or septoplasty in the same setting if that proves necessary. Osteotomies or more invasive septal procedures may prove difficult under local or topical anesthesia alone.

After the induction of general anesthesia, a topical intranasal anesthetic—typically a 1:1 mixture of 4% topical lidocaine and oxymetazoline—is applied intranasally to provide mucosal decongestion, diminished risk of bleeding and postoperative comfort. If more extensive intervention is anticipated, such as osteotomies or septal repair, then regional infiltration with a 1:1 mixture of 1% lidocaine and 0.25% bupivacaine with epinephrine is also done. Perioperative antibiotics are used at the surgeon’s discretion. Antibiotics are indicated in all cases of septal hematoma, however. Intranasal packing is avoided except when needed to manage epistaxis. Most patients will require only minimal postoperative analgesics.

We have assembled a limited instrument set specifically for closed fracture reduction (Fig. 11). This includes a nasal speculum, bayonet forceps, suction tips, Asch forceps, Walsham forceps, and a Boies elevator. Cottonoids are used for the application of topical anesthetic and to tamponade the occasional bleeding. These are often placed into the posterior nasal airway at the start of the procedure to provide a temporary barrier in order to minimize the migration of any blood down into the pharynx. Cottonoids are also useful to provide some cushioning between the elevator and the delicate mucosa under the nasal bones (Fig. 12). This simple addition protects the mucosa and limits bleeding while the bones are manipulated back into place.

A typical closed reduction is begun by elevating the bone on the side that is depressed with a Boies elevator using a bimanual technique to stabilize the bones and to feel when they are accurately reduced (Fig. 13). Occasionally, a Walsham forceps may be helpful to disimpact and elevate

Fig. 9  (A) A 26-year-old man who sustained substantial facial trauma in an autopedestrian incident. No vision changes. (B, C) CT scan demonstrating severe impaction and comminution of the nasal bones and septum. Minimally displaced right orbital fracture without entrapment. (D) Post-op following septal reconstruction and limited osteotomies needed to mobilize and reduce fractures.
depressed nasal bones (►Fig. 14). If the bony dorsum is impacted, an Asch or similar forceps are used to disimpact the bones (►Fig. 15). The Asch may also be helpful in reducing a dislocated septum back toward the midline over the maxillary crest. After adequate mobilization, the dorsum is then manipulated back into alignment with external digital pressure. Frequently an audible and palpable “pop” will occur during this process and may signify that the bones are disimpacted and the bony spicules of the fracture sites have become interdigitated.

If there is significant septal deviation from cartilage fracture or dislocation off the maxillary crest, septal realignment is indicated. In general, this author has tried to limit extensive septal reconstruction at the time of initial fracture repair because of concerns regarding unpredictable healing, increased risk of septal perforation when the mucosa is already traumatized and increased difficulty and risks when
secondary septoplasty is needed. Nonetheless, closed septal relocation and limited septal dissection are used as needed. The exposure along the maxillary crest and bony cartilaginous junction is done keeping mucoperiosteal dissection to a minimum. As a rule, the surgeon should strive to preserve as much septal cartilage as possible as there is a significant possibility that the patient may need definitive reconstructive rhinoplasty in the future and the septum is a critical source of graft material. In most instances, extensive septal reconstruction probably should be delayed for a few months when a formal septrhinoplasty procedure can be done in a setting where the cartilage is stable and the external edema is minimal.

On occasion, limited osteotomies may be needed to reduce and acute fracture. Typically this is in cases of displaced but impacted fractures or perhaps those fractures, which are displaced but incomplete. In general, osteotomies should be as limited as possible and only enough to allow mobilization of the displaced bones. Nasal trauma typically disrupts the periosteum of the nasal bones. Thus, one should limit soft tissue and periosteal elevation over the dorsum in the acute trauma situation as this may further destabilize the bones during healing. One should rarely perform complete osteotomies as are commonly performed in elective rhinoplasty as this might lead to additional postoperative instability and unpredictable healing. Instead, one should use small, sharp osteotomes and only complete the fracture lines enough to allow mobilization and reduction of the fracture segments. Periosteal lateral osteotomies may also be a good option, as these tend to preserve more periosteum and hence provide more postoperative stability.

In general, it is ill advised to incorporate other esthetic rhinoplasty maneuvers, such as tip modification, at the time of acute fracture repair given the potentially unpredictable healing following trauma.

In the most severe cases of nasal trauma bone or cartilage grafting might be indicated to maintain dorsal stability. This is most often indicated in those cases where there are associated fractures of the naso-orbito-ethmoid or other midface
fractures (►Fig. 10). Management of those types of injuries is beyond the scope of this article.

In all cases, an external splint of adhesive strips and perforated thermoplastic material is applied. The application of skin adhesive is usually helpful to secure the splint. If any septal manipulation or repair is done, an internal septal splint is also used. Internal and external splints are typically left in place for up to 1 week. The patient is advised to carefully avoid further trauma for at least 1 month after reduction. If they are involved in athletic activities, a protective face shield is advised. Definitive septrhinoplasty, if needed, is usually delayed at least 3 months to allow for complete bone healing and resolution of edema.

Summary

Nasoseptal trauma is one of the most common injuries in all of facial trauma. Careful history and physical assessment are key to diagnosis and the determination of appropriate treatment techniques. The goal of treatment is to restore the nose to its premorbid shape and function. A graduated approach from simple closed reduction to limited septal repair to osteotomies is presented with the intent of restoring the nose to its premorbid shape and function and to minimize the need for secondary septrhinoplasty.

References

Management of Nasal and Perinasal Soft Tissue Injuries

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Abstract

The prominence of the nose renders it susceptible to soft tissue trauma of multiple etiologies. In this review, we present a framework for evaluation and treatment of nasal soft tissue injuries. Initial evaluation of nasal soft tissue injuries should include a complete trauma assessment, history, and physical examination. Mechanisms described include lacerations, abrasions, bites, and thermal injuries. Finally, we discuss wound care and surgical treatment options, including local flap and free tissue transfer. Though timing of repair remains somewhat controversial, most sources indicate that immediate reconstruction should be undertaken when possible.

Numerous studies have examined the consequences of facial disfigurement, including poorer body image perception, lower satisfaction with life and increased rates of depression, and alcoholism.¹ Injuries to the soft tissues of the nose and perinasal region present unique challenges for the reconstructive surgeon. The prominence of the nose makes it particularly susceptible to soft tissue trauma of multiple etiologies, the most common of which is motor vehicle collision.² Each year, nearly 3 million patients are seen in U.S. emergency rooms for treatment of facial injuries.³ Injuries to the nose and perinasal region are more common in men than in women, occurring most frequently in the age range of 15 to 25 years. The nasal tip is most commonly injured, followed by the dorsum and nasal root.⁴

Examination

After the primary and secondary surveys have been completed, a more detailed examination of the face may be undertaken, assessing for both bony and soft tissue injury. Visual inspection should include an external nose and endonasal evaluation. Deviation from the midline is suggestive of nasal bone or cartilaginous injury. Though not always necessary or possible, a fiberoptic examination may uncover septal fracture, hematoma, or potentially a skull base defect and associated cerebrospinal fluid leak. Severe nasal injury should warrant prompt ophthalmologic evaluation as well because ocular damage may be seen in up to 59% of patients with nasal or midfacial fractures.⁴ Furthermore, given the proximity of the lacrimal drainage apparatus, one must have a low threshold for probing and possibly stenting the nasolacrimal duct.⁵ Typically, facial imaging has already been obtained by the time a facial trauma consultation has been requested. However, maxillofacial computed tomography (CT) should be...
obtained if examination reveals telecanthus, severe nasal injury, malocclusion, or facial numbness.

**History**
Following careful examination, relevant history must be obtained from the patient, or from the family if the patient is unconscious or altered. Specifically, medical and social factors that could affect healing should be elicited, including alcohol and drug use, smoking, diabetes, or immunocompromised state. Prior trauma and surgical history should be obtained as well as tetanus vaccination status. Current guidelines indicate that nonimmunized patients or those whose tetanus immunization status is unknown should receive tetanus immunoglobulin (TIG) as well as the tetanus toxoid vaccine. For complex or contaminated wounds involving avulsions, punctures, or deep lacerations, tetanus toxoid should be given to all patients unless the patient has had a booster within the prior 5 years. The rabies vaccine should also be considered in the case of animal bites unless the animal is known to have an updated rabies vaccination. Finally, a complete medication list should be obtained, being mindful of drugs that may affect bleeding risk during or after surgery.

**Documentation**
Each facial injury should be carefully documented in the medical record, ideally with photographs. These images often help patients visualize the severity of their injuries and understand the potential outcomes of treatment. Prior to soft tissue repair, informed consent must be obtained and should include a discussion of the repair plan as well as reasonable expectations. It is important to educate the family and patient regarding the inevitability of scarring and the likelihood of revision or additional surgery in the future.

**Initial Wound Management**
Initial care of facial wounds consists of gentle but thorough wound irrigation and removal of foreign material. Meticulous wound cleansing should be directed toward decreasing the bacterial wound flora. Most sources recommend only limited debridement to avoid further tissue trauma; however, compromised tissue should be removed to decrease the likelihood of subsequent infection. The extent of debridement will, of course, depend on the mechanism of injury. Additionally, the wounds should be palpated for underlying bony or cartilaginous injury.

**Antibiotics**
There is scant literature to support the routine use of antibiotics in facial soft tissue injuries. Severity of injury, communication with oral cavity, the patient’s immune status, injury mechanism, and wound contamination are all relative indications for antibiotic use.

**Anesthesia**
Most facial lacerations in adult patients can be repaired under local anesthesia. Regional nerve blocks are often used for wide-field anesthesia and decreased tissue distortion. Buffering with sodium bicarbonate may decrease patient discomfort.

**Pediatric Considerations**
Facial lacerations in children can frequently be repaired with local anesthesia, particularly if buffered. Application of EMLA (Eutectic Mixture of Local Anesthetics) cream (lidocaine 2.5% and prilocaine 2.5%; AstraZeneca, Wilmington, Delaware) prior to local injection may improve patient compliance. For more extensive lacerations or in less cooperative children, conscious sedation may be possible if a pediatric intensivist is available. For severe injuries, general anesthesia may be necessary. To prevent aspiration, it is advised to delay surgery until at least 6 to 8 hours after oral intake or to evacuate the stomach with an orogastric tube.

**Reconstruction**
The timing of surgical repair for severe facial injuries remains controversial. Reconstruction can certainly be delayed in the face of other life-threatening injuries noted on primary and secondary survey. Prompt irrigation, debridement, and definitive repair are recommended by several sources.

**Primary Closure**
While the mechanism of injury may dictate the timing of repair, primary closure within 6 hours of injury is most often indicated. Vasconez found that when surgery was delayed more than 24 hours, functional and structural deformity was more likely. Behnia and Motamedi showed that early definitive treatment led to lower morbidity while treating war casualties over an 8-year period. They described an early intervention protocol, which minimized the likelihood of graft rejection, infection, and wound dehiscence. Hochberg also advocated primary repair within 8 hours of injury.

**Delayed Primary Closure**
Patients with severe, life-threatening injuries can receive parenteral antibiotics while their facial wounds are irrigated, debrided, and cleaned over a 1- to 3-day period and then closed in delayed fashion in the operating room.

**Secondary Intent**
While not a first-line recommendation for treatment, healing by secondary intent may sometimes be an option in patients who are diabetic or hypoxic. Highly contaminated wounds such as severe bite injuries may be appropriately managed with healing by secondary intent and subsequent revision. Aggressive wound care is an absolute necessity and may even require adjunctive measures such as wound healing factors and hyperbaric oxygen.

**Nasal Injury Mechanisms**

**Lacerations**
Bolt evaluated the incidence of facial lacerations according to etiology and found that lacerations to the upper third of the
face were most common at 52%, and lip (14%) and chin (11%) lacerations were also common. Nasal lacerations comprised 7% of all documented injuries.12 Nasal lacerations should be carefully assessed for cartilaginous and bony injury and for foreign bodies. Contour defects should be addressed by aligning bones. After hemostasis is achieved, one may proceed to close the wound in layers. Though superficial lacerations may only require nonabsorbable skin stitches, deeper sutures may be needed to decrease tension and to ensure a narrow scar. Underlying tissues should be reapproximated to minimize dead space using absorbable sutures in the dermis to decrease epidermis tension. Similarly, if cartilage is involved, deep sutures may be necessary to properly align the tissue (►Fig. 1). While a running subcuticular stitch is preferred, if using interrupted sutures, one should avoid overtightening.2 Appropriately delicate instruments are necessary to close lacerations using atraumatic technique. During repair, the risk of foreign-body reaction or impaired blood supply can be kept to a minimum by strategically placing a limited number of nonreactive sutures.

When distinct nasal landmarks are involved in the laceration, deep sutures may help restore smooth contours of the nostril border, nasal rim, or alar rim. This may help prevent a notched or retracted appearance, especially along the alar rim. Interiorty, the vestibule may be repaired with an absorbable suture while the external ala can be closed with a nonabsorbable suture. Silastic stents may be used to minimize the risk of stenosis.

Abrasions
Partial-thickness disruption of the epidermis from sudden friction may result in an abrasion. The rich blood supply of the nose generally leads to significant tissue survival after abrasions. The thick dermis of the caudal end of the nose contains...
plentiful skin appendages, which enable regeneration. Prompt removal of embedded debris will minimize the potential for tattooing of the skin, particularly on the nose.

**Avulsion**
Full-thickness tissue loss, or avulsions, can sometimes involve underlying cartilage and even mucosa (►Fig. 2). It is generally recommended that these injuries be evaluated in the operating room with debridement and irrigation. The tissue should be frequently examined to determine if it remains viable. Reconstructive options range from secondary intention to free tissue transfer. Lehr and Fitts proposed five methods of addressing avulsed tissue: (1) debridement only, (2) debridement followed by excision of avulsed tissue with primary or secondary wound closure, (3) debridement and excision of avulsed tissue, which is then used as a free graft for closure, (4) debridement and excision followed by split- or full-thickness skin graft, (5) debridement and removal of avulsed tissue with pedicled flap closure.

**Bites**
Dog bite injuries account for approximately 1% of all emergency visits to U.S. hospitals. Because of the high incidence of wound contamination, antibiotics as well as rabies and tetanus immunization are recommended for patients with animal or human bites. Multiple studies have indicated that dog bite injuries can be closed primarily in the absence of tissue loss. Human bites, however, tend to be more serious, and delayed closure may be more prudent. Human bite injuries often require secondary scar revision. Bites involving tissue avulsion may be closed secondarily as well (►Fig. 3). Most dog bites occur in the pediatric population, with an infection rate of less than 1 in 10. Nearly half of these infections are caused by *Pasteurella multocida*. Tu et al have reported on the relatively high incidence of concomitant facial fractures due to the force exerted upon the facial skeleton by a dog's jaws. Therefore, maxillofacial CT scan may be indicated in cases of extensive facial bites.

**Burns**
As with all facial injuries, nasal and perinasal burns require limited debridement to preserve facial musculature. If nasal burns are limited to partial-thickness, topical antibiotic dressings alone may be sufficient for adequate healing. Frequent dressing changes may be necessary for deeper burns. Late effects of burns include predictable patterns of facial distortion due to the contractile forces of scars. After extensive burns, the nose is shortened with associated alar flaring.
Ersoy et al described a superiorly based columellar flap as a new alternative for reconstruction of soft triangle defects secondary to burns. Reconstruction of full-thickness burns of the nose can also be achieved with a paramedian forehead flap. Nasal reconstruction after full-thickness nasal burns generally requires multiple operations over several years, with results often compromised by contour irregularities and color mismatch.

**Frostbite**

The nasal and perinasal region can also be seriously injured by cold exposure. This may range from “cold nip” caused by skin surface ice crystal formation to frostbite, wherein the soft tissue freezes, leading to hypoxia and tissue ischemia. Treatment includes rapid tissue rewarming with warm compresses as well as pain control and antibiotics.

**Reconstruction**

The unique shape of the nose makes nasal reconstruction particularly challenging after soft tissue injury. In general, goals of treatment include minimizing collateral trauma as well as ensuring similarity of tissue characteristics such as color, texture, and thickness. As always, the repair options follow the reconstructive ladder and include secondary intention, primary closure, skin grafts, local flaps, composite grafts, and free flap. The approach must be tailored to the individual patient based on a multitude of variables, including age, adjacent soft tissue availability, size and location of defect, and any associated comorbidities.

**Skin Grafts**

For superficial defects, such as those on the nasal sidewall, a skin graft may be appropriate. Such grafts, however, may not be durable enough to provide coverage on the nasal tip or lobule. Limitations of skin grafting include the need for an intact underlying cartilaginous framework as well as unpredictable postoperative pigmentation changes. Preauricular skin serves as a good source of full-thickness skin grafts to the lower third of the nose, while supraclavicular or postauricular skin may have a better color match.

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**Fig. 4** (A) Full-thickness loss of left ala and columella and full-thickness loss of upper lip from a dog bite. (B, C) Intranasal mucosal flaps, septal cartilage grafts to external nose, pedicled forehead flap to nose, split-thickness skin graft to lip. (D) Six months after pedicle sectioning.
Composite Grafts
For patients who seek a single-stage treatment, auricular composite grafts can be a good option for partial-thickness defects of the nose (Fig. 2). Composite grafts are an ideal reconstruction option to form the inner lining of a nasal wing.

Local Flaps
Skin that is rotated from the cheek or forehead generally provides a good color and texture match of the skin of the external nose. The forehead flap, supplied by the supra-trochlear artery, is considered the gold standard for nasal reconstruction (Figs. 3 through 5). Shipkov et al maintain that the forehead flap is indicated for total or near-total nasal avulsion injuries, large through-and-through defects that cannot be closed by other methods and in large non-transfixiant defects where no other flap is applicable or that cannot be skin grafted. Huang and Wong have also described the feasibility of immediate nasal reconstruction with a forehead flap after animal bite injuries (Figs. 3 and 4). In a 14-patient series, Herford found that local interpolation flaps allow for adequate tissue recruitment and are a reliable and aesthetic treatment option for repair of traumatic soft tissue defects.

Other reconstructive options include local flaps with lateral pedicles, supplied by the facial artery. Random pattern flaps supplied by the subepidermal vessels may be used for defect closure in a 3:1 length to width ratio. Guo et al proposed a simple algorithm for management of small nasal defects by dividing the nose into proximal, intermediate, and distal thirds. There are many options for closure of defects of the proximal and intermediate nasal dorsum and sidewall. Defects of the osteocartilaginous pyramid and region near the medial canthus can be closed with regional glabellar flaps. Intermediate and caudal dorsal defects may be amenable to a standard or Rieger extended glabellar flap or a V-Y advancement. Defects in the intermediate nasal sidewall can be closed using a combination of advancement and sliding flaps. Certainly, for large defects and those near the nasal tip, the workhorse paramedian flap is the ideal reconstructive option.

Repair of distal sidewall or nasal wing defects may involve all three layers, necessitating reconstruction of mucosa, cartilage, and skin. Dermal reconstruction may be achieved with a caudally pedicled nasolabial flap. When the edge of the ala is involved, the internal lining may be repaired using a flap from the wound edge if the defect is small. If the defect is larger, a

Fig. 5 (A, B) Traumatic amputation of nose involving columella, glabella, right alar region, and medial aspect of left alar region. (C) Septal cartilage graft to nose, paramedian forehead flap. (D) Six months post-op after pedicle sectioning, scar revision, flap defatting.
two-layer composite graft can be used to restore concavity and stability. Depending on the size of the defect, a suitable transposition flap such as a paramedian forehead flap or a superiorly pedicled nasolabial flap may be used to repair the external skin defect (►Fig. 3).

When the defect extends beyond the nose into the perinasal region, additional measures must be undertaken to restore adjacent facial units (►Fig. 4). Skin grafts, cheek advancement, Imre flap, or cheek rotation flaps can be used for reconstruction.

Columellar reconstruction poses a unique challenge (►Figs. 3 through 5). After the underlying cartilaginous structures are stabilized, a forehead flap may be needed to restore the nasal tip. Meticulous technique must be used when placing sutures between the vestibular skin and flap to avoid contraction and eversion.23 In some instances, the forehead flap may also be partially de-epithelialized and tunneled to the nasal tip or ala.

When the forehead flap cannot provide sufficient soft tissue for wound closure, several free tissue transfer option exist.24 Swartz described the use of three flaps for nasal reconstruction: radial forearm, dorsalis pedis and posterior auricular free flaps.25

Postoperative Management
Proper wound care is critical to healing in the postinjury setting. Gentle cleaning with hydrogen peroxide should precede antibiotic ointment application. Suture removal can usually be performed in 5 days for uncomplicated wounds or after 7 to 10 days for wounds under tension or with impaired healing. Patients should be advised to keep sun exposure to a minimum for 6 months or longer. Usually the scars will mature and soften over a 6- to 24-month period. Only after the maturation process has completed should scar revision be considered.2

Complications
Soft tissue injuries are frequently complicated by wound-healing issues, which are increased in the setting of smoking, diabetes, contamination, poor nutrition, and circulatory impairment. Wound infections, most often due to Staphylococcus aureus, may also affect scar formation and wound healing. Furthermore, hypertrophic scarring or keloids may also develop in predisposed patients.

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Complex Nasal Fractures in the Adult—A Changing Management Philosophy

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Abstract

Acute management of complex nasal fractures in the adult nose is still frequently conducted using closed reduction techniques as first-line therapy. Treatment outcomes from closed reduction are often disappointing and secondary surgical corrections are required in a sizeable subset of patients. In response to the shortcomings of closed fracture manipulation, classic rhinoplasty techniques have been introduced to improve anatomic fracture reduction. Although these techniques improve the accuracy of skeletal reduction, they also weaken the nose, leaving it susceptible to the deformational forces of healing. To provide optimal anatomic fracture reduction and concomitant stabilization of the skeletal framework, we have been using contemporary strategies derived from open structure rhinoplasty and extracorporeal septal reconstruction for initial fracture treatment. Using wide-field exposure with open rhinoplasty, these strategies provide optimal fracture reduction and rigid stabilization of the septal L-strut using suture-based fixation and structural grafting techniques. The result is unsurpassed contour restoration and lasting architectural stability of the nose. When combined with power-driven instruments to cut, shape, mobilize, and create osseous suture holes, open structure stabilization of the disrupted skeletal framework establishes a new benchmark in acute fracture management.

Keywords
► nasal fracture
► closed reduction
► open fracture stabilization
► L-strut reconstruction

The nasal bones are the most commonly fractured of all facial bones and account for more than 50,000 fractures annually in the United States.1,2 Males are more commonly injured, and nasal trauma occurs most often during the second and third decades of life.3 Common mechanisms of injury include motor vehicle accidents, sports injuries, falls, and assaults.3,4 Because nasal fractures frequently occur in combination with other facial injuries, nasal trauma may go unnoticed or untreated due to polytrauma and/or the presence of other more critical injuries. Unfortunately prolonged treatment delays often result in greater morbidity as a consequence of soft tissue contracture, skeletal malunion, and/or bone remodeling, making successful management far more challenging when treatment is eventually undertaken. Other causes of unsatisfactory treatment outcomes include failure to recognize septal injury or deviation, edema, preexisting nasal deformity, and/or the method of treatment.5–8

Treatment Rationale

In this chapter, we present our philosophy for the diagnosis and treatment of acute skeletal trauma of the adult nose. The time-honored principles of maxillofacial trauma management—open reduction and internal fixation (ORIF)—provide the foundation for our treatment philosophy. Consistent with these principles, we most often utilize the external (open) rhinoplasty approach for wide-field surgical access. Just as ORIF has transformed craniofacial fracture management, open surgical exploration is equally beneficial in the management of the severely disrupted nasal skeleton. In addition to unsurpassed accuracy in the characterization of skeletal

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injuries, including the differentiation of acute fractures from radiographic artifact, and the detection of fractures, tears, and avulsions of nasal cartilage which are often unseen on radiographic evaluation, wide-field surgical exposure also facilitates more effective and precise fracture reduction. Without question, however, the most useful benefit of open surgical intervention is rigid stabilization of the weakened skeletal framework using the time-honored principles of open structure rhinoplasty such as structural grafting. And when the synergistic advantages of open structure rhinoplasty are combined—(1) unparalleled diagnostic accuracy, (2) precise anatomic fracture reduction, and (3) dependable techniques for stabilization of the severely disrupted skeletal framework—a new benchmark for nasal fracture management is established. Because clinical outcomes are consistently superior to either closed fracture reduction or to surgical reduction without open structure stabilization (OSS), we have adopted OSS as our workhorse for the management of complex nasal trauma.

To optimize clinical outcomes and reduce long-term morbidity, open fracture management must be undertaken in a timely manner. However, unlike non-nasal (facial) fractures that can be treated effectively despite moderate soft tissue edema, nasal fracture reduction is best performed in the absence of swelling and acute inflammation as palpation and visual assessment are the primary means of guiding fracture reduction. The absence of soft tissue swelling and inflammation is essential to an accurate determination of nasal alignment, symmetry, and contour, and thus to successful fracture management, and for this reason treatment delays are necessary in most cases. Although early closed fracture reduction is still favored by some authors, treatment prior to the onset of masking edema is not always possible, and we see little value in attempting closed manipulation in an acutely inflamed and swollen nose. And though most authors agree that edema should be given time to subside, recommended recovery intervals vary widely from 3 to 5 days to more than 2 weeks. As with closed reduction, open surgical treatment of a swollen and ecchymotic nose is generally ill-advised as excessive bleeding and unwanted soft tissue distortion reduce visibility and make open treatment unnecessarily difficult. Consequently, unless severe collateral injuries prompt emergent treatment, it is our preference to delay definitive intervention of all nasal fractures until the majority of soft tissue swelling, tenderness, and inflammation have resolved, typically within 3 to 4 weeks. In our experience, delaying treatment for up to 6 weeks (or more) rarely precludes effective fracture reduction when utilizing the open surgical approach (see case presentation two), and a less hostile working environment is generally well worth the wait. In addition to avoiding an antagonistic and distorted surgical field, the dissipation of swelling and inflammation also serves to optimize soft tissue perfusion for better graft survival, reduced infection risk, and faster overall recovery following open surgical treatment.

Delaying initial treatment until the resolution of acute swelling and inflammation has another benefit as not all posttraumatic contour irregularities are the result of displaced bone. Periosteal inflammation and thickening frequently mimic acute bone trauma, and a delay of several weeks often leads to spontaneous resolution of the posttraumatic callous, and thus the nasal deformity. In a prospective analysis of nasal fracture management involving 756 patients referred from general practitioners or the emergency room, Murray and Maran found that 445 patients (59%) ultimately did not require fracture reduction. Of these, 187 had contour irregularities without radiographic evidence of fracture, presumably the result of soft tissue swelling and/or callous formation. Logan and coworkers also observed that 40% of patients referred from the emergency room with radiographic evidence of nasal fracture did not require proactive treatment. We can only presume that some of these cases had temporary contour distortion as a consequence of callous formation whereas other had stable nondisplaced fractures without contour disturbances. We have also observed that a significant number of patients who present with acute contour changes following blunt nasal trauma will eventually recover spontaneously with nothing more than supportive care. Hence the benefits of delaying treatment also include more accurate treatment planning, fewer misguided attempts at fracture reduction in noses without skeletal displacement, and subsequent cost savings from fewer inappropriate interventions. However, even periosteal inflammation can lead to permanent contour disturbances. In young or physically active individuals, peristeal healing responses may progress to neo-osteogenesis with calcification of the inflamed periosteum. For callouses that increase in size or fail to regress several weeks after injury, we frequently inject the callous with low-dose triamcinolone acetate (5–10 mg/cc diluted in 1% lidocaine with 1:100,000 epinephrine) to suppress periosteal inflammation and to promote periosteal involution prior to calcification. Although many patients respond favorably to only a single injection, stubborn callouses may require serial monthly injections before the risk neo-osteogenesis has been eliminated, and long-term follow-up is necessary to ensure complete recovery.

The Case for Open Fracture Treatment

Until recently, open surgical treatment has been reserved for the failure of closed fracture reduction, and a delay of several months was often recommended before definitive surgical treatment was deemed appropriate. Furthermore, the intent of open surgical treatment was primarily reduction of the intractable nasal fracture, and comparatively little emphasis was directed at intrinsic stabilization of the skeletal framework. Potentially destabilizing rhinoplasty maneuvers have long been used for surgical fracture reduction, including septal cartilage excision, septal cartilage remodeling, medial and/or lateral osteotomies, rasping, release of the upper lateral cartilages (ULCs), and/or fracture repositioning of the perpendicular ethmoid plate. Typically these classic rhinoplasty techniques were used in a graduated manner until satisfactory (intraoperative) alignment, symmetry, and contour were achieved. Although these maneuvers often achieved effective fracture reduction and outcomes were
generally better than closed reduction alone, structural instability resulting from such techniques leave the nose vulnerable to unwanted postoperative skeletal distortion, particularly when excessive swelling, scar contracture, or cutaneous shrink wrap are also at play. It is our belief that without concomitant skeletal stabilization, the long-term functional and cosmetic outcome of open skeletal reduction remains both haphazard and unpredictable and far more susceptible to wound-healing aberrations.

In contrast to classic rhinoplasty maneuvers that typically weaken the nose, and in keeping with the principles of open structure rhinoplasty, we routinely use surgical techniques designed to stabilize the skeletal framework by means of suture fixation and/or structural grafting. Whenever possible, these stabilization techniques are implemented sequentially so as to minimize the potential for additional destabilization of the already weakened skeletal framework. Individual zones are exposed, manipulated into anatomic reduction, and surgically stabilized before the process is repeated in an adjacent area. The strategic use of autologous structural grafts and suture fixation techniques—time-honored techniques borrowed from cosmetic and revision rhinoplasty—restores (or even enhance) structural integrity of damaged skeletal tissues. These techniques are indispensable in complex fracture management. We have coined the term "open structure stabilization" (OSS) to denote the application of open structural rhinoplasty concepts to acute fracture management and to differentiate mere fracture reduction from the proactive surgical reconstitution of structural support. Stabilization strategies borrowed from open structure rhinoplasty have proven so reliable that we frequently (and successfully) perform concomitant cosmetic alterations such as dorsal hump reduction or cosmetic tip refinement at the time of fracture repair. Additional innovations such as the use of bony drill holes for secure bone stabilization, and for reconstitution of the keystone area as described by Gubisch in his work with extracorporeal septal reconstruction, extends internal (suture) fixation beyond the confines of the cartilaginous vault to include much of the outer bony nasal pyramid. Furthermore, even when treatment delays lead to unwanted bony malunion or to contour irregularities from neo-osteogenesis, the introduction of electric surgical instruments for cutting, shaving, or sculpting of the bony pyramid—made tenable by the open rhinoplasty approach—can overcome undesirable changes in bone contour or bone configuration produced by aberrant healing responses or by preexisting bony deformities.

We believe that open structure rhinoplasty has transformed the management of acute skeletal trauma in the adult nose, and early OSS of the disrupted nasal framework is rapidly becoming the gold standard for complex fracture management. Like the modern principles of maxillofacial trauma management, reduced morbidity and improved long-term outcomes are the hallmark of this treatment paradigm. However, the successful implementation of OSS first requires a sophisticated mastery of open structure rhinoplasty techniques since open treatment of the severely disrupted skeletal framework represents one of the most daunting challenges in nasal surgery, and favorable results are unlikely to come at the hands of the novice surgeon. Treating physicians should also consider the repercussions of undertaking these highly specialized and multifaceted techniques when deciding upon whether or not patient referral is appropriate.

The medical literature has long documented the disappointing and unpredictable results of closed reduction techniques in nasal fracture management. However, with the growing success of open surgical treatment, a more reliable treatment alternative for complex nasal fractures is now emerging. In a recent study of complex nasal fracture management in which open septrhinoplasty was used as first-line intervention, Reilly and Davison reported a revision rate of only 4% (1 in 25 cases) despite treatment delays of up to 14 days.2 In a prospective, nonrandomized sequential trial comparing closed reduction techniques with a graduated open reduction protocol involving septrhinoplasty, osteotomies, ULC release, anterior perpendicular plate fracture, and optional camouflage grafting, Staffel found a statistically significant improvement in favorable outcomes from only 40% (6/15) after closed reduction to 71% (42/59) using rhinoplasty techniques as first-line treatment.3 Most patients were treated within 2 weeks of injury and cosmetic hump reduction was also performed in some surgical cases. Rohrich and Adams conducted a retrospective review of 110 complex nasal fractures treated with traditional closed reduction techniques augmented by septal resection and/or septal reconstruction for an overall revision rate of only 9%.4 All patients were treated using general anesthesia combined with topical decongestion and local anesthetic infiltration, and surgery was delayed for up to 7 days to permit the resolution of edema. In another study comparing primary endonasal septrhinoplasty techniques with traditional closed reduction techniques, Fernandes found aesthetic or obstructive complaints in 62% of patients treated with closed reduction versus only 12% in the surgical treatment group.5 Surgery was delayed up to 30 days (an average of 15.6 days) following injury, and immediate treatment was deemed less important in the surgical treatment group. Various rhinoplasty techniques were used in the surgical treatment group including septal resection and remodeling, detachment of the ULCs, and medial and lateral osteotomies. The importance of recognizing and treating septal injuries was also emphasized as critical to success. After an extensive review of the medical literature, Fernandes concluded that “early full septrhinoplasty correction is indicated because the results of closed reduction are poor” and “although closed reduction of nasal fractures may be valid in some circumstances of unavailable expertise, equipment, and expense, it should not be optioned for automatically in all cases.” In another large prospective study, Murray and coworkers conducted two clinical trials to compare traditional closed reduction techniques with open surgical treatment of complex nasal fractures.6 The first trial involved a single experienced nasal surgeon, while the second trial included five additional surgeons of varying experience levels including junior residents. Cadaver noses were also subjected to blunt force...
trauma to elucidate patterns of skeletal injury. Murray and coworkers discovered a 30% and 40% failure rate of closed reduction techniques within 3 month of treatment for the first and second trials, respectively. Cadaver studies also suggested that unsuccessful closed reductions were likely the result of persistent C-shaped fractures involving the bony and cartilaginous septum, which occurred in nearly all displaced bony fractures. Analysis of clinical outcomes confirmed a statistically significant improvement in the treatment scores following (primary) open surgical reduction for the severely fractured nose in both clinical trials. Renner published his philosophy for the management of complex nasal fractures and advocated internal fixation of severe fractures using small bony drill holes for the placement of narrow-gauge wire or long-lasting resorbable sutures. Low-profile titanium plates and screws were also used in select cases of severe skeletal trauma especially when traumatic lacerations provided direct fracture access, but open skin incisions over the bony vault were used in other cases. Renner concluded that for “the severely fractured nose, in which significant deformity is very likely, the creation of a relatively small, well-planned incisional scar may be a better alternative than an inadequate skeletal correction” and we agree. Although we seldom use direct skin incisions, we support the notion that effective reduction and stabilization of severe nasal fractures necessitates and justifies open surgical treatment as the consequences of inadequate treatment can be difficult to reverse.

The growing number of published series documenting improved clinical outcomes with (early) open surgical intervention using classic rhinoplasty techniques, coupled with anecdotal reports of improved outcomes with open skeletal fixation, parallel our own clinical experience with primary open fracture management and suggest that the principles of early “open reduction and internal fixation” (ORIF) are equally applicable to the treatment of complex nasal fractures. Furthermore, by combining time-tested techniques from open-structure cosmetic rhinoplasty with more recent innovations derived from extracorporeal septal reconstruction and the use of power-driven surgical instruments, OSS represents an even more potent and reliable tool for severe nasal fracture management.

The Role of Closed Nasal Fracture Reduction

With the advent of open surgical fracture reduction, the once-heavy reliance on closed fracture reduction as the sole means of fracture treatment has been called into question. Although closed reduction techniques may have had a role in fracture management before contemporary septrhinoplasty techniques evolved, restricting treatment to traditional closed manipulation is often prone to failure, particularly in nasal fractures with (1) septal involvement, (2) severe skeletal comminution, and/or (3) pyramidal instability. And while closed reduction alone may still prove effective in localized bony fractures with modest bone displacement and limited skeletal instability, overzealous attempts at closed reduction in complex fractures are likely to further destabilize the nose and exacerbate the skeletal deformity. Nevertheless, open surgical treatment of severe injuries also requires effective skeletal reduction, and we have found the judicious use of closed manipulation techniques to disimpact or realign the severely distorted nasal pyramid can be a useful adjunct when used in conjunction with OSS to consolidate the repositioned skeletal framework.

While closed reduction may be performed under local anesthesia in the outpatient setting and may therefore be more cost-effective, satisfaction rates are comparatively poor and revision rhinoplasty rates remain unacceptably high, calling into question the long-term cost-effectiveness of the closed approach. In a detailed literature review of 13 studies evaluating closed reduction of nasal fractures published between 1960 and 2000, Staffel found that surgeons were frequently dissatisfied with the clinical outcome for an average satisfaction rate of only 37%. Other patient series have also shown disappointing results with closed fracture reduction and revision rates as high as 50%. Although Fattahi and coworkers reported revision rates of only 11% (4 of 35 patients) following closed fracture reduction performed within 14 days of injury, treatment was performed under general anesthesia and open septal reduction was included as part of the “closed” reduction protocol. The inclusion of open septal surgery suggests that revision rates may have been much higher if treatment had been restricted only to traditional closed manipulation techniques, particularly because septal deformities are widely regarded as a major source of treatment failure. Similarly, Rohrich and Adams also reported a 9% revision rate after closed reduction when primary septal surgery was included in the initial treatment protocol. Because septal fractures are known to resist attempts at closed reduction, and because septal fracture are present in almost any displaced bony fracture and are often more severe than initially suspected, it comes as no surprise that traditional closed reduction techniques often fail as a sole treatment modality. In light of the high revision rates associated with traditional closed reduction, coupled with the prevalence of occult septal injury and the well-documented adverse consequences of untreated septal fractures, we rely on OSS, occasionally supplemented by intraoperative closed manipulation techniques, for the first-line treatment of nearly all complex adult nasal fractures.

Diagnosis and Assessment

Initial assessment of nasal trauma begins with a complete trauma survey to exclude life-threatening intracranial injury, spinal cord injury, or other craniofacial fractures. Once other injuries are excluded, a comprehensive history should then be obtained from the patient to understand the mechanism and force of nasal injury. Pertinent information should include the presence of airway obstruction before and after injury, perceived differences in aesthetic nasal appearance, and any previous history of nasal trauma or nasal surgery. Also the surgeon should attempt to obtain patient photographs taken prior to injury to assess the pretraumatic nasal contour.
Following a complete medical history, a preliminary nasal examination is undertaken. Often severe soft tissue swelling, epistaxis, and/or severe tenderness preclude a definitive diagnostic examination at the initial presentation, and in this scenario our preference is to delay the full nasal examination until circumstances improve. However, a targeted examination to rule out injuries requiring immediate medical intervention is still mandatory, and cerebrospinal fluid (CSF) leak, septal hematoma, or brisk epistaxis are examples of injuries that must be excluded initially.\textsuperscript{1,10,14} CSF rhinorrhea is often best managed conservatively as spontaneous resolution is common, but the potential for pneumocephalus, infection, or collateral neurologic injury generally warrant neurosurgical and radiographic evaluation. Failure to recognize, drain, and compress a septal hematoma may give rise to saddle-nose collapse and/or columellar retraction stemming from septal abscess formation and/or ischemic necrosis of the involved septal cartilage, and a septal hematoma should be sought in any patient presenting with acute nasal obstruction following blunt nasal trauma.\textsuperscript{1,10,14} Topical decongestion with oxymetazoline will usually control persistent epistaxis, but nasal packing or even embolization is occasionally needed for refractory cases.

### Imaging

The radiographic assessment of complex nasal fractures has greatly improved with the advent of high-resolution computed tomographic (CT) scans. In contrast, the diagnostic utility of plain X-rays in the evaluation of nasal fractures is questionable at best.\textsuperscript{1,3,4,7,10,11,14} Often adding little useful information beyond that obtained from a thorough physical examination alone.\textsuperscript{5,9,10} Although plain films are quick and comparatively inexpensive, radiographic artifacts derived from osseous suture lines, natural variations in bone thickness, prominent vascular markings, previous fracture lines, or previous osteotomy sites often result in false-positive diagnoses.\textsuperscript{4,10} Moreover, the specificity and sensitivity of plain radiographs remains suboptimal in comparison to high-resolution CT scanning.\textsuperscript{1,10,16} And even when nasal fractures are clearly evident on plain films, decisions regarding appropriate treatment should be based primarily on physical findings (such as skeletal displacement and/or skeletal instability) and clinical judgment, and not on radiographs alone because not all fractures require medical intervention.\textsuperscript{3,5,9,10} In our experience, an accurate diagnosis and treatment plan can usually be established without plain radiographs and we seldom use this diagnostic modality. In contrast, when intracranial injury or fractures of the surrounding facial bones are also suspected, radiographic evaluation with a high-resolution CT scan is the gold standard for evaluating the scope and severity of skeletal injury (Fig. 1) and to exclude intracranial injury. Although CT scanning provides a far more accurate diagnostic tool compared with plain radiographs, only severe nasal fractures or injuries involving adjacent vital structures warrant the use of this costly radiation-emitting modality.\textsuperscript{1,3–5,7,10} For maximum cost efficiency and for limiting radiation exposure, we seldom use CT for isolated nasal fractures.

Instead, a thorough history and careful physical examination, including contour inspection, palpation of the nasal framework, and anterior rhinoscopy/endoscopy, are nearly always sufficient to characterize the skeletal injury and to devise an appropriate treatment plan.

### Treatment Planning

After resolution of acute soft tissue swelling, a more informative and thus more useful physical examination is possible. To reduce nasal swelling promptly and to expedite treatment planning, patients are advised to avoid strenuous activity, exercise, supine posture, platelet inhibitors, or vigorous manipulation of the nose. Topical application of ice to the nose and orbits is also used to further speed the resolution of soft tissue swelling and inflammation. Extraneous sources of nasal inflammation should also be addressed in preparation for surgical treatment, most notably allergic rhinitis. Swelling and erythema of the nasal mucosa stemming from uncontrollable allergic rhinitis will create a far more severe inflammatory response following nasal trauma, which will delay definitive treatment. And unless allergic inflammation is prevented, a similar inflammatory response will occur following subsequent surgical intervention. Consequently, it is our practice to initiate oral nonsedating antihistamine therapy immediately and topical nasal steroid treatment once the risk of posttraumatic epistaxis has subsided—usually within 7 days of initial injury—to mitigate all forms of inflammation, traumatic, allergic, or otherwise. For this same reason, we routinely resume topical steroid treatment shortly after definitive surgery to hasten recovery.

Typically an accurate and definitive physical examination can be completed within 2 weeks of initial injury. The

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**Fig. 1** Coronal computed tomography (CT) scan of the nose, orbits, and paranasal sinuses at the level of the upper central incisors. Note fracture of the right piriform aperture and right inferomedial orbital rim with intranasal displacement of the bone fragment.
definitive nasal examination begins with visual inspection to exclude misalignment of the nasal axis, displacement of the nasal bones, or dislocation of the caudal septum. Photograph-ic documentation of the posttraumatic nasal contour using standard high-resolution rhinoplasty views is essential and should be obtained in all patients. Palpation of the nasal vault is then performed to detect bony step-offs, excessive skeletal instability, bony or cartilaginous depressions, or skeletal deviations. The intranasal examination should include a thorough evaluation of the anterior and posterior septum, with particular emphasis upon the septal L-strut. Rohrich and Adams found that low-velocity septal fractures most commonly presented inferiorly along the vomerine groove, whereas high-velocity injuries resulted in more severe fractures higher in the nasal vault along the quadrangular cartilage and into the perpendicular plate of the ethmoid bone. They concluded that aggressive management of septal fractures is essential for satisfactory outcomes and we concur. Murray and coworkers found that frontal impacts were also likely to produce more severe septal fractures in comparison to lateral impacts. Their clinical studies also showed that unrecognized septal deformities contributed to a high rate of persistent (postreduction) nasal deformity and they advocated open reduction with septal resection as the key to favor-able long-term cosmetic and functional outcomes. It has also been our experience that failure of initial treatment often stems from persistent septal deformities that are often refractory to closed reduction techniques. Consequently, our treatment algorithm excludes closed reduction when septal displacement is evident, especially when dislocations from the anterior nasal spine (ANS) or maxillary crest are identified or when obvious disruption of the septal L-strut is observed. Moreover, an initial trial of closed reduction is only attempted in displaced bony fractures that lack comminution and skeletal instability. Other more complicated fractures including saddled, comminuted, telescoping, or flail injuries to the dorsum, all of which indicate severe disruption and instability of the dorsal L-strut, or any fracture with significant septal displacement, are treated primarily with OSS.

Although many authors recommend delaying open surgery for 3 to 9 months after failure of closed reduction, we have found prolonged treatment delays to be unnecessary and counter-productive. The senior author has observed that most fractured nasal bones can be remobilized—gently and without osteotomies—as long as 6 weeks following injury, and sometimes months later (see case presentation 2). Moreover, prolonged delays in treatment will eventually lead to fibrous and/or osseous bony malunion, and/or osseous remodeling, which typically require more aggressive treatment strategies. Renner concluded that “early aggressive (surgical) treatment may avert, or at least minimize, the need for secondary nasal revision (since) deformities can be mini-mized with the initial procedure.” and we enthusiastically agree. Perhaps the most severe complication of unsuccessful primary treatment is progressive soft tissue contracture, an unfavorable healing response that may lead to quasi-perma-nent shrinkage of the inner or outer nasal lining that makes secondary attempts to reexpand the skeletal framework exceedingly difficult or impossible. Avoiding soft tissue contracture with timely intervention is often the difference between success and failure, and though initial delays to allow for the resolution of acute swelling and inflammation are justified, we disagree with the recommendation to postpone definitive treatment beyond that needed for acute inflammatory changes to subside. We have been confronted on numerous occasions by patients seeking correction of long-standing posttraumatic deformities in which failed primary treatment lead to progressive and sometimes irreversible contracture of the inner and outer nasal linings. Even when skeletal replacement tissue is available in abundance, the lack of soft tissue elasticity makes skeletal reexpansion physically challenging, and aggressive efforts to forcefully distend the inner and/or outer nasal linings invites an increased risk of vascular insufficiency, infection, contour de-formity, and treatment failure. Just as with other maxillofacial skeletal injuries, in the treatment of severe nasal fractures, the proverbial “ounce of prevention” is well-worth “a pound of cure.”

Surgical Intervention

In our hands, we use a graduated approach to complex fracture treatment in which open surgical reconstruction is the foundation of fracture management. However, in select cases, such as a collapsed nasal bone, or bilateral bony fractures that are visibly displaced but free of significant septal involvement, we will attempt primary closed reduction in hopes of avoiding open surgical intervention. Because effective reduction is contingent upon visual confirmation, we also postpone treatment until a majority of the soft tissue swelling has resolved. General anesthesia with controlled hypotension, combined with topical decongestion of the nasal mucosa and infiltration of the inner and outer soft tissue lining using an epinephrine-containing local anesthetic, is administered for comfort and for improved hemostasis prior to closed reduction (or open surgery). After allowing for full vasoconstriction, gentle manipulation of the nasal pyramid is performed using a bimanual technique. For side-impact trauma, a Goldman or Boies elevator (Black & Black Surgical Inc., Tucker, GA) is inserted into the nasal cavum beneath the displaced bony sidewall (on the side opposite deviation) to gently but firmly lift and lateralize the collapsed ipsilateral nasal sidewall. While lifting and stabilizing the collapsed segment, the laterally displaced (contralateral) sidewall is then gently directed back toward the midline with digital manipulation. If a stable and symmetric bony pyramid with appropriate projection results, a protective outer splint is gently applied and the procedure is terminated. For frontal-impact trauma with telescoping impaction of the nose, Goldman or Boies elevators are inserted bilaterally and used to simultaneously lift both sides of the nasal pyramid from beneath. When performed gently with slowly escalating force, disimpaction is often possible, but reliable stability is seldom achieved with closed reduction alone. If the attempt at closed reduction is unsuccessful, or when the reduced bone fragments remain unstable, we immediately convert the
procedure to a definitive open fracture repair and patients are consented in advance for this contingency.

Unless an attempt at closed reduction proves successful, we use the open (external) rhinoplasty approach to undertake definitive fracture management. Although wide-field surgical exposure provides unparalleled access to the skeletal framework, unnecessary elevation of the outer or inner nasal lining can needlessly compromise already weakened structural support as the “laminating” effect of nasal skin and mucosa lends considerable strength to a fragmented skeletal framework. Similarly, aggressive elevation of the nasal covering can also compromise soft tissue perfusion, and medical comorbidities that adversely impact nutrient blood supply should be taken into account when performing open fracture surgery. Although severe skeletal trauma usually necessitates aggressive degloving of the skeletal framework, sometimes encompassing the entire outer nose and septum, the prudent surgeon will continually reassess the need for additional soft tissue elevation, as well as the cumulative impact of degloving upon skeletal stability and soft tissue perfusion. And while aggressive degloving is not well tolerated in every nose, in the severely fractured nose where skeletal reduction and internal stabilization are essential to a reasonable clinical outcome, wide-field degloving is justified and usually very well tolerated. Nevertheless, meticulous soft tissue techniques, including the judicious use of electrocautery and retraction, the avoidance of soft tissue desiccation, and liberal use of cold saline irrigation, are recommended to optimize soft tissue perfusion and minimize the risk of infection and/or vascular insufficiency following nasal degloving.

L-Strut Reconstruction

Fundamental to virtually any surgery involving the outer nasal skeleton, particularly in the treatment of a traumatically fragmented and destabilized nasal framework, is the establishment of a (1) strong (2), flat (3), size-appropriate, and (4) properly aligned septal L-strut. Often called the “nasal backbone,” the septal L-strut provides critical support to all three segments of the nose and to the most sensitive regions of the nasal airway. Without a flat L-strut of appropriate stiffness, height, and length, an array of contour and functional deformities will inevitably ensue. Traumatic disruption of the L-strut can result from fractures or tears of the septal cartilage or bone, dislocations of the septum from the ANS or maxillary crest, and/or separation of bony-cartilaginous keystone area or quadrangular-vomerine junction. Side impacts to the bony vault often causes lateral displacement of the bony L-strut with canting or curvature of the nasal dorsum (see case presentation 2), while frontal impacts may produce accordion-like telescoping injuries, impactions, or collapse of the dorsal and/or caudal L-strut. In addition to conspicuous cosmetic deformities, most L-strut deformities also result in symptomatic nasal airway dysfunction with impingement at one or more locations along the nasal airway, and the risk of airway obstruction is much greater in narrow noses or noses with naturally weak and brittle skeletal tissues. Nasal fractures also occur in noses with preexisting L-strut deformities (many of which are previously unrecognized) adding additional complexity to fracture management. Unless these preexisting deformities are recognized and eliminated, treatment failures are virtually inevitable.

Regardless of the underlying etiology of the L-strut deformity—an acute traumatic deformity or a combination of preexisting and traumatic deformities—complete and permanent elimination of all L-strut deformities is required for satisfactory nasal form and function. Ideally the entire septal partition should be straight, flat, and residing in the midline to prevent airway obstruction, but septal deformities not involving the L-strut will seldom disturb outer nasal contour, alignment, or symmetry. Conversely, virtually any significant deformity of the L-strut will lead to functional and/or cosmetic problems. Deviation in the dorsal segment can produce C- or S-shaped curvatures and/or canting of the nasal dorsum, whereas deviations or dislocation of the caudal L-strut can cause angulation, displacement, or curvature of the columella (see case presentation 1). Deformities in either segment can lead to lateral displacement of the anterior septal angle with skewing of the nasal tip. When the anterior septal angle is subject to reductions in height and/or length, a corresponding loss of tip projection and/or unwanted tip rotation often occurs. Loss of projection of the cartilaginous L-strut can also produce saddle deformities, whereas a loss of projection within the bony vault will typically lead to flattening and spaying of the bony pyramid. When loss of projection involves the entire L-strut, severe pan-dorsal collapse will ensue (see case presentation 1).

Contemporary methods of L-strut reconstruction are derived from the principles of both open structure rhinoplasty and extracorporeal septal reconstruction. In the aftermath of acute skeletal trauma, our protocol for L-strut reconstruction begins with diagnostic exploration of the outer nasal framework to assess L-strut shape and skeletal continuity. Careful degloving of the cartilaginous L-strut, in conjunction with anterior rhinoscopy, will determine the position and structural integrity of the sepal L-strut and its attachments to the ULCs, bony nasal vault, ANS, maxillary crest, and vomerine/ethmoid partition. Fractures, tears, dislocations, avulsions, and other injuries will become apparent and should be repaired upon discovery whenever possible to limit overall destabilization. We prefer long-lasting resorbable suture material for skeletal fixation such as 4–0 and 5–0 polydioxanone. Cartilaginous tears or fractures are usually amenable to direct suture reapproximation with a combination of simple, mattress, figure-of-eight, or running sutures as deemed appropriate. However, in the severely fractured nose, suture fixation alone may prove inadequate. When L-strut rigidity or continuity remains compromised despite suture fixation, structural grafting with unilateral or bilateral spreader grafts or osseous splinting grafts is required to enhance structural support and stability. Unstable solitary fractures can be bridged with small unilateral grafts whereas more extensive injuries can be treated with full-length unilateral or bilateral grafts as indicated. Although adequate structural integrity is paramount, care must be taken to avoid unnecessary graft bulk to optimize both the cosmetic and

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functional results. In slender noses where additional dorsal width is undesirable, spreader grafts measuring 3 to 5 mm in height are recessed 1 to 3 mm below the profile line (depending on graft thickness) to prevent unwanted widening of the middle vault. Persistent curvature of the dorsum following release of the ULCs can usually be eliminated with a unilateral spreader graft to straighten the L-strut and restore linearity with negligible increases in overall dorsal width. Spreader grafts can also be extended cephalically to support inwardly collapsed nasal bones, and/or caudally to realign the tip complex, increase tip support, and/or to increase nasal length. Release of the ULCs from the dorsal septum is frequently useful to fully straighten and realign the dorsal L-strut, but suture reapproximation of the ULCs, with or without structural grafting and/or clocking sutures, is always performed to reconstitute pyramidal strength and support. When osteotomies are required to realign or narrow the bony vault, medial osteotomies are usually created using an electric micro-drill (Stryker, Kalamazoo, Michigan) fitted with a cross-cut bur (►Fig. 2C) to yield precise positioning of the bone cuts and to minimize bony destabilization from blunt force osteotomies. And when reductions in bone projection or alterations in bone contour are also required, an electric micro-reciprocating saw fitted with a large tear-shaped rasp (►Fig. 3A) (Stryker, Kalamazoo, Michigan) and/or electric micro-sagittal saw equipped with a precision thin-cutting blade (►Fig. 3B) is used for bone removal to further limit blunt force trauma. If bone fragments remain unstable following open reduction, a 1.0-mm drill bit (►Fig. 2B) is used to create osseous drill holes along the caudal margin of the bony vault to allow suture fixation of nasal bone to the L-strut, to the ULCs, or to each other. Traumatic separation of the keystone area, anatomically analogous to septal resection during extracorporeal septal reconstruction, can also be repaired using osseous drill holes in the adjacent nasal bones to resuspend the septal partition and/or to reattach avulsed ULCs. Reattachment of a dislocated caudal septum is also performed using transverse (osseous) drill holes placed through the ANS to permit secure suture fixation. Multiple passes with a 4–0 polydioxanone suture via one or more osseous drill holes provides lasting fixation in most cases. When additional stability is required, a midline groove is created within the ANS using the cross-cutting bur to cradle the caudal septum when adequate bony width permits. In most cases of caudal L-strut injury, columellar straightening and/or support can be accomplished with negligible increases

**Fig. 2** Electric drill attachments for nasal surgery. (A) Pear-shaped cutting bur for contouring of ethmoid/vomerine splinting grafts, (B) 1.0-mm drill bit for creation of osseous suture holes, (C) side-cutting “cross-cut bur” for medial osteotomies, and (D) perforated osseous splinting graft fashioned from autologous septal bone.

**Fig. 3** Electric-powered micro-saws for nasal surgery. (A) Micro-reciprocating saw fitted with a large tear-shaped rasp. (B) Micro-sagittal saw fitted with a precision thin-cutting saw blade.
in columellar width using an osseous splinting graft\(^\text{12}\) (\textbf{Fig. 2D}). Alternative techniques for columellar stabilization, such as tongue-in-groove fixation of the medial crura, are also used when appropriate contour changes to the nasal base are indicated.\(^\text{19}\)

In most noses, quadrangular cartilage, ethmoid bone, and/or vomerine bone can be harvested safely for use as donor graft material as long as a residual L-strut of reasonable width is preserved. In general a wider L-strut is preferable, but narrower remnants are acceptable in noses with stiff septal cartilage, or in severely fractured noses when appropriate L-strut grafting is planned. Traumatic disruption of the septal partition may also make graft harvest more challenging, and care must be taken to avoid further nasal destabilization during graft removal. However, septal cartilage or bone residing outside of an appropriate-sized L-strut is expendable, and these skeletal tissues provide an invaluable material for fortifying and strengthening the outer septal partition.\(^\text{12,18}\) Moreover, the net effect of structural augmentation grafting is typically a far stronger and more durable L-strut framework than can be achieved using only open rhinoplasty techniques.

One of the most effective and least obtrusive options for structural grafting are osseous splinting grafts fashioned from ethmoid and/or vomerine bone. These thin yet rigid grafts can be used to bridge fracture lines, tears, or flail segments with negligible increases in skeletal bulk. When a long, thin, and flat segment of septal bone is unavailable, thick septal bone can be contoured using a cylindrical or pear-shaped cutting bur (\textbf{Fig. 2A}) to thin and straighten the specimen, usually to a final thickness of 1.0 mm or less depending upon bone rigidity. Multiple 1.0-mm drill holes are then used to liberally perforate the graft to facilitate easy suture fixation and rigorous vascular in-growth (\textbf{Fig. 2D}). Although low-profile osseous splinting grafts are preferentially used to straighten and/or strengthen a traumatized caudal septum, the entire nasal L-strut can be reinforced in this manner when sufficient graft material is available (\textbf{Fig. 4}). Conversely, when donor graft material is in short supply, smaller splinting grafts can be used to strategically bridge focal L-strut injuries. Occasionally, prior septal surgery, congenitally small septi, or severe trauma to the septal partition may prohibit adequate graft harvest. Autologous rib and/or ear cartilage may also be used for structural grafting when septal tissues are unavailable or unsuitable. To prepare for this possibility, we routinely obtain prior informed consent for possible conchal and/or rib cartilage harvest in all patients.

Once skeletal reconstruction is complete, irrigation of the subcutaneous pocket with copious saline is performed to reduce infection risk and air-tight closure is performed along the entire incision line. Additional (temporary) skeletal support is achieved with endonasal septal splints secured with trans-septal sutures (see case presentation one). Splints are placed high in the anterior nasal vault to undergird the dorsal L-strut and are supported with endonasal packing fashioned from rolled Telfa (Covidien, Mansfield, MA) and coated with antibiotic ointment. Following placement of a cinch dressing to limit swelling, a dorsal splint fashioned from premolded aluminum is gently crimped over the bony vault to prevent spaying of the nasal dorsum. Strips of Surgicel absorbable hemostat (Ethicon Inc., Somerville, NJ) is also tightly packed into both nostrils for hemostasis and tamponade. All packing material is typically removed on the following day, and the remaining bandage material and splints are removed after 7 to 10 days.

**Case Presentation 1**

A 30-year old man presented to the outpatient clinic approximately 7 days after blunt facial trauma sustained in an assault. The patient reported brief loss of consciousness, initially brisk but self-limiting epistaxis, and heavy periorbital and nasal swelling. A full neurologic evaluation at an outside hospital immediately after injury, including a CT scan of the brain, was unremarkable.

Physical examination revealed heavy right periorbital ecchymosis and mild enophthalmos (OD). Palpation of the right infraorbital rim revealed medial tenderness and absent infraorbital bone extending from the mid-pupillary line to the anterior lacrimal crest. Mild infraorbital hypesthesia was detected within the right midface. No loss of visual acuity, diplopia, hyphema, or chemosis was detected. Inspection also revealed severe leftward displacement of the nasal dorsum and tip with a modest loss of dorsal height and increased tip rotation (\textbf{Fig. 5A, B}). Overly long and retracted nostrils were also seen on profile view and were attributed to preexisting nasal contour. Nasal palpation revealed exquisite tenderness with crepitus and severe instability of the skeletal framework. Endonasal examination revealed diffuse mucosa edema, leftward deviation of the anterior septum obstructing the left nasal caviit, and contralateral airway obstruction from what appeared to be an enlarged inferior turbinate. No evidence of septal hematoma, epistaxis, or CSF rhinorrhea was observed.

A CT scan obtained immediately following injury was also available for review. High-resolution noncontrasted axial and coronal cuts optimized for bone resolution revealed a severely comminuted and displaced nasal fracture (\textbf{Fig. 6A, B}). An adjacent displaced fracture of the right infraorbital orbital rim and piriform aperture was also observed (\textbf{Fig. 1}). Severe comminution and displacement of the entire bony pyramid was seen extending cephalically to the intercanthal line.

**Fig. 4** Example of a large osseous splinting graft used to straighten and stabilize the entire cartilaginous L-strut.
Fracture displacement of the perpendicular ethmoid plate and C-shaped fracture deformity of the dorsal L-strut were also observed.

Open surgical treatment, including cosmetic alterations to the nasal tip and nasal base, was performed shortly after presentation under general endotracheal anesthesia with controlled hypotension (mean arterial pressure = 65 mm Hg) supplemented with topical cocaineization of the nasal mucosa and soft tissue infiltration nose and right lower eyelid with 1% lidocaine containing a 1:100,000 concentration of epinephrine. Treatment began with ORIF of the right orbital fracture via lateral canthotomy and inferior cantholysis, and a transconjunctival approach to the infraorbital rim. After ORIF of the orbital rim fracture using titanium microplates, attention was temporarily diverted to nasal fracture repair. Closed reduction of the nasal fracture was initially performed to

![Preoperative (A) frontal view following blunt nasal trauma. Note severe leftward displacement of the nasal framework and tip complex. Preoperative (B) profile view. Note the pan-dorsal loss of projection and the upward tip rotation. Initial postoperative (C) frontal and (D) profile views demonstrating improved nasal contour, symmetry, and alignment after open structure stabilization (OSS). Long-term postoperative (E) frontal and (F) profile views demonstrating acceptable posttraumatic nasal contour.](image1)

**Fig. 5**

![Fig. 6 (A) Coronal and (B) axial computed tomography (CT) scans of the nose, orbits, and paranasal sinuses demonstrating leftward fracture-displacement of the septum and nasal pyramid with severe comminution of the nasal bones and bony septum.](image2)

**Fig. 6**
align the nasal axis and to disimpact the nasal dorsum. Although partially successful, closed reduction could not achieve stable anatomic reduction and open surgical treatment was undertaken.

Using the external rhinoplasty approach, a combination of blunt and sharp dissection was used to deglove both tip cartilages. The membranous septum was then separated to expose the caudal septum and the ANS. Fracture displacement of the entire quadrangular and bony septum into the left nasal airway was observed. After elevating bilateral mucoperichondrial and mucoperiosteal flaps over the quadrangular septum and the surrounding nasal bones, examination revealed dislocation of the quadrangular septum from the maxillary crest and ANS. The ANS was also asymmetric and protruding into the left nasal vestibule. A large graft was harvested from the inferior portion of the cartilaginous and bony septum and used in orbital floor and L-strut reconstruction. Care was taken to preserve an L-strut of 15 mm or greater in width, and multiple interrupted quilting sutures of 5–0 poliglecaprone 25 were used to approximate the mucosal flaps and minimize septal dead space. The left half of the ANS was then resected to create a midline bony remnant, and a transverse drill hole was placed for suture fixation of the caudal septum. After midline fixation of the caudal septum using multiple passes with 4–0 polydioxanone suture, the caudal septum was shaved by 1 to 2 mm to reduce caudal projection. A tongue-in-groove setback was then performed to reduce tip projection, decrease columellar show, and retrodisplace the columellar/labial junction while providing additional stability to the caudal L-strut. Tip projection was further reduced by vertically dividing the alar domes and lowering dome projection by 2 mm. The domes were then reconstituted with 4–0 polydioxanone mattress sutures.

Additional blunt and sharp dissection was then used to expose the ULC and dorsal septal cartilage complex. Persistent deviation of the nasal dorsum necessitated release of the ULC from the dorsal septum revealing curvature and fractures of the underlying L-strut. A single full-length spreader graft was then designed with modest concavity to mirror the residual concavity of the dorsal L-strut. After creation of a precise sub-mucoperichondrial pocket on the right (concave) side of the dorsal septum, the graft was inserted so that the concavities were directly opposed. Fixation of the spreader graft to the cartilaginous L-strut with multiple 4–0 polydioxanone mattress sutures stabilized the spreader graft while simultaneously eliminating the residual L-strut curvature. The remaining septal cartilage was used as a free graft to reconstruct the right orbital floor defect. Clocking sutures were then used to reattach the ULCs to the L-strut/spreader graft complex and to realign the nasal axis. Although further open manipulation of the nasal bones eventually led to satisfactory alignment, projection, and symmetry, stability of the bony pyramid remained questionable. Consequently, large endonasal splints fashioned from 2-mm-thick reinforced silicone sheeting were then designed to span the full height of the nasal septum at the level of the rhinion and bony vault. Bilateral splints were inserted and positioned against the uppermost aspect of the cartilaginous and (anterior) bony dorsum and secured with 4–0 nylon trans-septal sutures at three separate points for secure immobilization. Undergirding provided by the oversized and anteriorly positioned splints served to stabilize the dorsal L-strut against loss of projection during healing. Following closure of the skin flap, both nasal passages were packed with rolled Telfa gauze coated with antibiotic ointment. The dorsum was covered with Mastisol (Eloquest Healthcare Inc., Ferndale, MI) and sterile tape strips, followed by a prebent aluminum nasal splint that was lightly crimped over the bony vault to prevent lateral drift of the bony vault. Nasal packing was removed the following day, and the internal and external splints were removed after 10 days. Satisfactory alignment, symmetry, projection, and airway patency were noted on initial follow-up examination (Fig. 5C, D). Long-term follow-up at 1-year postsurgery revealed satisfactory contour stability and normal airway function (Fig. 5E, F).

Despite severe comminution, displacement, and destabilization of the entire osseocartilaginous nasal vault, early OSS resulted in a satisfactory cosmetic and functional restoration. Gentle reduction in the traumatized skeletal framework using a combination of closed and open manipulation techniques, combined with internal skeletal fixation including...
transosseous suture fixation of the caudal septum, nasal base stabilization (and cosmetic refinement) with tongue-and-groove imbrication, unilateral full-length spreader graft placement combined with clocking suture placement, served to sequentially reshape and stabilize the septal L-strut. Additional temporary stabilization using both endonasal and external splinting devices enabled satisfactory molding of the comminuted bony nasal sidewalls for a favorable long-term result. Simultaneous alterations in tip configuration further enhanced the cosmetic outcome.

Case Presentation 2

A 30-year-old woman presented complaining of nasal airway obstruction, rhinogenic headaches, and a persistent posttraumatic nasal deformity following blunt nasal trauma sustained 12 weeks earlier. A comminuted and displaced nasal fracture and lacerations involving the right brow ridge, columellar-labial junction, and left supra-alar skin were sustained in a head-on motor vehicle collision in which the patient impacted the steering wheel (Fig. 7A). The patient was taken immediately to the emergency room where she underwent closed fracture reduction and suture repair of the facial lacerations (Fig. 7B). She reported no history of nasal obstruction, headaches, or nasal deformity prior to injury, and photographs taken immediately prior to injury revealed a symmetric and attractive premorbid nasal contour.

Physical examination revealed a scoliotic nose with leftward displacement of the bony pyramid beginning at the nasion (Fig. 8A). Medial collapse of the right nasal bone and right ULC, lateral displacement of the left nasal bone and left ULC, and leftward canting of the dorsum were also observed. Palpation of the dorsum revealed multiple subcutaneous irregularities consistent with previously comminuted nasal bone. Despite leftward canting of the dorsum, tip positioning remained midline and the dorsal profile was unremarkable (Fig. 8B). The endonasal examination revealed an S-shaped septal deviation with bilateral nasal obstruction, mostly on the patient’s left side. Hypertrophic thickening of the left supra-alar scar was also noted and the remaining examination was unremarkable. Definitive open surgical treatment was recommended and performed 18 days after consultation.

Using the external rhinoplasty approach, the tip complex was carefully degloved revealing only a small tear in the right medial crus. After separation of the membranous septum, bilateral mucoperichondrial and mucoperiosteal flaps were elevated from both sides of the septal partition. Quadrangular cartilage attachments to the ANS and maxillary crest were

Fig. 8 Perioperative photos following delayed open structure stabilization (OSS) for treatment of a persistent posttraumatic nasoseptal deformity. (A) Preoperative frontal view showing leftward displacement of the entire nasal dorsum, and (B) unremarkable nasal profile. Initial postoperative (C) frontal and (D) profile views demonstrating satisfactory contour restoration. Nine-month postoperative (E) frontal and (F) profile views demonstrating satisfactory nasoseptal contour following delayed OSS.
unremarkable, but multiple fractures were encountered in the upper portions of the bony and cartilaginous septum. Multiple bony fractures were observed in the anterior portion of the perpendicular ethmoid plate. Two large fractures were also encountered in the quadrangular cartilage, intersecting at the dorsum approximately 1.0 cm caudal to the rhinion (Fig. 9). The more posterior fracture transected the upper half of the quadrangular cartilage as it paralleled the bony-cartilaginous septal junction. The second fracture ran anteriorly transecting the dorsal L-strut obliquely. At the point of fracture intersection at the mid-dorsum, palpation revealed excessive dorsal instability consistent with subtotal transection of the dorsal L-strut, with movement limited only by the overlying ULCs and soft tissues.

A submucous resection of the septal partition was then performed to eliminate airway obstruction and to obtain donor septal graft material. An L-strut remnant with two large dorsal fractures and an approximate width of 15.0 mm was preserved, and quilting sutures were used to coapt the mucosal leaflets within the donor site. Further degloving in the sub-perichondrial and sub-periosteal plane was then used to expose the outer nasal dorsum. An irregular longitudinal tear was observed along the entire ULC-septal cartilage junction on the patient’s left side. The bony vault was also severely disrupted and malpositioned. The left nasal bone was displaced laterally and oriented vertically. An open roof deformity separated the left nasal bone from the central ethmoid complex and right nasal bone. Although still in continuity, the central ethmoid complex and upper right nasal bone were also displaced to the left of midline resulting in a conspicuous leftward displacement of the entire bony pyramid at the nasal root. To realign the bony nasal vault, an “en bloc reduction” was performed as described by I. Wayne, MD (personal oral communication, presented at the October 2013 Fall Meeting of the AAFPRS). This was accomplished by turning a sharpened Rubin osteotome (Black & Black Surgical Inc.) on its side (with the blade in a sagittal orientation) and driving the osteotome into the nasal process of the frontal bone. With the Rubin osteotome securely anchored in the frontal bone, it was then used to pry the bony septum and right nasal bone (en bloc) into reduction by forcefully displacing the complex toward the patient’s right side. This served to simultaneously realign the malpositioned bony L-strut, and elevate, reduce, and stabilize the previously collapsed right bony sidewall. Once anatomic reduction was achieved, the left nasal bone was then easily in-fractured using only digital pressure. A small area of missing bone at the upper end of the open roof was replaced with crushed septal

Fig. 9  Rhinoplasty worksheet detailing steps for secondary open structure stabilization (OSS) following unsuccessful closed nasoseptal fracture reduction.
cartilage and covered with fibromuscular tissue harvested from beneath the supratip skin. Following open reduction, the bony pyramid remained stable and no further stabilization measures were required.

Once open reduction of the displaced bony pyramid was completed, reconstruction of the comminuted dorsal L-strut was begun. Following separation of the right ULC from the dorsal septum, a 1.5-mm polybeak deformity was resected from the lower dorsal septum. A septal cartilage graft measuring 25 mm long × 8 mm wide × 1.5 to 2.0 mm thick was then placed into a sub-mucoperichondrial pocket created on the right side of the dorsal L-strut. The various L-strut fragments were then sutured independently to the spreader graft with 5–0 polydioxanone sutures, creating a splinting effect and realigning the various fragments in the sagittal midline. The right ULC was then sutured to the complex with interrupted mattress sutures of 5–0 polydioxanone. The torn left ULC was then sutured to the L-strut complex with a running 5–0 polydioxanone suture to fully reconstitute the middle vault. A septal extension graft (SEG) fashioned from septal cartilage was then sutured to the caudal septum using 5–0 polydioxanone figure-of-eight sutures. Modest counter-rotation of the nasal tip was accomplished by inferiorly displacing the medial crura before suturing them to the SEG with 5–0 polydioxanone. The nasal domes were then sutured to the upper end of the SEG and a small infratip shield graft was sewn to the infratip lobule, also with 5–0 polydioxanone, for additional counter-rotation.

Bilateral “articulated” alar rim grafts were then sewn to the nasal domes (on either side of the SEG) for contour enhancement and stabilization of the external nasal valves. After copious irrigation of the subcutaneous pocket with saline, water-tight closure of the skin flap was performed. The nasal cavity was then packed with rolled Telfa gauze coated with antibiotic ointment, and a cinch dressing was applied using Mastisol and sterile tape strips. A prebent aluminum splint was gently crimped over the nasal dorsum for support and both nostrils were tightly packed with strips of Surgicel (Ethicon US LLC, Somerville, NJ) for hemostasis and tamponade.

Despite a well-meaning attempt at closed reduction, this patient presented 3 months later with significant functional and cosmetic sequelae of blunt nasal trauma. Photographs taken immediately prior to closed reduction revealed significant soft tissue edema that increased considerably during the closed reduction attempt (►Fig. 7C, D). The combination of significant swelling and multiple unrecognized septal fractures undoubtedly contributed significantly to the persistent skeletal deformity after attempted closed reduction. Although nearly 15 weeks had elapsed from the time of injury, open reduction in the displaced skeletal fracture was still accomplished with relative ease. Moreover, large amounts of autologous septal cartilage were safely harvested for both L-strut reconstruction and minor cosmetic tip modifications. Inspection following bandage removal revealed improved nasal alignment and normal nasal airway function (►Fig. 8C, D). Long-term follow-up 9 months post-op after several low-dose triamcinolone acetate injections to eliminate left-sided callous formation revealed good functional and cosmetic restoration following secondary open surgery despite the prolonged treatment delay (►Fig. 8E, F).

Discussion

The emotional impact of a misshapen nose can be devastating to self-esteem and may lead to significant psychosocial stress and dysfunction. No less severe are the related functional disturbances that can eventually lead to significant adverse health consequences. Without exception, complete restoration of cosmetic and functional normalcy must be the goal of all initial nasal fracture management. The notion that complex nasal fractures are simple problems that can be effectively treated in the office using closed reduction is not supported by the medical literature. To the contrary, complex nasal fractures are among the most difficult challenges confronting the nasal surgeon, and we believe that consistently favorable outcomes demand the skillful application of advanced open structure rhinoplasty techniques by seasoned practitioners. The timing of treatment is less critical when relying on open fracture management, and allowing for acute swelling, inflammation, and tenderness to subside aids in both treatment planning and in surgical intervention. While plain radiographs may occasionally demonstrate a nasal fracture with clarity, the notoriously poor sensitivity and specificity of plain films render them unreliable and misleading, and there is little justification for obtaining plain X-rays in nasal fracture management, particularly when using open fracture assessment. And while CT scanning is comparatively more informative, it should be reserved for complications of nasal trauma or injuries involving the adjacent craniofacial tissues.

Until the past few decades, consistently effective treatment options for the restoration of severe nasal fractures have been lacking. For this reason, the historical reluctance to pursue early aggressive surgical treatment is both prudent and understandable, and likely explains the widespread tacit acceptance of substandard treatment outcomes. At the same time, sophisticated structural grafting techniques—devised in response to decades of overaggressive incisional rhinoplasty—have become ever more effective and reliable when used in revision rhinoplasty or secondary fracture management. And in light of the undisputed success of timely ORIF in the treatment of maxillofacial fractures, the analogous use of structural grafting techniques for primary stabilization of severe nasal fractures seems both medically appropriate and long overdue. The introduction of motor-driven surgical instrumentation to facilitate precise treatment of bony contour deformities and suture fixation between osseous skeletal components only serves to further justify the use of open surgical intervention for first-line treatment of complex nasal fractures.

The benefits of open fracture management are many. Diagnostic accuracy far exceeds that obtained with either physical examination or contemporary radiographic imaging, and while a thorough physical examination alone is usually sufficient for treatment planning, effective fracture reduction and fixation demands the accuracy of direct visual inspection of the skeletal tissues. Moreover, the same wide-field surgical exposure that optimizes diagnostic accuracy also affords unequalled surgical access for efficacious anatomic fracture reduction—the first step in successful fracture management.
Perhaps more importantly, the open approach also permits direct skeletal fixation using suture-based techniques and structural grafting—time-honored rhinoplasty stabilization techniques that are of critical value in effective fracture management.

The importance of effective skeletal stabilization after successful anatomic fracture reduction cannot be overstated. Without secure skeletal stabilization, the nose remains vulnerable to progressive anatomic distortion from swelling, inflammation, fibrosis, and contracture. Structural stabilization prior to the onset of osseous malunion and/or malicious soft tissue contracture is paramount, as the effects of severe soft tissue contracture are often difficult or impossible to correct in the susceptible patient. Moreover, casual reliance upon secondary surgical intervention as an effective failsafe for unsuccessful closed reduction is both naïve and overly optimistic. Patients with long-standing nasal deformities from inadequate skeletal reduction have a dwindling prospect for successful restoration and would likely have been better served by early OSS. The senior author has been using aggressive OSS of severe nasal fractures as routine first-line treatment for well over a decade, and our clinical experience parallels the successful use of ORIF as the standard of care for other maxillofacial skeletal injuries. Although initial treatment costs are clearly higher than those associated with closed reduction, it is our conviction that avoiding debilitating complications, as well as the costly and sometimes unsuccessful secondary surgeries needed to restore acceptable nasal form and function, more than offsets the initial cost expenditure of primary OSS when administered in skilled hands. Although many practitioners may lack the skill, judgment, or experience to execute these techniques successfully, when cutting-edge strategies and technologies are placed in the hands of a legitimate open structure rhinoplasty expert, unsurpassed clinical outcomes are the rule, and the health care consumer and society at large become the beneficiaries.

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References

Management of the Deviated Nasal Dorsum

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Abstract

The deviated nasal dorsum veers off the ideal straight vertical orientation at midline. Deviations in the dorsum lead to functional and aesthetic consequences that frequently prompt the patient to seek consultation with a rhinoplasty surgeon. An inability to breathe through the nose and self-image perception significantly detracts from the patient's quality of life. Correction of the deviated nasal dorsum represents a challenge for the rhinoplasty surgeon. Anatomic correction of deviations is the goal. Straightening a deviated nasal dorsum will require maneuvers to realign the nose distinct from traditional aesthetic rhinoplasty techniques. The nasal dorsum is formed by the three-dimensional structures of the septum, the bony nasal pyramid, and the cartilaginous nasal midvault. Restoring the position of the septum at midline is the first step in providing adequate support to the nasal architecture. Extracorporeal septoplasty and anterior septal transplant are often necessary techniques to correct the septum and achieve dorsal correction. Subsequently, asymmetric maneuvers to bony dorsum and midvault are performed to restore symmetry. Asymmetric hump reduction and nasal osteotomies are often necessary. Supporting the midvault to avoid nasal collapse often requires asymmetric maneuvers to the upper lateral cartilages and asymmetric spreader grafts. Finally, camouflaging grafts to the nasal dorsum may be necessary. Significant rigidty and memory of the native tissues must be overcome to successfully straighten a nose. The surgeon who can master the deviated dorsum will significantly improve the appearance and quality of life of the patients he or she treats.

Keywords

► deviated nasal dorsum
► crooked nose
► straightening rhinoplasty
► anterior septal transplant
► intermediate osteotomy

The deviated nasal dorsum veers off the ideal straight vertical orientation at midline. Deviations in the dorsum lead to functional and aesthetic consequences that frequently prompt the patient to seek consultation with a rhinoplasty surgeon. Nasal obstruction and asymmetry are often patient complaints. Patients describe their nose as twisted, crooked, or simply asymmetric. Crooked noses are considered less attractive than straight noses.1 In patients with deviated noses, inability to breathe through the nose and self-image perception significantly detracts from their quality of life.1,2

Common causes of crooked noses include congenital asymmetries or acquired defects after traumatic or previous surgery. Congenital crooked noses are often a manifestation of a larger facial skeleton asymmetry such as hemifacial microsomia. The most common facial bone fractures are nasal bone fractures.3 Nasal and facial fractures are often the result of motor vehicle collisions, sports injuries, or assaults. Treatment of chronically deviated noses from trauma that occurred during childhood will differ from the treatment needed for acutely traumatized noses in adulthood. A crooked dorsum and midvault collapse are the second most common causes for revision rhinoplasty following tip asymmetries.4–6 Additionally, patients after rhinoplasty have an increased risk of nasal fractures for up to a year postoperatively.7

Correction of the deviated nasal dorsum represents a challenge for the rhinoplasty surgeon. Anatomic correction of deviations is the goal. Straightening a deviated nasal dorsum will require maneuvers to realign the nose distinct
from traditional aesthetic rhinoplasty techniques. The nasal dorsum is formed by the three-dimensional structures of the septum, the bony nasal pyramid, and the cartilaginous nasal mid vault. Restoring the position of the septum at midline is the first step in providing adequate support to the nasal architecture. Extracorporeal septoplasty and anterior septal transplant are often necessary techniques to correct the septum and achieve dorsal correction. Subsequently, the bony nasal dorsum and the midvault can be addressed. Asymmetric maneuvers to reposition and match one side to the other by augmenting or reducing the nasal walls are necessary. Asymmetric hump reduction and unilateral intermediate osteotomies are often used to address the bony dorsum. Changes to the nasal dorsum must be performed to provide support and avoid midvault collapse. Asymmetric spreader grafts might be necessary. Finally, camouflaging grafts for the nasal dorsum might be utilized. Significant rigidity and memory of the native tissues must be overcome to successfully straighten a nose. The surgeon who can master the deviated dorsum will significantly improve the appearance and quality of life of the patients he or she treats.\(^1,2\)

**Diagnosis of Dorsal Deviations**

The diagnosis of a deviated nose is a clinical diagnosis. A detailed history and physical examination are necessary for appropriate patient selection and timing of potential surgery. Past history of trauma or prior surgeries should be elicited. If an injury occurred, the mechanism should be considered. The time of the injury or past surgery and the age of the patient will influence the need for intervention. During the initial consultation a medical history should elicit concerns of impaired nasal breathing and unsatisfactory nasal appearance. In the case of acquired deformities, it is often useful to compare the current nose with previous photographs.

An accurate preoperative evaluation requires the surgeon to understand the three-dimensional, structural anatomy of the nose (\(\text{Fig. 1}\)). The nasal dorsum should be inspected and palpated. The bony components of the nose are primarily the nasal bones surrounded by the frontal and ethmoid bones superiorly, the maxilla laterally, and the vomer underneath the nasal bones. The nasal bones are thinner and broader caudally, and nasal fractures tend to occur in this location.\(^8\)

The cartilaginous nasal structures include the paired upper and lower lateral cartilages and the midline septum. The attachment of the upper lateral cartilages to the nasal bones prevents collapse at the midvault. The stability of the upper and lower lateral cartilages will give support to the midline position of the septum. The lower lateral cartilages contribute to tip position and contour. External examination of a crooked nose includes an assessment of the bony pyramid, the cartilaginous vault, and the nasal tip separately. Asymmetric spreader grafts might be necessary. Finally, camouflaging grafts for the nasal dorsum might be utilized. Significant rigidity and memory of the native tissues must be overcome to successfully straighten a nose. The surgeon who can master the deviated dorsum will significantly improve the appearance and quality of life of the patients he or she treats.\(^1,2\)

**Fig. 1** Anatomical considerations of the nasal bones. The relationship of the nasal bones to the frontal bone, maxilla, orbit, and upper and lower nasal cartilages is shown. A sagittal view of the components of the nasal septum is shown.
Fracture (Fig. 3). Palpation of the nasal dorsum will also reveal that the nose can be reduced and impacted at the nasofrontal region. NOE fractures require an ophthalmologic evaluation to assess the orbit, medial canthal ligament, and the lacrimal system. Fig. 4 shows the classification of NOE fractures.

Equally important to the external examination is the internal examination of the nose. The nasal septum supports the nasal dorsum at midline. The quadrangular cartilage forms most of the nasal septum. The cartilage tends to thin more caudally, making this portion particularly susceptible to traumatic injury and dislocation. In the case of acute trauma, the septum should be examined for a hematoma that can lead to cartilage infection and reabsorption with further loss of support. In addition to the septum, the nasal valves and nasal cavity should be examined. The internal nasal valve is the point of maximum airflow resistance in the nasal cavity. Nasal valve compromise is a common cause of nasal obstruction and physical examination remains the main diagnostic strategy. The borders of the internal nasal valve are the septum, head of the inferior turbinate, and the lateral nasal wall. The angle between the septum and the upper lateral cartilages should be at least 10 degrees. Nasal endoscopy can be considered as an adjunct method to perform an internal nasal exam.

Different classifications have been described for the variations in nasal deviation. Rohrich et al describe deviations in three main categories: I) caudal septal deviation, II) concave dorsal deformities (C-shaped deformities), and III) concave/convex deformities (S-shaped deformities). Jang et al use five categories to describe if the bony and cartilaginous dorsum are tilted or bent and in which direction. These

Fig. 2 Diagram and picture of a crooked nose. The nasal deviation is a result of an acute nasal fracture. Note the bony dorsum deviated to the right, whereas the midvault and the tip are deviated to the left. Each component should be analyzed independently.

Fig. 3 Physical examination signs of nasoethmoidal fractures (NOE). Telecanthus of the left eye is noted in the first image. Impaction of the nasal dorsum at the nasofrontal region on palpation is noted on the subsequent images.
classifications highlight that to correct twisted noses, it is necessary to note the alignment of the bony pyramid and the cartilaginous dorsum and the shape of each component of the bony and cartilaginous nasal wall independently. Similarly, different classifications have been described for nasal fractures. Nasal fracture classifications highlight the need to examine the anatomical areas surrounding the nasal bones for injuries. Stanc and Robert’s classification is separated into three categories: the first limited to cartilaginous portion of the nose, the second includes the nasal bones, and the third including intracranial and orbital injuries.14 Likewise, Harrison’s classification also reminds the examiner to evaluate for the presence of maxillary, frontal, and orbital injuries.15 Of note, congenital classifications tend to be linear, with the bony dorsum, midvault, and nasal tip pointing in the same direction. In contrast, in acquired nasal deviations the bony dorsum and the midvault often point in different directions.

Preoperative photographs are advised for appropriate documentation and for preoperative discussions of the areas of concern for the patient. The frontal view facilitates examination of dorsal deviations, whereas the lateral view is more helpful for evaluating the radix, dorsal projection, and midvault collapse. On the frontal view, the symmetry and the width of the nose should be inspected. Adequate lighting will allow identification of subtle contour irregularities. Radiographic imaging is rarely necessary even in the case of nasal fractures. Plain X-rays are unreliable and not advised for the diagnosis of nasal fractures. Computer tomography (CT) scans has a better sensitivity and specificity for nasal fractures; however, they are not necessary for the diagnosis of isolated nasal fractures and they carry an additional cost and radiation exposure. Thin cut CT scans are recommended for the management of maxillofacial trauma in which other fractures in addition to nasal fractures are suspected.16

Surgical Management of Nasal Deviation

Closed and Open Reduction of Nasal Fractures

Closed reduction is the simplest way to treat nasal fractures and is reserved for early fractures that are noncomminuted. Open reduction in nasal fractures refers to surgical procedures that require osteotomies and/or incisions. Endonasal and external open approaches are both considered open reduction techniques.17,18 Close reductions are fast and minimally invasive. However, in certain instances closed manipulation of the nasal bones will not be sufficient to achieve symmetry after nasal fractures. Severely comminuted fractures or fractures with severe cartilaginous injuries require open approaches for optimal outcomes. Nasal osteotomies or septorhinoplasty may be necessary to optimally address complicated nasal fractures. Close reduction may be the optimal and definitive treatment for a nasal fracture or alternatively a first step in treatment. Initial closed reduction followed by subsequent open treatments is sometimes planned. The initial closed reduction can help reduce the deformity sustained during the nasal fracture even if the final result requires a revision at a later time when the nasal architecture is more stable.

During closed reduction, instruments or external digital pressure are used to reposition the nasal bones and reduce the nasal fractures. Boies or Goldman nasal elevators are helpful instruments in fracture reduction. When a nasal bone is displaced medially, the elevator can be placed under the depressed nasal bone, to elevate it anteriorly and reposition the nasal bone on the frontal process of the maxilla laterally. When a nasal bone is displaced laterally, digital pressure toward the more medial position is usually sufficient to mobilize the nasal bone medially and reduce the fracture (Fig. 5). To be able to successfully perform a closed reduction, the nasal bones should still be mobile. If the repair is delayed too long, the fracture may have healed and a rigid union solidified. Closed reduction is usually advised 5 to 10 days after the initial injury in adults and 3 to 7 days for...
children. Open reduction may be performed acutely or in a delayed fashion where new osteotomies will be necessary. The Asch or Walsham septum-straightening forceps can be used to straighten a mildly deviated nasal septum or even to elevate centrally depressed and impacted nasal bones. Moderate or severe septal deviations should be addressed separately via a septoplasty. Failure to correct a septal deviation, particularly a high septal deflection, may exert tension on the mobile nasal bones and displace them even after a successful fracture reduction.

Multiple studies, including randomized trials, have examined the use of local anesthesia versus general anesthesia for nasal fracture reduction finding equal cosmetic and functional results. Patient safety, overall health, and cooperativeness, as well as overall cost and operating room availability should all be considered. Nasal blocks, administered either intranasally or externally, are effective in providing local anesthesia to the nose. Children usually require general anesthesia, whereas selected adults can benefit from local anesthetics. Postoperatively, nasal casts and intranasal packing can be used to maintain the reduction.

Following closed reduction, patient satisfaction rates range from 60% to 90%, whereas physician satisfaction is typically lower in the 20% to 60% range. Revisions in cases of closed reductions are not uncommon and have been described in ranges of 9% to 50% in prospective clinical trials. Improved precision from these more invasive approaches is the goal in open reduction. Studies indeed suggest better corrections and higher patient satisfaction can be achieved with open reduction than with closed reduction.

**Straightening and Supporting the Dorsal Septum**

The septum represents the central support of the nose and, because of this septal deviations, will manifest as external nose deviations. The nasal septum must be straightened and stabilized at midline to allow for a successful correction of a crooked nose. The upper lateral cartilages, the midvault, and even the bony pyramid will parallel the dorsal septum. The nasal tip will follow the caudal septum. The dorsal septum is particularly important because it forms part of the internal nasal valve and correcting any deviation is key in restoring nasal breathing. When a septal deviation is present, it is necessary to isolate it from the surrounding structures to be able to address each component of the nose independently. Failure to correct a deviated nasal septum is often quoted by authors as the main cause of redeviation after straightening rhinoplasty.

When performing a septoplasty, the deviated cartilage can be removed while preserving a 1 cm L-strut for nasal support dorsally and caudally. The keystone area is the junction of the perpendicular plate of the ethmoid with the dorsal septum. Preserving the keystone area of the septum is important as it...
represents the support area for the junction of the nasal bones with the upper lateral cartilages (►Fig. 6). Fractures or thinning of the cartilage along the L-strut should be noted as they might require reinforcement. Mild and moderate deflections of the septum in the dorsal middle-vault region can often be straightened with spreader grafts secured to the septum and the upper lateral cartilages. When using this technique, the grafts splint the deviated dorsal septum and should overcome the curvature of the septum. Cross-hatching of the cartilage can be employed to weaken any remaining memory of prior curvature prior to placement of the spreader grafts. The concave surface of the cartilage is the one that is cross-hatched to allow this shorter surface to extend and match the longer length of the contralateral convex surface (►Fig. 7).

Severe deviations of the nasal septum may require more extensive reconstruction of the septum such as extracorporeal septoplasty, subtotal, or anterior septal transplant via an external approach (►Fig. 8). In these techniques, large portions of the septum or the entire septum are removed en bloc, straightened, and then replaced inside the nose. After the resection of the deviated portion, a new L-strut is constructed with cartilage grafts. If the whole septum is entirely removed, a new L-strut must be stabilized and fixated onto three points: the most cephalic portion of the dorsum, the nasal spine, and to each other. The dorsal limb of the L-strut reconstructs the profile of the dorsum, and the caudal limb at the nasal spine reconstructs the posterior septal angle. When necessary, the dorsal limb can be secured to the remnant bone by drilling holes into the bony septum to allow for suture resuspension of the cartilage construct. The caudal limb to be resuspended to the nasal spine might require suturing the graft to the periosteum. Once the L-strut has been positioned at midline, the upper and lower lateral cartilages can then be reattached. It is important to remember the position of the medial crura and the caudal limb of the L-strut will determine nasal projection and rotation (►Fig. 9). When the whole cartilaginous septum is resected and the dorsal strut is reconstructed, there is a risk of collapse and of dorsal asymmetries at the rhinion. Where the nasal skin is thinnest, that should be taken into consideration. Dr. Gubisch reported postoperative dorsal asymmetries and saddling at a rate of 8% (50/567) and patients elected revision septoplasty in 5% of cases (28/567).29

When possible, the integrity of the dorsal septal strut and its attachment to the keystone area can be preserved in situ and an anterior septal reconstruction be pursued. Preserving the dorsal strut facilitates the reconstruction and can help prevent dorsal asymmetries and collapse. By resecting the caudal septum, caudal septal deflections can successfully be corrected (►Fig. 10). The caudal septum and its attachments to the dorsal septum must now be restored. Different designs for the reconstruction grafts have been described.28–31 The reconstruction graft must function as both: an extended spreader and an extended columnella strut. One or two separate cartilage grafts can be used depending on the available cartilage. When the two grafts are going to be used, the extended spreader graft is secured to the remaining dorsum and to the upper lateral cartilages and it is allowed to come anteriorly to overlap with the columnella strut (►Fig. 12). An anterior pocket is dissected between the medial crura of the lower lateral cartilages to allow for placement of the columella strut. The columnellar strut must be tall enough to allow the overlap and project the anterior septal angle. The medial crura are secured to the columnella strut to restore tip support. ►Figs. 13 through 15 show pre- and postoperative pictures of a patient who successfully underwent an anterior septal transplant.
Although the extracorporeal septoplasty and the anterior septal reconstruction can be technically demanding to perform, complication rates are similar to other septoplasty techniques. If the integrity of the L-strut is compromised, the patient is at risk for developing a saddle nose deformity and an over-rotated tip. In recent years, absorbable plates have been used to support the newly reconstructed septum as a temporary healing scaffold. Polydioxanone (PDS) plates are now commercially available for this purpose. The lack of long-term outcomes particularly regarding infections rates, the product’s cost, and insurance coverage should be taken into consideration prior to its use.

**Hump Reduction**

Given the asymmetric size of the nasal bones in deviated noses, hump reduction in these cases requires asymmetric resection of the hump. The height of the nasal bone on the side that is deviated laterally is longer than the opposite side. The more vertically oriented nasal bone is usually shorter in height. To symmetrically correct a dorsal hump, the longer nasal bones will require greater resection than the shorter bone. When calculating how much hump resection is necessary on each side, it is useful to plan where the osteotomies will be placed and to estimate the resultant size of walls of the bony pyramid. To be able to achieve a greater resection...
of the hump on the lateralized side, the position of the instruments should be oblique with a lower position on the side that requires greater resection (Fig. 17). The hump reduction is performed prior to osteotomies when the bony vault is still stable to increase precision. Subsequently, the nasal osteotomies can be performed to close any open roof, narrow the bony dorsum, and often to straighten the nasal bones. After the osteotomies are performed, the nasal bones will be straightened by medializing the previously lateralized nasal bone. If the hump reduction does not account for the difference in sizes of the nasal bones, the dorsum will not be symmetric after osteotomies. The difference in sizes of the nasal bones might not be apparent until the nasal bones are approximated medially after lateral osteotomies, but should be considered in advance. Additional rasping might be necessary after the nasal bones are repositioned to avoid irregularities in the dorsum. As with traditional hump reduction, the periosteum should be elevated off the nasal bones prior to the chisel or the raspatory being used.

Nasal Osteotomies
In crooked noses, the nasal bones the position and height of the nasal bones is different on each side. Osteotomies will mobilize and may help reshape the bony pyramid. A combination of lateral, intermediate, and transverse osteotomies may be necessary to straighten a twisted bony dorsum (Fig. 18). The side that is deviated laterally is longer than the opposite side. The more vertically oriented nasal bone is usually shorter in height. A unilateral lateral osteotomy to medialize the longer lateralized nasal bone or, more often, bilateral osteotomies in conjunction with an additional intermediate osteotomy on the longer nasal bone may be necessary.

In subtle deviation, a unilateral lateral osteotomy might be enough to match the size of the nasal bones. In more marked deviation, medializing the more lateral nasal bone with a lateral osteotomy will not be enough to match the height of the contralateral nasal bone. In those more severe cases, an intermediate osteotomy is used to further reduce the height of the longer side (Fig. 19). The intermediate osteotomy is
designed in the middle of the longer nasal bone and paralleling the path of the lateral osteotomies to prevent comminution of the nasal bones. Intermediate osteotomies should be performed before performing lateral osteotomies.

Lateral osteotomies start in the pyriform aperture and follow a “high-low-high” pattern, creating a fracture along the ascending process of the maxilla and the nasal bones. The osteotomy should start above the insertion of the inferior turbinate to prevent medialization of the turbinate, which would result in nasal obstruction. If a hump reduction was previously performed, the lateral osteotomies will allow the bony pyramid to be mobilized to a straight position. If a hump reduction is not performed, a transverse osteotomy at the radix will be necessary to separate the attachment of the perpendicular plate of the ethmoid to the nasal bones. The transverse osteotomy effectively separates the nasal bones from the base of skull, allowing the bony pyramid mobility to be repositioned at the midline (Fig. 20).

After performing multiple osteotomies, preserving the periosteal attachment to the nasal bones will prevent destabilization and collapse by preserving the attachment.
to the overlying soft tissue envelope. The osteotome will tend to follow prior fractures lines where fibrous union has occurred and control of the path of the osteotomy is critical to achieve precise fractures. These maneuvers rely on palpation rather than direct visualization. Intranasal or percutaneous osteotomy techniques can be used. We advocate performing nasal osteotomies prior to proceeding to midvault reconstruction. Changes in alignment of the bony dorsum will change the anatomy of the midvault and may change the decision making of the surgeon. Intraoperative bleeding has not been a problem in our practice. To minimize bleeding, we advocate injection with local anesthetic and epinephrine along the path of the osteotomy and the use of sharp osteotomes that will avoid unnecessary bone trauma.

Midvault Reconstruction
Reconstruction of the midvault relies on asymmetric spreader grafts to straighten and support the dorsal septum and on matching the size of the upper lateral cartilages. The goal is to support the midvault and restore the dorsal aesthetic lines. Spreader grafts are placed in a pocket between the septum and the upper lateral cartilages, and they span the length of the midvault. Cephalically, the grafts extend to the caudal edge of the nasal bones and caudally, to the anterior septal angle. The grafts are secured in place with sutures between the upper lateral cartilages, the grafts, and the septum.\(^\text{36,37}\) In deviated noses, a concave side needs more grafting material to match the more convex side. A larger graft or even two spreader grafts may be needed on a collapsed nasal side.\(^\text{37}\) Septal cartilage is the preferred grafting material for spreader grafts given its straight conformation. Auricular and costochondral cartilage, ethmoid bone, or alloplastic material might also be used.\(^\text{37,38}\) Alternatively to spreader cartilage grafts, ethmoid bone may be used as a graft to straighten the dorsal septum. Bone grafts in the nose, however, tend to be more noticeable than cartilage and are often partially or completely resorbed.\(^\text{39,40}\)

Figs. 21 and 22 show pre- and postoperative images of a patient with a crooked nose that
required asymmetric spreader grafts with an autospreader graft used only on one side.

As with the nasal bones, the length of the upper lateral cartilages is also asymmetric in crooked noses (Fig. 23). There is a longer more lateral side and a shorter more medial side. Asymmetric upper lateral cartilages may need size adjustments to achieve symmetry. These differences will only be noticeable after the upper lateral cartilages have been separated from the septum and the bony dorsum has been straightened. A longer upper lateral cartilage may be trimmed to match the contralateral side. Rarely, is there a need to adjust the length of the upper lateral cartilages caudocephalic dimension, but routinely the height of the cartilages in anterior to posterior dimension needs to be equalized. The upper lateral cartilages are held straight before they are secured in place to help prevent cartilage buckling.

Minor concavities in the nasal dorsum can be addressed with onlay camouflage grafts. Onlay grafts have a tendency to be noticeable over time, especially in patients with thin skin. To minimize visibility, the cartilage should be crushed. Temporoparietal or temporalis fascia can be used to cover the cartilage grafts and minimize the chance of the grafts being visible through the skin. Fig. 24 shows a patient that required a camouflage dorsal graft.

**Conclusion**

In a crooked nasal dorsum, anatomic realignment of the septum and surrounding structures is necessary to achieve
an aesthetic result and relieve nasal obstruction. Extrinsic and intrinsic forces that contribute to deviation should be isolated and addressed. Addressing the nasal septum is a priority. Often, an extracorporeal septoplasty and L-strut reconstruction will be necessary. The bony nasal dorsum requires asymmetric hump reduction and asymmetric osteotomies, often including intermediate osteotomies. The midvault relies on asymmetric spreader grafts and on adjusting the upper lateral cartilage to stabilize and prevent nasal collapse. The inherent memory of bones and cartilage should be expected and overcompensated to prevent recurrence.

References
Autologous Rib Grafts in the Management of the Crooked Nose

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Abstract

Keywords
- rhinoplasty
- costal cartilage
- crooked nose

Rhinoplasty is arguably one of the most challenging procedures a facial plastic surgeon performs. Numerous techniques have been developed since the inception of rhinoplasty to aid in correction of aesthetic and functional issues. Congenital, iatrogenic, and traumatic etiologies can all lead to a crooked nose. Autologous rib or costal cartilage grafting is a powerful tool that can aid the surgeon in successful correction of the crooked nose.

Analysis of the Crooked Nose

Septorhinoplasty requires a keen eye to examine and understand the deformity prior to formulating a surgical approach. A thorough physical examination is a necessary step when planning rhinoplasty. Assessment of skin type and thickness is important as thicker skin will better camouflage irregularities in a reconstructed nasal framework. It is also important to assess symmetry of the nose as well as overall facial asymmetry that may generate the perception of nasal deviation. The nose must be considered as one portion of the entire face to ensure facial harmony. Visual evaluation of the nasal alignment is performed with attention to the bony vault, the middle vault (cartilaginous dorsum), and the nasal tip.1 Anterior rhinoscopy may reveal septal deviation contributing to the outward appearance of the nose. The internal nasal valves are examined and assessed for obstruction. Observation during normal and deep inspiration may reveal external valve collapse. Once a thorough evaluation is completed, we obtain photographs, including frontal, oblique, lateral, and basal views (► Figs. 1 and 2). Subtle deformities missed in the clinical examination are sometimes noticed during systematic review of the photographs for surgical planning. Photographs also serve as a tool to candidly discuss the findings with the patient and appropriately manage their expectations prior to undergoing any surgery.2

The Evolution of Grafting in Rhinoplasty

Von Mangoldt described the first autologous costal or rib cartilage graft used in nasal reconstruction in 1889.3 Rib cartilage is now widely recognized as a viable material for grafting in advanced rhinoplasty. Alternative grafting materials in the nose include nasal septal cartilage, auricular cartilage, allografts, and alloplasts. Septal cartilage that can be easily harvested does not carry with it the risk of secondary donor site morbidity. However, previous cartilaginous trauma, septal perforation, or prior nasal/septal surgery can diminish the amount of available cartilage stock.4 Auricular cartilage is another readily available source of grafting material. Though auricular cartilage harvest has minimal donor-site complications, its intrinsic elasticity and curvature make it less useful in correction of the crooked nose.5 Irradiated homologous cartilage allografts have been described as a grafting source in rhinoplasty but have fallen out of favor due to propensity for unpredictable resorption over time.6,7 Alloplastic implants such as silicone or porous polyethylene have also been described for use in rhinoplasty but carry with them risks of extrusion, infection, foreign-body reaction, as well as scarring of the soft tissue envelope of the nose.8,9 For correction of the crooked or twisted nose, we have found autologous rib cartilage to be a very useful grafting material.
Fig. 1  A 52-year-old patient with a history of childhood nasal trauma. Had corrective septorhinoplasty at age 17 but complained of persistent deviation of nose to the right and left greater than right nasal obstruction owing to left high septal deviation and bilateral internal valve obstruction.

Fig. 2  One year s/p external septorhinoplasty with rib grafting for bilateral extended spreader grafts, caudal septal extension graft, onlay lower lateral cartilage replacement grafts, and crushed cartilage Peck graft. Bony vault was addressed with lateral osteotomies.
**Patient Selection: When to Use a Rib Cartilage Graft**

While costal cartilage harvest provides a substantial stock of strong and versatile grafting material, harvest can carry morbidity. Therefore, careful patient selection is important. The most common indication for costal cartilage grafting is a lack of septal cartilage. In revision rhinoplasty, a large portion of the septal cartilage has often already been removed. Previous trauma may also diminish the amount of quality septal cartilage available because of dense scarring, resorption, and/or fracture lines. Marked caudal or dorsal septal deviation is another indication to use costal cartilage. Because of its stiffness, costal cartilage is ideal for buttressing or replacing deviated segments of the dorsal or caudal septum. We also harvest rib cartilage when numerous grafts are required. In a patient with a severely crooked nose, it is not uncommon to place spreader grafts, septal battens, and lateral crural strut or batten grafts as seen in the patient in Figs. 3 and 4. Even in the unoperated nose, it is challenging to fashion all of these grafts from septal cartilage alone, and auricular cartilage may be too elastic or curved for major reconstruction.

**Technique for Rib Cartilage Harvest**

Numerous techniques have been described for the harvest of costal cartilage. We favor an open approach to the fifth, sixth, or seventh ribs. These ribs provide a substantial and relatively straight piece of cartilage that can be carved into appropriate grafts for rhinoplasty. Once the patient is prepped and draped, a 2- to 4-cm incision overlying the fifth rib in males and just above the inframammary crease in females is made through the skin with a number 15 blade. The incision is placed medial to the nipple line (Fig. 5A) as the cartilaginous portion of the rib is located medial to this line. Prior to making the incision,

![Fig. 3](image-url) A 29-year-old patient with history of previous nasal trauma and severe nasal obstruction secondary to internal and external valve collapse. (A–D) Note that these four images represent the standard views for a rhinoplasty candidate.
Subcutaneous infiltration of 1% lidocaine and 0.25% bupivacaine, with 1:100,000 epinephrine is performed for hemostasis and postoperative pain control. Subcutaneous dissection through fat, fascia, and muscular layers is performed bluntly or with electrocautery as needed. One must dissect directly over the rib; palpation within the dissection field is important to ensure good exposure. Once dissection down to the perichondrium is complete, the bony-cartilaginous junction can be identified by careful insertion of a 27-gauge needle into the rib serially. This maneuver helps the surgeon detect the lateral most portion of the rib cartilage that can be harvested. The thickest rib cartilage stock is typically located adjacent to the junction. A scalpel is used to make incisions around the borders of the perichondrium of the rib. The anterior perichondrium is lifted as a single piece off of the underlying rib using a Freer elevator (Anthony Products, Inc., Indianapolis, IN) (Fig. 5B). The excised perichondrial layer is valuable as a camouflage graft later in the procedure and is placed in saline. The glistening white hyaline cartilage of the rib is identified just deep to the removed perichondrium. In older patients, the cartilage can become more yellow and granular in appearance. The cartilage of older patients is also more likely to contain calcification deposits.

A Freer elevator is used to develop a subperichondrial plane initially along the superior cut edge. Similar elevation is performed along the inferior edge so that the perichondrium is completely elevated from the undersurface of the rib. Incisions are made at the medial and lateral aspects of the cartilage segment while protecting the underlying perichondrium with the Freer elevator. Blunt dissection of the rib cartilage from any remaining perichondrial attachments completes the release of the rib segment (Fig. 5C). The harvested cartilage is placed into saline. Careful inspection of the deep layer of perichondrium is performed and saline is placed in the dissection cavity. The anesthesia provider increases the intrathoracic pressure with a Valsalva maneuver.
maneuver to check for an air leak that signifies a tear of the parietal pleura. We close the donor site in layered fashion. We routinely obtain a chest radiograph after the procedure to rule out a pneumothorax. Donor site incisions typically heal well (Fig. 5D).

Although the aforementioned technique is our method to procure costal cartilage grafts, several other methods have been described. Ching and Hsiao described a method for transumbilical rib graft harvest. Visible scars after cosmetic surgery, including those on the chest wall, are a major concern in Asian culture. In a case series of eight patients, they describe a method using an incision hidden in the superior umbilical crease. With endoscopic dissection in a plane superficial to the rectus sheath, they obtained a segment of the eighth rib. They report that portions of the seventh and ninth ribs can be harvested for additional cartilage stock. Overall length from harvested cartilage ranged from 4.5 to 7 cm. Another method described by Kobayashi et al involved using a small 1.5- to 2-cm skin incision in the inframammary crease then using rigid endoscopes to assist with dissection of the costal cartilage not directly visualized in the field. They report ease of dissection due to magnified clear images even when using such a small skin incision.

Complications of Rib Cartilage Harvest

Costal cartilage is a mainstay of revision and difficult septorhinoplasty; however, it carries risks to the patient that must be discussed. Pain at the donor site is the most common sequela of rib cartilage harvest. While it is a foreseen consequence of dissection on the chest wall, it is still disconcerting for patients in the immediate postoperative period. We routinely use bupivacaine injection that provides local pain control in the first few hours after surgery. Uppal et al endorsed placement of a catheter within the wound bed to administer bupivacaine over the first 48 hours in the immediate postoperative period. In addition to pain at the site, clicking and crepitus can occur after harvest of multiple ribs. While this is reported more often in the case of costal cartilage harvest for auricular reconstruction, it is a potential complication of single rib harvest for rhinoplasty as well. In a case series of patients who underwent rib cartilage harvest for auricular reconstruction, only 3 of 42 patients experienced clicking of the chest wall. It resolved spontaneously in all patients and none of them found it disconcerting.

Another complication of costal cartilage harvest is postoperative chest wall deformity. Once again, this complication is more often reported in cases of multiple rib harvest for auricular reconstruction, but should be a concern of any surgeon procuring rib cartilage during his or her procedure. Several studies that have examined multilevel costal cartilage harvest for microtia repair demonstrated that post-surgical chest wall deformity can result in secondary spinal deformity. This is thought to be a sequela of altered or asymmetric growth between the operated and normal sides of the chest in growing patients.

Another study by Wallace et al used CT imaging to measure the growth and dimensions of the chest in both adult and growing patients after multiple level costal cartilage harvest for microtia repair. They demonstrated that in growing patients there is significant deformity in the sagittal plane at the donor site at 1 and 6 months with CT scan, suggesting...
that the operated chest wall does not grow at the same rate as the unoperated side.\textsuperscript{16} Though most studies that show marked chest wall deformity and subsequent morbidity have focused on microtia patients, it is still a complication of which surgeons performing costal cartilage harvest should be cognizant. Fortunately, because most rhinoplasty patients are adults and only a single rib is harvested, chest wall deformities have not been observed in our practice.

Pneumothorax is the most concerning immediate complication of costal cartilage harvest. One series quotes the incidence of “pleural perforation” to be as high as 22\%\textsuperscript{15} We have observed a very low incidence of pneumothorax with our described method of rib cartilage harvest. Though thoracostomy tube placement may be indicated if this complication occurs, the likely need is extremely small. Small tears to the parietal pleura may occasionally be noted intraoperatively when the Valsalva is performed. Because the visceral pleura is unlikely to be injured, an ongoing air leak is not expected. All remaining air can be evacuated with negative pressure through a red rubber catheter placed into the tear and removed just prior to wound closure. Most of these patients are asymptomatic and can undergo observation without major intervention. Though chest X-ray remains the diagnostic study of choice, ultrasound has been suggested for early detection of pneumothorax as well. One study showed that ultrasound was more sensitive than conventional upright chest radiography to diagnose pneumothorax.\textsuperscript{17} Another case report details the use of an ultrasound to rule out pneumothorax in a woman who underwent rhinoplasty and concurrent costal cartilage harvest at an outpatient surgery center where rapid chest radiography was not possible.\textsuperscript{18}

Costal cartilage provides generous stock from which the surgeon can carve multiple grafts for correction of various deformities in septrhinoplasty. There is a known risk, however, for the grafts to warp over time. Warming may cause aesthetic deformity or compromise the stability of functional rhinoplasty repair. Though the time it takes for a graft to warp entirely is debated, numerous studies have been performed to investigate the properties of costal cartilage and how best to mitigate warping factors. Gibson and Davis had one of the first studies exploring warping for costal cartilage used for dorsal augmentation in rhinoplasty patients in the 1950s. Through review of their techniques, they discovered that grafts carved from the central portion of the harvested rib cartilage had a lower propensity to warp over time.\textsuperscript{19} They popularized the method of “concentric” carving, whereby the central portion of the rib cartilage is carved into appropriate grafting pieces. Eccentric carving refers to the use of the outer, rounded cartilage around the periphery of the harvested block.

Numerous studies since have examined the warping properties of concentric versus eccentric carving on graft warping. Toriumi et al saw increased warping at 1 hour and 2 weeks postharvest of eccentrically carved grafts, while there was some initially warping noted in the concentric group, it was significantly less than the eccentric grafts.\textsuperscript{20} To combat this unpredictable warping, Gunter et al have suggested placement of K-wires into dorsal costal cartilage grafts.\textsuperscript{21} We do not typically use wire stabilization. It has been suggested that calcification of the costal cartilage that occurs naturally as we age leads to less warping over time. In one moderately sized retrospective review, the investigators found an inverse relationship between age and warping in patients who underwent costal cartilage grafting in conjunction with rhinoplasty. Younger patients had a higher incidence of side-to-side warping of costal cartilage grafts than did their older counterparts. Calcification of costal cartilage in older patients may be responsible for a lower incidence of warping.\textsuperscript{22}

**Correction of the Crooked Nose**

If any of the three major nasal divisions (bony vault, mid vault, tip) are asymmetric, the nose appears crooked. To achieve aesthetic functional goals, all divisions must be addressed at the time of surgery.

**Correction of the Upper Bony Vault**

Deviations of the upper third of the nose, or the bony vault, should be addressed during septrhinoplasty to correct the crooked nose. The brow-tip aesthetic lines should form a smooth curve tracing the brow and lateral aspects of the nose symmetrically.\textsuperscript{23} Classically, osteotomies have been used to straighten any deviation of the upper third of the nose. When evaluating the bony vault, it is important to visually inspect and palpate the contour. This may reveal irregularity, asymmetry, or prior fracture lines that must be corrected. In the deviated bony vault, discrepancies in nasal sidewall length are common. Multiple osteotomies of the longer sidewall may be required to restore nasal symmetry. Lateral osteotomies are a mainstay in rhinoplasty surgery. Webster et al introduced the “high-low-high” lateral osteotomy in the 1970s.\textsuperscript{24} This maneuver, performed in either a continuous or perforating manner, starts high on the pyriform aperture, then swings low on the ascending process of the maxilla, and finally finishes high superiority on the nasal bone to mobilize it. The surgeon can then use digital manipulation to appropriately mold the bony vault. The reason for this curvilinear trajectory is to protect the anterior nasal airway at the level of the pyriform aperture. A single asymmetric intermediate osteotomy can be used when one nasal bone is appreciably wider than the other.\textsuperscript{25} Parkes et al reported a “double lateral osteotomy” technique where essentially a second lateral osteotomy was performed on one side; this unilateral double osteotomy can be used on the side of an elongated nasal bone to correct deviation of the bony vault.\textsuperscript{26} Medial osteotomies may be a useful adjunct to control back fracture.

**Correction of the Middle Vault**

Deviations of the middle third of the nose may result from a displaced dorsal septum, asymmetric upper lateral cartilages, and separation of the upper laterals from their overlying nasal bones. Problems in this area are reflected in the internal nasal valve (INV), which is bordered by the septum, the upper lateral cartilages (ULCs), the superior pyriform aperture, and the head of the inferior turbinate. The mainstay of middle
vault correction in the severely deviated nose is the use of spreader grafts\textsuperscript{27} (\textit{Fig. 6}). These 1- to 2-mm-thick grafts can be used to reconstitute the cartilaginous nasal dorsum, fix asymmetry, and improve the function of the nasal airway.

Though spreader grafts can be placed through an endonasal approach, we prefer the external approach for correction of the crooked nose. This approach allows the ULCs to be completely separated from the septum in a submucoperichondrial plane. Spreader grafts can then be sutured between the cartilaginous septum and the ULCs.\textsuperscript{5} Several modifications of traditional spreader grafts are possible when using abundant costal cartilage. A septal batten is a modification that can be used to correct a deviated dorsal septal strut. The septal batten is placed in the traditional spreader graft location but may be 1 to 1.5 cm in height as needed. This graft overcomes intrinsic dorsal septal deviation. When the native dorsal strut must be divided to remove persistent deviation, the septal batten reestablishes dorsal support. Another modification of the traditional spreader graft is the extended spreader graft. Traditional spreader grafts only run the length of the upper lateral cartilages (\textit{Fig. 6}). Extended spreader grafts up to 4 cm in length can be fashioned from rib cartilage that span the entire distance from the nasal bones to the caudal edge of the septum. Extended spreaders and septal battens that extend to the caudal septum or beyond give the surgeon maximum control of the nasal axis and nasal tip position that is frequently useful when straightening the crooked nose (\textit{Fig. 7}).

Asymmetric spreader grafts are also very useful when correcting a crooked middle vault. Placing a unilateral spread graft on the concave side of the nose will open the INV and camouflage the deviated dorsum.\textsuperscript{28} If both INVs must be stented, double-thickness spreader grafts can be used on the concave side of the nose. In cases where septal cartilage can be used, an extended osteocartilaginous spreader composed of septal cartilage and perpendicular plate of the ethmoid can be used to correct middle vault asymmetry.\textsuperscript{29} It is important to attempt to reattach the ULCs in the midline if spreader grafts are not used, as this prevents on open roof which can lead to an inverted V deformity of the nasal bridge postoperatively. Infolding of the medial edge of the ULCs before suturing them in the midline has been described when spreader grafts are not indicated. These “spreader flaps” can also close the middle vault roof in a scenario with a minimally deviated dorsal septum.\textsuperscript{30}

### Correction of the Nasal Tip

Numerous techniques have been described for refinement of the nasal tip. As these techniques are extensively discussed in other publications, we will not address them directly here. We will focus on correcting deformities of the caudal septum and grafting to modify the lower lateral cartilages.

When the lower third of the nose is displaced compared with the upper two-thirds, a “clocking suture” is an asymmetric suture technique that can help reposition the tip in the...
Combining extended spreader grafts with a clocking horizontal mattress suture is a powerful technique to correct a persistently deviated nasal tip in the crooked nose. A horizontal mattress suture is first placed through the upper lateral cartilage that is contralateral to the direction of tip deviation. The suture is then passed through the caudal septal and extended spreader graft complex and tightened as desired to bring the tip back to the midline (Fig. 8).

Asymmetries of the lower lateral cartilages can be corrected with suture techniques and the use of lateral crural strut grafts. Careful dissection between the lateral crurae and the vestibular lining provides pockets for placement of the grafts. A pocket within the alar soft tissue or under the alar crease may be required to accommodate the lateral aspect of each graft. If alar retraction is present, the lateral extent of the graft can be positioned more caudally to reposition or stabilize the alar rim. Fig. 9 demonstrates standard technique for lateral crural strut graft placement.

After straightening the nasal axis and correcting lower lateral cartilage deformities, the tip must be reconstituted. For the crooked nose, the most reliable technique is to secure the medial crurae in tongue and groove fashion to the reconstructed caudal septum. Great care must be taken to keep tip rotation within acceptable limits when executing this maneuver. Alternatively, the traditional columnellar strut can be secured between the medial crurae if the LLCs are already sitting in the midline.

**Correction of the Nasal Septum**

In addition to correcting asymmetry in the three major divisions of the nose, septal pathology must also be corrected during septorhinoplasty. To prevent saddling, tip ptosis, and deprojection of the nose, 1-cm-wide dorsal and caudal L-struts should be left intact. Cartilage resection and scoring techniques have long been described to straighten a deviated septum, but more advanced techniques may be required in a severely crooked nose. If the caudal septum has been dislocated from the maxillary crest, it can cause both aesthetic

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**Fig. 8** Clocking suture and unilateral extended spreader graft or septal batten for correction of deviated middle vault and nasal tip.

**Fig. 9** (A) Meticulous dissection of vestibular lining from the lateral crus. (B) Pocket after complete release of vestibular lining. (C) Insertion of lateral crural strut graft. (D) Final graft placement prior to suture stabilization.
and functional concerns for a patient. This often occurs posttraumatically. A popular technique for correction of this deformity is referred to as the “swinging door” technique. The caudal portion of the septum may be displaced to one side of the maxillary crest. To reposition it during an open approach, the caudal septum is separated from the crest and anterior nasal spine and a small portion of the cartilage is resected inferiorly. The septum is then brought over the maxillary crest to the other side of the nasal cavity and the cartilage is scored on the concave side to help correct any bowing. The septum can be sutured to the premaxilla for stability. 

Occasionally there is bowing of the septal cartilage at the “elbow” of the L-strut. Following correction of other deviated portions of the septum, this area must be addressed independently. Excision of a “Burow” triangle involves making an incision through the anterior septal angle at the elbow of the L-strut to separate the dorsal and caudal limbs of the septum. Overlapping cartilage is then resected, and dorsal and caudal limbs are reapproximated at the newly straightened anterior sepal angle. Some deformities of the anterior septum are so marked, however, that they require complex reconstruction from harvested costal cartilage. Septal battens and caudal septal extension grafts have been described to assist with straightening the caudal septum. If the native caudal septal strut cannot be straightened, complete replacement may be necessary. Extended spreader grafts or a septal batten can be sutured to the caudal septum or caudal septal replacement to stabilize the entire L-strut.

Conclusion

Straightening a crooked nose remains one of the more challenging rhinoplasty procedures. Upper, middle, and lower thirds must be evaluated and appropriate maneuvers applied to each area if a successful result is to be achieved. Traditional osteotomies are used for the bony vault, but cartilage grafting is often required for the middle vault and tip. We favor the use of autologous rib grafts in our patients lacking sufficient septal cartilage stock. This includes patients undergoing revision surgery, those with prior trauma making sepal cartilage quality poor, and in those patients requiring numerous grafts that exceed the supply of septal cartilage. Meticulous attention is necessary during graft harvest to minimize the likelihood of pneumothorax and during carving to minimize graft warping. In a properly selected patient with a crooked nose, we find rib grafting to be a valuable tool.

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Nasal fractures are the most commonly encountered fractures of the human skeleton and account for more than 50% of facial fractures in the United States,\(^1\) with an estimate of more than 50,000 nasal fractures occurring every year.\(^1,2\) These are most commonly due to motor vehicle accidents, interpersonal altercations, and falls.\(^1,3,4\) Men are up to three times more likely than women to sustain a nasal fracture.\(^3,5\) An additional consideration is that what may be perceived as a minor trauma may have quite a large impact for the patient due to the cosmetic and functional changes.\(^6,7\)

Problematic sequelae of trauma may include simple lacerations, obvious nasal bone/cartilage deviation, nasal obstruction, or septal destruction with subsequent saddle-nose deformity. Scarring of the external nasal skin can lead to visible deformities, whereas internal nasal scarring can lead to internal nasal valve obstruction. From a functional standpoint, compromise may occur as a result of nasal bone collapse, septal deviation, or disarticulation of cartilaginous attachments.

From a clinical standpoint, nasal fracture repair is fraught with many considerations. There is debate regarding optimal timing, surgical approach, and extent of repair. Fractures are quite variable in presentation given the diversity of etiology, amount of force applied, and direction of impact.\(^8\) One additional unknown is how the healing process will affect future nasal appearance and cosmetic appearance. Seemingly small insults may, over time, lead to further complications in both the appearance of the nose and nasal patency. Given these uncertainties, patients are counseled on the possibility of multiple surgical interventions prior to undergoing the first procedure.

This article explores some of the basic anatomy, current understanding of nasal trauma biomechanics, current controversies in nasal fracture management, and techniques for nasal fracture reduction. By exploring the topic, the hope is to avoid common pitfalls and oversights when dealing with the traumatized nose and to compile current understanding of the topic.

**Pertinent Anatomy**

**Blood Supply**

The blood supply of the nose is a rich series of anastomoses between the external and internal carotid arteries.\(^9\) The external nose is mainly supplied by the angular artery and superior labial arteries (external carotid artery) with contributions from the dorsal nasal and external branch of the anterior ethmoidal arteries (internal carotid artery). The internal lining of the nose is supplied by a combination of the sphenopalatine and greater palatine arteries (external carotid artery) and the anterior and posterior ethmoidal arteries (internal carotid artery).
Notable external landmarks for nasal blood supply are the columella which possesses the columellar artery (branch of superior labial artery), nasal ala which is traversed by the lateral nasal artery (branch of the facial artery), lateral nasal sidewall along which runs the angular artery (terminal branch of the facial artery), medial palpebral ligament above which emerges the dorsal nasal artery (terminal branch of the ophthalmic artery), and keystone area where the external nasal branch of the anterior ethmoidal artery (branch of the internal carotid artery) emerges from between the nasal bones and upper lateral cartilages.

Notable internal landmarks for nasal blood supply include the posterior edge of the middle turbinate where the sphenopalatine artery emerges from the sphenopalatine foramen (branch of external carotid artery), the openings of the incisive canal in the anterior nasal floor (branch of external carotid artery), anterior and posterior ethmoidal arteries in the superior nasal cavity (branches of internal carotid artery), and Kiesselbach’s plexus in the anteroinferior portion of the septum, where many of these vessels converge.

**Innervation**

Branches of the trigeminal nerve are mainly responsible for sensation of the nose. The external nose is supplied by branches of the infraorbital nerve to the lateral nasal walls, columella, and vestibule. The nasal tip and dorsum receive contributions from the supratrochlear and anterior ethmoidal nerve (from the nasociliary nerve branch of the ophthalmic nerve). Internally, the lateral walls and septum are supplied by the sphenopalatine ganglion and branches of the anterior ethmoidal nerve. A branch of the sphenopalatine ganglion is the nasopalatine nerve, which descends down the septum to travel under the periosteum along the floor of the nose to enter the incisive foramen. Disruptions can lead to paresthesias or numbness of the central maxillary incisors following nasal surgery.

**Skin and Soft Tissue Envelope**

The nasal skin and soft tissue envelope varies in thickness and composition in different regions of the nose. The upper and lower thirds of the nose possess a thicker skin envelope, with the thinnest skin located in the middle third at the rhinion. Beneath the skin is the fibromuscular layer of the nose (also known as the nasal SMAS) which allows movement for facial expressions and nostril flaring. The underlying support of the nose is a combination of bone and cartilage that help support the skin and provide a rigid framework to prevent collapse of the nasal passages during inspiration. The foundation of the nose is built upon a bony platform that allows the nose to structurally span the pyriform aperture. The pyriform aperture is a heart-shaped opening composed of the nasal bones superiorly and the sharp edges of the nasal surfaces of the maxilla, both laterally and inferiorly, as they curve around to join the anterior nasal spine.

**Osseous Framework of the Nose**

The nasal bones comprise the bony vault and are paired pyramid-shaped bones that abut the nasal process of the frontal bone superiorly and the frontal process of the maxillary bone laterally. They are joined in the midline and are connected by fibrous attachments to the upper lateral cartilages inferiorly. Measurements of average nasal bone length are around 24 mm\(^{1,12}\) but vary in patients based on age and race. The thickness of the nasal bones is thickest superiorly, thinning inferiorly. The bones tend to be hourglass-shaped with the widest points superior and inferior and a narrowing of the nasal vault near the medial canthus. The junction of the nasal process of the frontal bones and paired nasal bones comprises the nasal root and corresponds with the radix. The position of the radix should be located at the upper eyelid crease, but may be lower in some ethnicities.\(^{13,14}\) Posterior to the superior nasal bones, as part of the medial orbit, lies the lacrimal bone, which the surgeon should be aware of when performing osteotomies.

Inferior to the nasal bones are connections to the bony septum, which are composed of the perpendicular plate of the ethmoid bone, superiorly, and the vomer, inferiorly. These two bones allow formation of a buttress to connect the cribiform plate of the ethmoid bone to the nasal floor. Beneath the vomer lies the nasal crest of the maxilla, anteriorly, and the nasal crest of the palatine bone, posteriorly. Underneath these crests is the support of the anterior nasal spine and palatine process of the maxillary bone. The anterior nasal spine is the attachment of the caudal septum and forms the posterior septal angle (\(\text{\textasciicircum}1 \text{~Figs. 1 and 2}\)).

**Cartilaginous Framework of the Nose**

The most important structural cartilage of the nose is the nasal septum, which comprises the lower third of the nose. Described as quadrilateral in shape, the average size of septal cartilage is around 33 mm in height and 37 mm in width, and varies with gender and ethnicity.\(^{15}\) The septum is connected posteriorly to the perpendicular plate of the ethmoid and vomer bones. Along the dorsal surface, the septum is attached on either side to the upper lateral cartilages. The caudal end of the dorsal septum begins a triangulated turn to the anterior nasal spine. These angles are known as the anterior, intermediate, and posterior septal angles. The width of the septal cartilage is variable, with thinner areas near the caudal edge and central portions and thicker cartilage near bony articulations.\(^{8}\) Recent evidence suggests that the collagen and glycosaminoglycan composition varies when comparing the dorsal septum to the caudal septum.\(^{16}\)

The lower two-thirds of the nose, or cartilaginous nasal vault, is built on the support of the nasal septum and composed of the paired upper lateral cartilages, paired alar cartilages, and minor contributions from the sesamoid cartilages. The upper lateral cartilages form the middle vault, are described as trapezoidal in shape, and originate beneath the nasal bones. Medial connections between the septum and upper lateral cartilages form part of the internal nasal valve with an ideal angle of 10 to 15 degrees.\(^{17}\) The alar, or lower lateral, cartilages are C-shaped cartilages that curve from the pyriform aperture, traveling medially to form the nasal tip, then inferiorly to rest near the anterior nasal spine. The alar cartilages are thus divided into three segments:
lateral crus, intermediate crus, and medial crus. The junction of the intermediate and lateral crura is the most projecting point of the nasal tip and is known as the tip-defining point. Support of the lower lateral cartilages derives from attachments to the pyriform aperture, which contain the sesamoid cartilages, superior attachments to the upper lateral cartilages at the scroll area, attachments to the nasal septum medially, and attachments to the contralateral alar cartilages. These cartilages allow support of the external nasal valve and are the defining external feature of the lower third of the nose.

**Biomechanics of Nasal Trauma**

Nasal injury secondary to the application of superphysiologic forces to the nose manifests in several traumatic patterns. The
amount of energy, the duration, and how force is distributed to the tissues are important factors in determining the resultant injury pattern. A blunt injury from a fall creates a much different outcome than a laceration from a knife or a blast from a bullet injury. The different combinations of vector and force result in a varying constellation of fractures of bones and cartilage, as well as soft tissue injuries.

The nasal bones require the least amount of force to fracture compared with the other bones of the face.\(^{18}\) Although not proven, this presumptive shock absorber function is beneficial when considering the adjacent vital structures, including the orbits, ethmoid sinuses, and cribiform plate. As little as 16 to 66 kPa can induce a lateral displacement of nasal bones, as demonstrated in cadaveric studies. A variation of direction will determine the amount of force required to cause a fracture, with frontal impacts generally requiring more force to cause a nasal fracture than impacts from the side.\(^{18}\) For frontal types of axial injuries, the nasal septum, and cartilages bear the brunt of force. Multiple investigators have described fracture patterns through cadaveric studies, showing many fractures originate behind the anterior nasal spine and traveling superiorly toward the regions of the perpendicular plate of the ethmoid bone.\(^{18-20}\)

High-energy injuries, as seen in motor vehicle accidents, can generate extremely large amounts of force and, when applied in an axial pattern, can result in telescoping injuries or saddle deformities that may be present in conjunction with other facial fractures including naso–orbito-ethmoidal (NOE), orbital, or frontobasilar fractures.\(^{18,21-23}\)

Shearing forces come into play in pediatric nasal trauma, where the more flexible cartilages and bone are less susceptible to fracture. As a result, small feeding vessels to the cartilage may rupture and cause hematomas under the mucoperichondrial flaps. Given the avascular nature of cartilage and its dependence on surrounding mucosa, cartilage necrosis may occur as soon as 24 hours after injury and progress to abscess formation.\(^{24}\) Even without an obvious outward appearance of a nasal fracture in children, suspicion of septal hematoma should remain high in the presence of nasal trauma\(^{25}\) (Fig. 3).

Fractures, displacement, and avulsions of cartilaginous structures are less apparent as these injuries are rarely visible on computed tomography (CT) or X-ray. The resultant negative impact on the anatomy, however, contributes to deformity and airway obstruction. Avulsions of the upper lateral cartilages are also frequently initially masked by swelling and hemorrhage (Fig. 4).

Clinical Presentation and Diagnosis

Patients with a history of nasal trauma may present with isolated nasal fractures or fractures in combination with other facial injuries. A thorough history including prior nasal trauma, surgery, and preexisting deviations should be documented. Typical histories may include epistaxis, nasal pain, nasal deformity, edema, bruising, and nasal obstruction. A history of epistaxis indicates damage to the mucosal lining and should raise suspicion for cartilage injury. The mechanism of injury, including force and direction, should be elicited. High-velocity and high-energy injuries may be compounded by tissue loss, additional facial fractures, or critical injuries. For example, a group of patients with a documented orbital or nasal fracture were shown in one study to have a 4.5% risk of having an associated cervical spine injury.\(^{26}\)

Examination should be performed as promptly as possible in the case of recent trauma. It is helpful to make a note of pretraumatic appearance with the assistance of a driver’s license or photograph. A nasal examination begins with an external observation of edema or ecchymosis. Lacerations of the skin, soft tissue, or cartilage should be noted. Obvious deviation of the nose and septum should be documented. Obvious deviations may be noticeable immediately, but subtle injuries may be masked by edema and become more evident as swelling subsides and fibrosis occurs. Specific deformities of the nose and nasal dorsum may include a foreshortened nose, saddle nose, alar retraction, crooked nose, septal deviation, middle vault collapse, and cicatrix of the external skin envelope or nasal lining (Fig. 5). In an acute injury, edema will frequently mask deformities and warrant reevaluation in 5 to 8 days.

The evaluation of the soft tissue is important to aid in the diagnosis of the potential injuries in the underlying skeletal features. The condition of the soft tissues will also influence the potential timing of any repair efforts. For instance, a laceration of the skin may overlie a disruption of the lateral crura. An avulsion of skin may be indicative of an avulsion of cartilage or bone. Massive swelling in the soft tissue envelope may delay surgical correction of the delicate underlying cartilaginous framework until the swelling subsides. Finally, skin with vascular compromise secondary to stellate lacerations may be put at further risk with early attempts at surgical correction of the nasal skeleton.

Examination of the nasal passages should be performed with anterior rhinoscopy. Nasal patency can be evaluated by examining the nose for internal and external valve collapse and the response to a modified Cottle maneuver. Palpation of
the nose should note any step-off deformities, crepitus, and swelling or stiffness. Support of the dorsum and nasal tip should be assessed as an indicator of septal integrity. If there is a question of a septal hematoma, a cotton tip applicator can be used to palpate the area of concern. Nasal endoscopy may be necessary to assess for posterior septal fractures. Septal injuries are relatively common. Recent studies confirm a high frequency of corresponding cartilaginous fractures with nasal bone fractures. Mucosal lacerations and epistaxis are also predictive indicators of septal trauma. Complications of septal fracture may include septal deviation, loss of support, nasal obstruction, septal hematoma, septal cartilage necrosis, septal abscess, and saddling. As mentioned previously, suspicion for septal hematoma should remain high in the pediatric population despite an absence of external findings. Any finding of a hematoma warrants decompression and stabilization.

With the increasing availability of CT scanning, many patients receive a maxillofacial CT to assess for nasal and other facial fractures on arrival to an emergency facility. The
value of CT scanning in the evaluation of isolated nasal fractures, however, is still a matter of debate.19,27

Classification of Injuries
A thorough discussion of nasal fracture classification is outside the scope of this manuscript. The reader is referred to the discussions of this topic by Murray et al and Ondik et al.18,28

Timing of Repair
There is limited consensus on the optimal timing of repair of posttraumatic nasal deformities and functional issues, because nasal injuries can be quite varied and present differently depending on the clinical setting. Situations that should be addressed promptly include lacerations and other soft tissue injuries, acute soft tissue loss, and acute severe saddling. More minor disruptions can frequently be left to allow swelling to subside for several weeks. At a timeframe of 6 weeks or later, nasal surgery of a more refined nature can be performed to achieve optimal aesthetics. When there is an acute deviation with nasal fracture, acute osteotomies may be performed as recommended by Ondik et al.28

In general, the authors address soft tissue injuries, avulsions, and exposed cartilage very early in the clinical course. The repair of major saddling or significant deviations is addressed in a subacute timeframe, and osteotomies and limited septoplasty may be performed. More minor corrections that require more of a rhinoplasty grade result are performed in a delayed timeframe to allow swelling to be completely resolved.

Commonly Used Grafting Techniques
Whether or not the surgeon uses an open or closed approach in the repair of the traumatic nose is a matter of personal experience and preference. Given the uncertainty of the patient’s posttraumatic anatomy, in many situations, there will be an advantage to performing these maneuvers via an open approach.

A review of commonly used grafting techniques in rhinoplasty after trauma follows. Clinical presentations that can be addressed with the techniques reviewed include foreshortening of the nose, saddling of the dorsum, columellar retraction, alar retraction, the crooked nose, septal deviation, middle vault collapse, cicatrix, and others. Although this article is focused on the posttraumatic situation, the techniques are also valuable in primary and revision rhinoplasty.

Sources of Grafting Materials
The authors routinely use cartilage to replace, buttress, and augment the skeletal structures of the nose. Grafting with bone is uncommon and is usually restricted to the use of cantilevered split calvarial bone grafts for the restoration of central nasal support in cases of complete saddle nose deformity as seen with nasoethmoid fracture. Thin pieces of ethmoid bone are also occasionally used in septal cartilage repair. In many instances, septal cartilage is the preferred cartilage to be used in rhinoplasty. In the situation of the posttraumatic nose, the nasal septal cartilage may be compromised, excessively crooked, or deficient. At this point in time, many surgeons consider the rib to be the next preferred donor site. The advantage of a rib donor site is the abundance of cartilage that can be carved into a variety of useful shapes to be used for grafting.

Fig. 6 Harvest of auricular cartilage via a posterior approach. (A) Intraoperative photograph showing placement of incision lateral to the postauricular sulcus. This positions the wound over the areas of cartilage to be harvested and facilitates closure. (B) Exposure of underlying postauricular musculature and perichondrium that will be divided and retracted. (C) Isolation dissection of cartilage of cymba concha.
Auricular cartilage is still used and is frequently chosen for a variety of factors, one of which may be the patient’s wish to avoid the harvesting of rib cartilage. Like the septal cartilage donor source, however, even auricular sources can be limited in the provision of adequate donor material.

Other tissues that have utility in reconstructive and corrective rhinoplasty are perichondrium from costal and auricular sources and fascia from the temporalis muscle. Many surgeons routinely use homologous grafting materials; the authors of this manuscript prefer autogenous materials. Given the multiple donor sources available from a particular patient, there is usually sufficient cartilage at hand without creating excessive donor site morbidity.

Septal cartilage is harvested at the time of septoplasty. The authors routinely elevate bilateral septal mucoperichondrial flaps to aid in cartilage harvesting. Sufficient dorsal and caudal support of the septum has to be preserved. It is optimal to leave approximately 1.5-cm-wide residual struts. However, in some circumstances, as little as 1 cm may be adequate. Acceptable harvested cartilage must have sufficient dimensions to carry out the necessary grafting tasks to be useful. The advantage of using septal cartilage is that it is readily available during nasal surgery. Disadvantages and risks are the frequent lack of sufficient cartilage and that harvesting may lead to septal perforation and diminishing support of the nasal dorsum.

Auricular cartilage can be harvested via either anterior or posterior incisions (►Fig. 6). The amount of cartilage that can be used will be relatively limited if one is to avoid creating a deformity. In essence, both the cymba concha and the concha cavum can be harvested. Leaving the intervening strut of cartilage will preserve the support of the ear and lessen deformity. An advantage of the auricular cartilage donor site is that the ears are close to the field during rhinoplasty. Disadvantages and risks include the relative limited amount of cartilage that can be harvested and also the unforgiving nature of auricular cartilage when placed along the dorsum. Unless precisely contoured, the grafts frequently reveal their edges and ridges through the overlying nasal skin envelope over time.

A major advantage of the use of costal cartilage in corrective and revision rhinoplasty is the availability of sufficient cartilage for most contingencies. In the younger patient, the cartilage is relatively soft and easily modifiable. The costal area is also an excellent source of a hearty perichondrium that can be used to help thicken the nasal soft tissue skin envelope, thus providing good cover over cartilage grafts. Disadvantages of the use of the chest wall for cartilage harvest are numerous and include the risk of significant pain, as well as the small but very real risk of pneumothorax. In the older patient, the cartilage may be calcified and unusable for carving into adequate graft sizes. Finally, there is a risk of graft warping, which can occur in spite of recommendations about balance carving and other modifications. Nevertheless, in the patient who needs a large amount of cartilage to use for grafting, the chest wall offers a reasonable alternative (►Fig. 7).

Spreaders, Extended Spreaders, and Articulated Spreaders

Spreaders and extended spreader grafts are used in a variety of ways to address traumatic anatomic nasal derangements. Spreaders can be used to correct deficiencies in the middle vault of the nose including collapse and avulsion of the upper lateral cartilages, to “brace” a fractured septum to a corrected midline position, and to serve to cosmetically restore the contour of the nasal sidewall. Spreaders are used in the correction of dorsal saddling, functional collapse of the nasal sidewall, internal nasal valve collapse, and the crooked nose. The role of spreader grafts in the correction of the severely deviated septum and the crooked nose is fundamental to reestablishing a straight midline. They are used in isolation and also in conjunction with other grafts, including caudal extension grafts, columellar strut grafts, and

Fig. 7 Intraoperative photograph of harvest of costal cartilage and perichondrium from right chest: (A) perichondrium removed from intact rim, (B) rib cartilage removed and access incision, (C) demonstration of cartilage being carved into usable grafts.
nasal sidewall grafts. These grafts can vary in width, thickness, and length, depending on donor site considerations and the purpose in using the grafts. Variations of the designs of spreader grafts include extended spreader grafts and pistol grafts. Finally, an articulated spreader graft may be constructed by suturing the spreader grafts to a caudal

Fig. 8 Drawings depicting the dynamics and structure of “articulated” spreader grafts. (A) Reference positioning of bilateral extended spreader grafts sutured to residual septum and septal caudal extension graft. The upper lateral cartilages are divided away from the septum. The lower lateral cartilages are not depicted. (B) By articulating the attachments between the spreader grafts and the septal caudal extension graft, the position and shape of the “new” septal caudal margin can be changed. After the desired positioning is obtained, the grafts undergo final suture fixation. This articulated spreader graft complex, in turn, will be a key factor in the final shape and height of the nasal dorsum and nasal tip positions.

Fig. 9 Intraoperative photographs of patient undergoing the construction of an articulated spreader graft: (A) The septum is isolated by performing septoplasty, elevation of bilateral mucoperichondrial flaps, and division of upper lateral cartilages from the septum. Note septum is foreshortened. (B) The septum is projected and lengthened by the placement of a caudal extension graft. (C, D) Articulated spreader graft complex is constructed by the suture of bilateral spreader grafts to the caudal extension graft to adjust overall height and length of a new anterior superior septal angle.
extension graft or vertical “strut,” thus creating a new “L-strut” for the nose (►Figs. 8 and 9).

By adjusting the position of the extended spreader grafts along the strut or caudal extension graft, the articulated spreader graft complex can be used to lengthen the nose and to change tip rotation and projection of the dorsum and tip. Spreader grafts can be created using auricular, septal, or rib cartilage. The need to construct the spreader grafts with a sizeable straight piece of cartilage will frequently influence the donor site selection. The use of septal cartilage and rib cartilage is preferred many instances.

Dorsal Augmentation and Nasal Sidewall Grafts

Graft selection for the augmentation of the nasal dorsum is dependent on the degree of saddling of the nose, the anticipated volume and dimension of the desirable correction, and the remaining skeletal support of the nasal dorsum. Grafts may be created to restore the entire dorsum or may be limited to only restoring selected portions of the nasal dorsum and sidewalls. 31 Restoration of support is necessary when there has been disruption of central nasal support along the midline axis caused by a significant loss of septal integrity, as seen with comminuted fractures, cartilage loss, and perforation. In these situations, the augmentation will have to be constructed to provide support by being cantilevered or be supported by other structural mechanisms, that is, spreader grafts. A new L-strut may be created to bridge a deficient support mechanism between the frontal or nasal bones and the maxilla. This can usually be done with cartilage grafts. In extreme situations, such as the complete loss of central nasal support, split calvarial bone may be used in a cantilevered fashion. 32

Graft materials include septal cartilage, rib cartilage, and layered auricular cartilage. It is sometimes helpful to use composite grafting with fascia and diced cartilage. 33 Recently, there have been several reports about dorsal augmentation performed with diced cartilage held together with biological adhesives. 34 In the case of the posttraumatic nose, septal cartilage is frequently deficient. Rib cartilage provides adequate volume and dimension to restore large amounts of volume and also has the structural strength to restore a new L-strut with connection with a caudal extension graft or columellar strut. If only volume is necessary, layered auricular cartilage may be used. The placement of temporalis fascia or rib perichondrium over the reconstructed dorsum is helpful to thicken the overlying thin skin and minimized the risk of the visibility of postoperative dorsal irregularities (►Figs. 10 and 11).

Septal Replacement and Caudal Extension Grafts

Caudal extension grafts have been described by several authors as a method to correct the foreshortened nose and deficiencies of the septum that are either the result of fractures or loss of cartilage. If the cartilage graft is used to replace a portion of the caudal septum that is missing because of previous surgery or trauma, it is sometimes referred to as a septal replacement graft. The caudal extension grafts can be used when there is sufficient integrity of the terminal portion

Fig. 10 (A–C) Preoperative photographs of the patient with history of severe nasal trauma with resultant saddling of the nasal dorsum, foreshortening of the nose, and septal perforation. (D–F) Postoperative photographs of the patient after reconstructive septorhinoplasty performed via an open approach. Corrections included the repair of the septal perforation with temporalis fascia, dorsal augmentation with a two-layer auricular cartilage graft and lengthening the nose, and derotating and projecting the tip with extended spreader grafts articulated with a columellar strut.
of the septum to allow the securing of the graft to the remnant of the septum. It can also be used in a modified form and incorporated into an articulated spreader graft. These grafts are typically used in underprojected and foreshortened noses to increase dorsal height, tip projection, and to lengthen the nose. Septal, auricular, or rib cartilage is used to create the grafts (Fig. 11 and 13).

Columellar Strut Grafts
Strut grafts have been described in a variety of ways. For this discussion, the strut grafts described are those that are sutured between the medial and intermediate crura. Strut grafts can be used to reestablish tip projection, to straighten deformed medial crura, replace cartilages that have been destroyed by trauma, widen the columella, and to provide further caudal projection of the columella. Typically, septal or rib cartilage is the preferred grafting material for the columellar strut. Auricular cartilage can be used, but care must be taken to find an optimally straight piece or laminate two opposing pieces together. This elongated rectangle-shaped cartilage graft is placed between the medial crus so that it spans from the anterior nasal spine toward the intermediate crus. It is a frequently used and powerful graft for increasing or preserving nasal tip support and projection. Some surgeons place columellar struts prophylactically to resist contractile forces that occur following...
septorhinoplasty, as well as resisting the ptosis of the nasal tip acquired with aging and lack of support from the septum. One drawback of placing a columellar strut can be avoided by leaving a cushion of soft tissue above the nasal spine, which helps prevent the “clicking” of the strut that some patients experience\(^\text{35}\) (Fig. 14).

**Tip Grafts**

There have been a variety of tip grafts described that have various functions, including those designed to lengthen the nose, improve the shape of the tip, influence tip rotation, increase projection, and to soften irregularities at the level to tip. Cap grafts\(^\text{36}\) placed on the nasal tip or supratip lobule can be fashioned from conchal, septal, or cephalic trim cartilage, and are used to increase tip projection or for definition of the supratip break. Shield-like grafts\(^\text{37}\) are used in the nasal tip and extend to the infratip lobule. Caution should be taken for all tip grafts used in thin skin patients where additional coverage with fascia, morselized cartilage, or crushed cartilage should be considered (Fig. 15).

**The Lateral Crural Strut Graft**

The lateral crural strut graft is used by the senior author primarily to change the axis of the lateral crus of the lower

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**Figure 13** (A) Pre- and (B) postoperative photographs of the patient who underwent revision septorhinoplasty after trauma and previously surgeries. He patient presented with nasal obstruction. Examination revealed a lack of support of the distal two-thirds of the nose and a positive modified Cottle maneuver. (C) Intraoperatively the patient was found to have an absence of his caudal septum. (D) Repair involved the use of bilateral lateral crural strut grafts, a left spreader graft, and a caudal extension graft. The photograph shows the caudal extension graft in place. The cartilage was obtained from a rib donor site.

**Figure 14** Intraoperative photograph depicting the suturing of a columellar strut between the medial crura. Note that the strut is sutured more posterior to allow the most caudal aspect of the medial crural to impart the contour of the columella.

**Figure 15** Intraoperative photograph depicting the suturing of a shield-like tip graft to the intermediate crural of this traumatized nose. In this position the graft will serve to increase tip projection and nasal length.
lateral cartilage, to support the ala, improve the airway, and to improve the lobule-alar contour. These grafts are placed between the vestibular lining and the lateral crus (Fig. 16). The lining can be undermined from the posterolateral two-thirds of the lateral crus to a point approaching the dome. The lateral undermining may extend over the pyriform aperture to allow for further support of the lower lateral cartilages. The grafts have considerable utility in the correction of external nasal valve and intervalve collapse. Inspection of the support of the ala during inspiration and the use of a modified Cottle maneuver will help the surgeon assess alar support and the need for the use of this grafting technique.

Alar Batten Graft
The alar batten graft is used in similar circumstances to those in which the lateral crural strut graft is used. The senior author, however, uses this grafting technique preferentially to the lateral crural strut graft technique when there is a significant need to change the actual shape and contour of the lateral crus itself. This may be encountered after trauma, after previous rhinoplasty, or with developmental deformity. The alar batten graft is different from the lateral strut graft in that it is sutured on the anterior surface of the lateral crus of the lower lateral cartilage. In this position, the graft provides improved integrity, support, and shape to the lateral crus, which is imparted to the ala. The sculpting and placement of the graft determines the final resultant shape. These grafts are placed either endonasally through an intercartilaginous incision into a pocket overlying the lateral crus or via an open rhinoplasty approach and sutured in place. They may vary in length and dimension and may extend along the entire lateral crus (Fig. 17).

Contour Grafts and Composite Grafts
Contour grafts and composite grafts are used to provide support, change the shape of the alar margin, and to change the alar-columellar relationship. Alar composite grafts and contour grafts are indicated for the treatment of alar notching or asymmetric rim height that may occur as a result of scarring. They will aid in the correction of alar retraction and the hanging columella. Whether or not a contour graft or composite graft is used depends on the clinical situation. Factors to be considered are the stiffness of the alar margin and other soft tissue factors. If it appears that there is an actual vertical deficiency of lining along the alar margin, the senior author will commonly use a composite graft. For alar defects greater than 3mm, alar composite grafting is typically recommended. Cymba concha cartilage with overlying skin is taken from the lateral surface of the ear and inserted in the vestibular incision. Typically, grafts are less than 1 cm in size to optimize graft survival. These techniques may be accomplished by either an open or closed technique.

Other Grafts and Other Considerations
Posttraumatic rhinoplasty presents as a surgical challenge. The magnitude of this challenge correlates directly with the extent of the original trauma. When there has been a significant disruption of the normal nasal anatomy and contour, the surgical challenge increases. Even after early adequate repair of cartilaginous and boney deformities, the patient’s nose continues to change over time as the destructive result of the energy dissipated through the nasal tissues. Deformity and dysfunction manifest with the resolution of swelling and evolving scar contraction. The patient may therefore present early or late after an injury. Revision surgery is common compared with elective rhinoplasty (Fig. 18).
The challenge frequently includes the need to replace and restore the underlying nasal anatomy. A wide repertoire of grafting techniques is important to address a wide variety of deformities. Stabilization grafts become as important as the selection and sculpting of the grafts if the surgery is to be successful. In these surgeons’ hands, the direct suturing of grafts has been demonstrated to be dependable and reproducible. The creation of precision pockets for the placement of grafts endonasally has equally been reliable. These authors have limited experience in the use of adhesives.

In some areas of the nose that come under tension, such as the nasal dorsum and the tip, additional care has to be exercised to prevent imperfectly contoured grafts from being visible over time. These authors frequently utilize methods to soften the graft contour, such as moralization of edges or the use of crushed cartilage. Fascia and perichondrium grafts are frequently added to thicken the soft tissue cover over cartilage grafts.

Finally, some mention must be made about the morbidities of these procedures. All the grafting and harvesting techniques presented here have been performed numerous times by

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Fig. 18 Series of photographs of the patient who presented after a nasal fracture (A) initial presentation, (B) the patient 3 months later after undergoing secondary septrhinoplasty with septrhplaty and osteotomies, (C) the patient 2 years after the procedure, (D–F) the patient 12 years later and without a history of intervening trauma presented with further crookedness to her nose, tip asymmetry, and flattening of the left ala, (G–I) secondary repair involving the use of lateral osteotomies, dorsal augmentation with auricular cartilage, a left alar batten graft, and a complete strip on the left.
these authors. It is felt that all of the harvesting techniques have acceptable morbidities to justify their use in the restoration of these patients’ appearances and nasal function. It should be remarked that these procedures do have risks that have to be considered as these procedures are executed. Donor site complications include infection, pain, pneumothorax, deformity, and hematoma.

**Conclusion**

This manuscript has presented several grafting techniques that are frequently used by these authors. These techniques have been found to be reliable and usable in a variety of patients after trauma, as well as in the setting of revision and primary rhinoplasty. This is not meant to be a comprehensive presentation of all available techniques, and the readers are encouraged to investigate other sources beyond the associated references to gain an even broader appreciation of the repertoire of grafting techniques available.

**References**


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Essential Grafting in the Traumatized Nose

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The Role of Transverse Osteotomies in Severe Nasal Trauma

John L. Frodel, Jr., MD


Abstract

Facial trauma commonly produces trauma to the nose and perinasal area. In this review, emphasis is on the treatment of the severely deviated nose in terms of excessive shift of the bony dorsum and bony pyramid. In particular, we focus on the problem of centering the severely deviated bony dorsum and when we believe it is helpful to move the entire bony dorsum as a unit, utilizing the transverse osteotomy in addition to traditional osteotomies.

Keywords

► deviated nose
► crooked nose
► osteotomies

Nasal trauma represents the most common form of trauma in the craniomaxillofacial region and is the most frequently seen fracture for most facial plastic surgeons. It is well known that such injuries commonly lead to both the functional and aesthetic deformities, and it is generally accepted that not all fractures are correctable with acute management. The literature is replete with a wide variety of surgical techniques for the deviated or crooked nose after nasal fractures.1–5

There is further discussion in the literature of the evaluation and management "saddle" or compressed nose.6,7 The crooked or deviated nasal fracture deformity is most common and likely results from a blow of any etiology that arises at a side or oblique angle to the nasal region. It is this healed, established deformity that will be the focus of review. It is reasonable to state that not all nasal deviations are the same and that the degree of complexity will escalate with the addition of surrounding perinasal fractures and soft tissue injuries such as dislocation or avulsion of the medial canthal region.

The surgeon must evaluate the posttraumatic deviation in terms of specific contributions of various nasal components: septal deviation, deviation of the middle cartilaginous vault and tip, nasal pyramid asymmetries, fracture irregularities of the bony dorsum, and true deviation of the bony dorsum.

The evaluating surgeon of a secondary posttraumatic nasal deformity must take into account the initial injury complexity as inadequate primary management may greatly impact how one approaches these injuries and the counseling required from the doctor to the patient regarding the various issues that exist in addition to an obvious functional and aesthetic posttraumatic nasal deformity.

In this review, we discuss the more traditional management of significantly deviated posttraumatic nose, but focus on, using case examples, a particular subset of the deviated or crooked nose where severe fracture deformities that lead to true deviation of the actual bony dorsum (with or without fracture irregularities and/or cartilaginous deflection and deviation) exist. We review why traditionally described techniques may not always be effective for such deformities.

The Deviated Nose

Discussions of the management of the deviated nose abound in the literature and clearly demonstrate that there is no single proper or sufficient way to manage such deformities. It is important when assessing the deviated nose to determine the components that are involved in contributing to the external deviation. These can be isolated bony or cartilaginous deformities, but most commonly a combination of both the bone and cartilaginous middle vault as the pathophysiologic cause for the deviation. Certainly these patients often present with functional nasal obstruction that can be the result of the underlying deviated septum and other issues such as collapsed internal nasal valves and sidewall collapse. Occasionally there is external nasal valve or alar instability as well that can be part
of the cause for the nasal obstruction. Accordingly, a sequential evaluation of the functional deformity is essential.

While most deviated noses can be addressed with a variety of accepted osteotomy and restructuring techniques, the more severely deviated nose can be fraught with inadequate straightening unless the bony pyramid is adequately mobilized. Experience has shown that when the bony rhinion is deviated well off the midline, it will pull with it the attached dorsal septum and attached upper lateral cartilages. With this in mind, techniques that release the upper lateral cartilages from the dorsal septum with the use of other techniques such as spreader grafts and upper lateral cartilage onlay batten grafts may not provide adequate improvement or adequate apparent straightening of the external nose. Additionally, the use of traditional lateral, medial, and intermediate osteotomies may not adequately mobilize the deviated bony rhinion to assist with straightening of the nose. Most discussions of management of the deviated nose in the literature assume that there is the requirement of bony hump reduction that either creates an open roof to the dorsum or at least adequately weakens the bony dorsum such that when lateral and/or intermediate osteotomies are performed, there will be easy movement of the dorsum (and the rhinion) to the midline.

Once becoming aware of the frustrations that could result from inadequate mobilization of the deviated bony dorsum with traditional osteotomy techniques, we begin to realize that an osteotomy must be designed to allow for release of the nasal bones, the attached ascending process of the maxilla to meet the lateral osteotomies, but a deeper penetration of the attached underlying perpendicular plate of the ethmoid. Without release via osteotomy of the lower septal perpendicular plate, the internal nasal structure immobilization of the bony dorsum to the midline is not possible. It is certain that care must be taken to osteotomize lower anterior in the perpendicular plate of the ethmoid to avoid any injury superiorly to the cribriform plate (in our experience, this complication has not happened). We have found that most of these severe deviated rhinoplasties require a “disassembly” septoplasty with total release of the upper lateral cartilages, followed the use of accepted restructuring techniques such as spreader grafts and extended spreader grafts, caudal extension grafts, and traditional tip restructuring along with additional tip restructuring techniques as well as various forms of batten grafts, depending on the situation. We do not review these well-established techniques in this manuscript.

Case 1 (Fig. 5A, B) demonstrates a 25-year-old woman with a history of nasal trauma, with resultant nasal obstruction and deformity. She is noted to have a deviated septum along with deviation of the bony dorsum, including the bony rhinion, to the left. She had good residual structural support

![Fig. 1](https://example.com/image1) A cross-section of the nasal pyramid demonstrates the relatively longer slope and obtuse angulation on the right side, with a shorter slope and more acute angulation on the left side.

![Fig. 2](https://example.com/image2) Osteotomy placement: bilateral low-to-high osteotomies and an intermediate osteotomy on the long-sloped side.
of the middle vault and tip. Note the more flat transition from the right maxilla along the bony pyramid relative to the steeper left side. Via an endonasal surgical approach, she underwent septoplasty and release of the upper lateral cartilages from the dorsal septum. This was followed by a right intermediate osteotomy, bilateral low-to-high ostotomies with infracture on the right side only, then percutaneous transverse osteotomy of the nasal bones and septal perpendicular plate release. Digital pressure on the left nasal pyramid then allowed for movement of the left pyramid and entire bony dorsum toward the midline. This, in turn, allowed for movement of the rhinion and attached upper lateral cartilage/dorsal septal complex toward the midline. In her case, no further middle vault grafting was performed. Fig. 5B shows her result after 6 months.

Case 2 (Fig. 6A–D) shows a 35-year-old man with a history of nasal trauma in the past, who presented with nasal obstruction and a deviated nose. On examination, he was noted to have tip ptosis due to loss of distal structural support, along with cartilaginous and bony deviation of the nose to the left. The septum was buckled and obstructive. His cosmetic concerns were only related to the external deviation of the nose. Via an external approach, he underwent open septoplasty with release of the upper lateral cartilages from the dorsal septum, and restructuring of the middle vault with a thick right-sided extended spreader graft, tip restructuring with a caudal batten/extension graft, and lower lateral cartilage/dome positioning to provide support and some rotation. Limited rasping of the dorsum was performed. This was followed by the sequence of osteotomies as described in case 1 to allow for centering of the bony rhinion and attached cartilaginous dorsum toward the midline. A small radix graft was placed as well. Results after 1 year show a much straighter dorsum and nasal pyramid.

Case 3 (Fig. 7A–D) demonstrates a man in his early 20s who suffered a motor vehicle accident 9 months prior to evaluation for secondary functional nasal obstruction and deformity. The initial insult included LeFort II injuries along with a left nasal orbital ethmoid displacement injury. Overall he was successfully reconstructed and presented at a later date with the principal concern of nasal obstruction and deformity. On examination, he was noted to have bony and cartilaginous deviation to the right with structural weakening of the tip and resulting minor limited tip ptosis. Intranasal examination demonstrated a severely deviated septum with buckling to the left and a high deviation consistent with the deviation to the right of the external nose. Besides the external deviation, he requested narrowing of his tip. A functional septorhinoplasty was performed, via an external approach, at which time there was disassembly of the septum followed by the osteotomy techniques noted above (including bilateral low-to-high lateral osteotomies, a left

Fig. 3 Osteotomy placement, including the transverse osteotomy that cuts free the perpendicular plate of the ethmoid. Arrow demonstrates direction of mobilization.

Fig. 4 Depiction of dorsal medialization with the combination of osteotomies as described in the text. Arrow demonstrates direction of mobilization.
Fig. 5 (A) Preoperative photo of the patient with previous nasal trauma. Note the bony-cartilaginous deviation, but with good cartilaginous and tip support. (B) Postoperative view.

Fig. 6 (A, C) Preoperative photos of the patient with previous severe nasal trauma. Note the bony-cartilaginous deviation, along with collapse of the middle vault and tip. (B, D) Postoperative views.
intermediate osteotomy and a percutaneous transverse osteotomy). He had extended spreader graft on the left side, a caudal extension graft/batten over the caudal septum, a columellar strut, as well as limited cephalic trim of the lateral crura of the lower lateral cartilages and dome sutures. His result 1 year after surgery is noted in Fig. 7 (C, D). Key to success of this procedure is the adequate mobilization of the bony dorsum, which then allows for partial straightening of the middle cartilaginous vault upon the bony deflection. However, the middle cartilaginous vault may not centralize while if there is not adequate release of the upper lateral cartilages that are restored with or without structural interposition spreader grafts, depending on the situation. The patient has done well and at 6 years after surgery maintains a good structural and functional improvement of his previous traumatized nose.

Case 4 (Fig. 8A–D) reviews a 20-year-old man with a history of at least two previous nasal fractures, presenting with nasal obstruction and deformity. Note the severe bony pyramid and dorsal deviation as well as fracture irregularities. He has loss of cartilaginous support with a slight saddle deformity, as well. As with the above cases, through and external approach, he underwent open septoplasty, restructuring of the “L” strut with both a thick and strong left-sided extended spreader graft and caudal batten graft, rasping of the right-sided bony fracture irregularities, then the sequence of osteotomies, including a transverse osteotomy leading to movement of the dorsum and rhinion toward the midline. Because of the severity of the deviation, further onlay grafting along the left sidewall was performed. Fig. 8 (C, D) shows the improvement 8 months postoperatively.

Case 5 (Fig. 9A–D) demonstrates a case of a deviated nose due to congenital facial growth disturbance resulting in a shift of the mandible and maxilla. Typical of such situations is a shift of the maxilla, which results in a shift of the nasal base with subsequent nostril asymmetry. Unlike many cases, in addition to deviation of the cartilaginous dorsum, there is also a deviation of the bony dorsum and bony pyramid asymmetry. Accordingly, her deformity is treated quite similarly to the above posttraumatic deformities, with the inclusion of the osteotomy sequence, including in her case of a strong left-sided extended spreader graft, a left intermediate osteotomy, bilateral low-to-high osteotomies, and the
transverse osteotomy to bring the dorsum and rhinion toward the midline. — Fig. 9 (C, D) shows her appearance 1 year after surgery.

Discussion

The aforementioned cases are used to illustrate the complexities that can present with posttraumatic nasal deformities, and specifically with the severely deviated nose. To be clear, most cases with the deviated nose can be managed with traditional techniques including septoplasty, middle vault and tip restructuring, rasping/hump reduction, and standard osteotomies. However, we demonstrate a small subset of patients who have more severe deviation of the bony pyramid and bony dorsum that, in our hands, is best managed by the addition of the percutaneous transverse osteotomy and subsequent mobilization of a composite section of the nose that includes the nasal bones (the bony dorsum), one of the bony sidewalls (the pyramid), and the rhinion with the attached middle cartilaginous vault (the dorsal septum and upper lateral cartilages). Key to adequate movement of the composite segment is adequate release, via the dorsal transverse osteotomy, of the septal perpendicular plate. We have not found this in any way to be difficult or dangerous, as the osteotomy of the perpendicular plate is usually into old fractures and is well removed from the skull base attachment of the perpendicular plate. Also, as demonstrated in the last case, the same principles can be useful in patients with significant nasal deviation that has resulted from congenital growth abnormalities.

It should be pointed out that the described osteotomy sequence is not without problems, however. In particular, in some posttraumatic situations, there may be inadequately healed fractures that, during sidewall pyramid (low-to-high) lateral osteotomies, may open up resulting in undesirable fragmentation with flail bony segments. When this happens, the dorsum can usually be adequately centered as the transverse portion of the sequence is still effective, but the bony structure is less stable.

Just as in most rhinoplasties, postoperative massage is very important in these particular cases. We find that the nose tends to heal toward the original directions of deviation, so massage is warranted.

Fig. 8 (A, C) Preoperative photos of the patient with multiple previous nasal fractures. Note the severe bony-cartilaginous deviation, along with collapse of the middle vault and tip. (B, D) Postoperative views.
Fig. 9 (A, C) The patient with history of facial growth disturbance and facial asymmetries, with resulting severe nasal deviation and deformities. (B, D) Postoperative photographs.

References
Posttraumatic Nasal Deformities: Correcting the Crooked and Saddle Nose

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Abstract
The nose is frequently traumatized in facial injuries and this often results from motor vehicle accidents, sports-related injuries, and altercations. Subsequently, posttraumatic nasal deformity is one of the most common reasons that patients seek consultation in the doctor’s office. Depending on the type of nasal deformities, this can result in functional impairment and aesthetic problems. Two challenging problems to be addressed in the posttraumatic nose include the crooked nose deformity and the saddle nose deformity. The numerous publications on these two topics attest to the exacting surgical expertise required in its treatment. The key features in management of these conditions are discussed further.

Keywords
► saddle nose
► crooked nose
► nasal deformity
► nasal trauma

Relevant Anatomy
Crooked Nose
It is crucial to identify the anatomical causes of the external deviation. The nose can frequently be divided into thirds with the upper third composed of paired nasal bones and bony septum. The nasal bones articulate with the frontal bones superiorly, the ascending process of the maxilla laterally, the upper lateral cartilage inferiorly, and deep to this the perpendicular plate of the ethmoid. The nasal bones are thickest superiorly at the nasion and become thinner caudally where they are prone to fractures. Asymmetry of the upper third of the nose from nasal fractures is often combined with a deviation of the middle third (►Fig. 1). Deflections of the bony pyramid are not all identical. It is important to delineate (1) the aberrant side, (2) the contour of the nasal bones, and (3) potential involvement of the bony septum. Bony deviations may involve only one side where an isolated segment is depressed medially from a direct traumatic injury. In this situation, a closed nasal reduction to elevate the segment may be unstable and this may require unilateral nasal packing. If a high deviated bony septum is present, this can potentially impede nasal bone movements during a closed nasal reduction and prevent a successful reduction.

The cartilaginous middle one-third consists of the upper lateral cartilages that articulate with the nasal bones superiorly and lower lateral cartilage caudally at the scroll region. Deep to this, it articulates with the cartilaginous septum, and a persistent deviation of the nasal septum with passive distortion of the upper lateral cartilages is a common cause of deviated middle third (►Fig. 2). Releasing the fibrous attachments between the upper lateral cartilage and the dorsal septum will reveal the deflected dorsal septum and correction of the upper lateral cartilage deformity.

There are two instances of the twisted middle vault where the upper lateral cartilages are the primary culprit rather than...
the dorsal septum. The upper lateral cartilage can be disarticulated off its supporting structure (usually the dorsal septum or occasionally the nasal bones) and this results in a gradual depression of the upper lateral cartilage medially. This disrupts the brow-tip aesthetic line on the affected side and gives an illusion of the twisted nose. The second scenario occurs in patients with intrinsic deformities of the upper lateral cartilages, with concavity or buckling of the upper lateral cartilage. These will have to be directly repaired or camouflaged with cartilage grafts.

The keystone area is an important anatomical landmark where the paired nasal bones, paired upper lateral cartilage, perpendicular plate of ethmoid and the quadrangular cartilage meets. Disruption of the keystone area during trauma results in instability and possibly a saddle nose deformity. A high dorsal septal deviation can result in a deviated middle one-third and this will have to be addressed to straighten the crooked middle third.

The lower one-third of the nose comprises the paired lower lateral cartilages, caudal nasal septum, and the nasal spine. Tip position is dependent on numerous forces that work in concert to hold the tip in midline. Deviation of the caudal septum from trauma is a common cause of the lower third nasal asymmetry (Fig. 3). The nasal septum comprising the perpendicular plate of the ethmoid, quadrangular cartilage, vomer, and maxillary crest plays a crucial role in determining the deviations of the nose in all horizontal thirds as described previously. The adage “where the septum goes, so goes the nose” is especially applicable for the traumatic crooked nose.

Saddle Nose
A saddle nose deformity is one the most feared complication posttrauma. This frequently results from an untreated septal hematoma that becomes infected. The resultant septal abscess causes septal cartilage resorption and subsequently a saddle nose deformity over time. Alternatively, if the precipitating trauma disrupted the keystone area as mentioned previously, this can similarly result in a saddle nose deformity. The patient will appear to have an illusion of a widened nose on frontal view and on profile view, a scooped out appearance.

Clinical Assessment
A comprehensive history should elucidate a detailed mechanism of injury, including the vector and magnitude of the force. Frontal impact injuries from motor vehicle collisions or projectiles are usually higher impact and result in a greater degree of comminution and septal injury. Sports-related injuries and assaults frequently result in a low impact laterally directed blow that typically results in an infrastructre of the ipsilateral nasal bone and outfracture on the contralateral side. The timeline is crucial for consideration of closed nasal reduction of a nasal fracture. It is generally advisable to reduce it within 3 to 5 hours of injury before edema sets in or delayed till after 5 to 7 days for the swelling to resolve.
edema impacts accurate clinical assessment of the nasal deformity and can impede mobilization of the nasal fragments. A closed nasal reduction should generally be attempted before 2 weeks as osseous union beyond this period will make reduction challenging. A previous history of nasal injuries and deformities is important. Preinjury photographs are useful to obtain a baseline, and it is crucial to explain to the patient that preexisting deformity cannot be altered during the closed nasal reduction.

Beyond aesthetic considerations, functional impairments such as nasal obstruction or rhinorrhea should be characterized. The patient’s concerns run the gamut between functional and aesthetic concerns, and this should be clarified prior to management. Functional impairment such as nasal obstruction should take precedence in the management and any other aesthetic issues that the patient has should be discussed at lengths before treatment. Occasionally, the desire for improvement in nasal breathing may be contrary to the patient’s desire for a smaller nose and this should be highlighted to the patient.

Physical examination begins systematically with observation of the patient’s nasal breathing at rest. Inspection in specific views, such as the frontal, profile, and basal views, provide information about anatomical abnormalities at rest and during inspiration. On the frontal view, one divides the nose into horizontal thirds and inspects for any deviations of the nasal bones, narrow middle vault, or a twisted tip. The brow–nasal tip aesthetic lines are made up of the medial orbital rims, nasal root, middle vault, and nasal tip, and should be symmetrical. The profile provides information about the height of the radix, saddle nose, tip projection, and rotation. If a saddle nose deformity exists, the area of maximal deficiency should be localized so as to aid in quantifying the degree of augmentation necessary. The basal view reveals the vestibular shape, columellar width, lateral crural recurrvature, and fluctuations with inspiration. A deviated caudal septum can cause a twisted nasal tip.

Palpation of the nose cannot be overemphasized. One can get a sense of the resilience, degree of support and stability along the lateral nasal wall and nasal tip. The anatomy of the twisted middle vault can be elucidated from direct palpation and tightening the nasal skin over the nasal dorsum to outline the dorsal septum. Intranasal examination should be done with and without topical decongestant. Another useful tool is a stick or a cotton-tip applicator in the precise midline of the face which should traverse the glabella, philtrum, upper incisor, and menton, assuming facial symmetry in the patient. The nasal speculum should be used judiciously because it distorts the lateral wall. Deviations of the septum should be identified, and the presence of dorsal or caudal deviation may correspond to a crooked nose in either thirds.

Management of the Crooked Nose
Upper Third Deviations
The treatment of the deviated upper third can be broadly divided into acute management with closed nasal reduction or surgical reduction comprising surgical techniques such as osteotomies, septrhaphy, or camouflage graft.

Closed nasal Reduction
Closed nasal reduction can be performed when the nasal fracture presents within the first 2 weeks to the office, and the patient understands the limitations of closed nasal reduction and possible need for surgical correction of residual deformities at a later time. Topical anesthesia can first be applied using a mixture of oxymetazoline/lidocaine nasal spray. Next, a cotton soaked in the same mixture of oxymetazoline/lidocaine solution or the equivalent is tucked right up to the nasal vault of the concave deformity and approximates the position of where the Boies elevator will be placed during reduction. A local anesthesia comprising 1% lidocaine and 1:100,000 epinephrine is infiltrated in a supraperiosteal and subdermal plane along the bony vault. The patient is then

Fig. 3 (A) Deviation of the caudal septum resulting in a twisted nose in the lower third. (B) Dorsal deformity involving the nasal tip.
Osteotomies
The purpose of osteotomies is to create precise fracture lines to allow mobilization of the nasal bones to return to a favorable position. Medial, lateral, intermediate, and possibly transverse root osteotomies are performed to achieve this purpose. This procedure is performed relying more on tactile feedback than on visualization. The types of osteotomies used on the patient is dependent on the deformity present. For the patient with both nasal bones that are relatively straight but deviated to the same side, bilateral lateral osteotomies may suffice, allowing the bony pyramid to realign as a single unit.

The lateral osteotomies are performed in a “high-low-high” orientation in a subperiosteal plane beginning from the pyriform aperture, down toward the ascending process of the maxilla, and curving toward the medial canthus (Fig. 6). It is important not to carry the osteotomy too high into the frontal bone to avoid a “rocker deformity.” The nasal speculum is used to straddle the pyriform aperture and a horizontal stab incision is made above just above the head of the inferior turbinate. It is important not to start the lateral osteotomy below the inferior turbinate as incorporating this into the medialized segment of bone can result in airway obstruction. A Joseph periosteal elevator is used to create a subperiosteal tunnel along where the lateral osteotomy will be created. This preserves the overlying periosteum and increases stability of the nasal fragments created. A curved, guarded osteotome is then introduced and directed along the intended path toward the medial canthus. A mallet is used in a “tap-tap” fashion to advance the osteotome to create a controlled fracture cephalad. The surgeon uses the left hand to palpate the osteotome beneath the skin while the right hand is used to direct the osteotome. Just below the medial canthus, a gentle rotation of the osteotome medially is performed to create a back fracture toward the midline.

Medial osteotomies are performed for more significant deviations and this can be done usually with a 2-mm straight, unguarded osteotome beginning at the rhinion near the bony septum and nasal bones. This can be approached via an intercartilaginous incision or transnasally by engaging the caudal border of the nasal bone at its junction with the dorsal septum and upper lateral cartilage and this fades approximately 20 degrees laterally to avoid the nasofrontal area. If there is resistance in creating a back fracture to connect the medial and lateral osteotomies, a percutaneous osteotomy can be created using a 2-mm osteotome to aid in its formation. For severe upper third deviation, the sequence of osteotomies can be performed akin to flipping the pages of a book with the lateral osteotomy of the concave side performed followed by the medial osteotomy of the concave side, then the medial osteotomy and lateral osteotomy of the convex side follows. This allows mobilization of the depressed segment on the concave side to create sufficient space so that the deviated segments on the convex side can be shifted over.
The intermediate osteotomy is used to correct a deviated nose with one sidewall much longer than the other. This can occur in patients with nasal deformities sustained at a young age and the differential growth of the nasal bones on either side results in a different length of the nasal bones. It is also used to straighten a distinctly convex or concave nasal bone. Simple realignment of the nasal bones to the midline can leave a persistent deformity to the dorsal or sidewall. Third, it can also be used to narrow the extremely wide nose with good height. It may be difficult to narrow these broad noses with just medial and lateral osteotomies. The intermediate osteotomy is placed parallel to the lateral osteotomy along the midportion of the nasal sidewall and is created before the lateral osteotomies are made (Fig. 6). This ensures a stable platform for the intermediate osteotomies to be made. Occasionally, the nasal fragments are immobile despite these osteotomies due to a deviated high bony septum or a deviated central nasal bony segment between the two medial osteotomies. A percutaneous transverse root osteotomy will be necessary to mobilize this central bony segment or a deviated high bony septum. This can be performed with the 2-mm osteotome over the nasal root just below the nasion to ensure it sits below the cribiform plate.

Immediately after the osteotomies and reduction is performed, pressure with a sponge is held over the nasal bones for 2 to 3 minutes to minimize swelling and ecchymosis. External tape with a splint is placed over the nasal bones for 1 week after.

**Bony Septal Deviations**

The perpendicular plate of ethmoid attaches to the undersurface of nasal bones and can result in a crooked upper third. If the deflection of the perpendicular plate of ethmoid is severe, this has to be corrected with a septoplasty by fracturing the ethmoid and gently reducing it to the midline. More severe deviations can be treated with a 2-mm percutaneous root osteotome to create a controlled fracture in this bony septum in order to allow movement of the deviated upper third.

**Camouflage Grafts**

This is a direct and simple way to improve the twisted upper third. They are often used in patients with a unilateral depression with a normal contralateral side. These grafts can be used placed under the periosteum with theoretical advantage of better camouflage of the edges and improved security. The grafts can also be placed in the supraperiostal...
plane, and this can potentially increase viability by enhancing vascularity from both sides of the graft. However, a supra-periosteal graft runs the risk of migration and can appear more prominently under the nasal skin.

**Middle Third Deviations**

There can be persistent deviations of the middle third of the nose despite correction of the upper third. Correcting the twisted middle vault is challenging and useful techniques include septoplasty, spreader grafts, or a camouflage onlay grafts. Frequently a high dorsal septum deviation can be a cause of the crooked middle third. As the upper lateral cartilages are attached to the septum by firm fibrous attachments, a full release of the upper lateral cartilages from the septum can be performed in milder deviations and this can help straighten the middle vault asymmetry. A formal septoplasty may be necessary in more severe septal deviations. Spread grafts or camouflage onlay grafts can be used in an asymmetric fashion for middle vault asymmetry. It is important to assess for airway obstruction especially on the convex side as the internal nasal valve is narrowed, and this helps decide whether a camouflage onlay graft or spreader graft is necessary.

**Septoplasty**

During a septoplasty, a stepwise approach consists of detaching the upper lateral cartilages from the septum bilaterally. This releases the extrinsic binding structures that can potentially be causing the deformity. Next, a full release of the mucoperichondrial flap on the concave side relieves the intrinsic tension forces resulting in the deformity. These two maneuvers can correct milder deviations. The deviated dorsum may be a linear deformity to one side. When the dorsal strut is straight but misaligned, it may need to be detached from the posterior bony septum and maxillary crest to allow it to be swung back to the center. The keystone area should be preserved to avoid destabilization and future saddle nose deformity.

Combinations of scoring the cartilage, resecting deviated portions or placement of batten grafts can help straighten any further septal deformities. Scoring involves placing partial thickness incisions on the concave side of the cartilage. This releases the forces holding the cartilage in its deformity and is akin to releasing the string on a bow. However, relying solely on scoring may not achieve the long-term result one desires in straightening the deviated septum. The scoring results in wedge-shaped spaces created that eventually heals with scar tissue and subsequent wound contracture that can result in a relapse of septal deformity (Fig. 7). A batten graft may be necessary to hold it in place. A permanent suture placed in a horizontal mattress with the knot on the convex side can help bend the cartilage in a favorable manner and serve to reinforce the dorsal strut.

**Spreader Grafts**

Spreader grafts placed between the upper lateral cartilage and septum can help correct middle vault asymmetry by laterally displacing the depressed upper lateral cartilage if placed on the concave septum and also improve a narrowed internal nasal valve with increased airflow. Typically, spreader grafts are placed bilaterally to aid in splinting of a high deviated septum and it is fashioned thicker on the concave side to match the middle vault asymmetry. Edges of the spreader grafts are beveled to prevent show through the skin. Dimensions of the spreader grafts vary, but they usually range from 6 to 12 mm in length, 3 to 5 mm in height, and 2 to 4 mm in thickness. They usually span the entire vertical length of the upper lateral cartilage and are secured in a mattress fashion (Fig. 8).

**Camouflage Grafts**

Occasionally in patients without airflow problems and small depressions on the middle vault, a camouflage onlay graft can be used. This is created typically from a small-sized crushed...
septal cartilage. The septal cartilage is hammered till it loses its memory but not overtly traumatized as this can potentially result in increased resorption of the graft. It is placed on the concave side of the deviation in a precise dimension over the perichondrium, and the skin is redraped over it and assessed to ensure it does not show too prominently. Marking the skin should be done prior to infiltrating local anesthesia. Securing the graft in place can be performed although this is usually not necessary if a snug pocket is created for its placement.

**Lower Third Deviations**

The techniques commonly used to correct nasal tip asymmetry include septoplasty for the deviated caudal septum, tip suture techniques, or camouflage tip grafting. For mild to moderate deviations of the caudal septum, a septoplasty via a hemitransfixion incision allows mucoperichondrial flaps to be fully released on both sides of the septum. Occasionally this is sufficient to allow straightening of the caudal septum. Scoring of the deviated caudal septum on the concave side can be performed to decrease memory of the cartilage and further straightening of the septum. Cartilage grafts in the form of a caudal septal batten graft can also be used to splint the caudal septum to keep it straight and provide additional stability (Fig. 9). If the posterior septal angle is dislocated off the nasal spine, the septum can be trimmed inferiorly in a conservative fashion and then brought over to the midline and resutured to the spine in a figure-of-eight manner with a 5–0 clear nylon to keep the septum in the midline.

For more severe caudal septal deviations, the caudal septum may have to be replaced with a straight L-shaped autologous cartilage graft, commonly from the septal cartilage (Fig. 10). A stable dorsal strut is left in situ for the new graft to be sutured to and the other end is anchored to a remnant of cartilage at the posterior septal angle for to the peristeum around the nasal spine. The lower lateral cartilage can then be sutured to this newly constructed L-strut with horizontal mattress for further stability. This newly constructed L-shaped cartilage graft determines the optimal position of the anterior septal angle, caudal septal margin, and posterior septal angle. Changes in graft length, position, and relative position of the medial crura stabilization on the graft will affect the nasal tip position, rotation, and projection. For more severe caudal and dorsal septal deviations, similar principles apply and a subtotal septal reconstruction can be performed. The deviated cartilage is resected and a longer straight L-shaped autologous cartilage graft can be used in the same manner. In situations where there is

![Fig. 8](image1.png) **Fig. 8** Spreader grafts placed bilaterally to aid in straightening the deviated dorsal septum.

![Fig. 9](image2.png) **Fig. 9** (A) Deviated caudal septum with concavity on the left. (B) Caudal septal batten graft used to straighten the septum and provide additional stability. A left spreader graft was also used inserted for additional middle vault stability.
insufficient autologous septal cartilage, double-layered auricular cartilage can be sutured together for use after scoring the concave surface although this is less ideal. Auricular cartilage is not as strong as septal cartilage in providing tip support and its intrinsic curvature makes it challenging for use at this site. Rib autologous cartilage can be considered although it has added donor site morbidity. Also, rib cartilage is prone to warping and is thicker than septal cartilage.

**Pediatric Nasal Injuries Resulting in a Crooked Nose**

An estimated half of all nasal fractures occur in the pediatric population. There are important anatomical differences between the nose in a pediatric patient compared with an adult. The nose in a young child is more cartilaginous, has less projection from the face, and is characterized by suture lines that have not yet fused. The soft, compliant cartilage bends easily during blunt trauma. The resilient nasal bones are also more prone to “greenstick” fractures and less likely to comminute when compared with adults. Importantly, the nose is still growing and two potential growth centers have been described along the nasal septum. The sphenodorsal zone extends from the sphenoid to the nasal dorsum and the sphenospinal zone extends from the sphenoid to the anterior nasal spine. Vertical growth in the sphenodorsal zone results in increased length and height of the nasal dorsum whereas sagittal growth in the sphenospinal zone contributes to anterior projection of the nose and maxilla. Injury to either of these growth centers may lead to a loss of vertical height and sagittal projection of the nose or even the midface, as the developmental organization provided by the nasal septum suffers.

When the patient presents acutely within 1 to 2 weeks of the injury, a closed nasal reduction in the nasal fracture can be performed under general anesthesia in the operating room similar to that described for adults above. If the patient presents in the nonacute phase with a severely deviated upper third, careful consideration of osteotomies can be used to straighten the upper third. In the author’s opinion, this can be performed safely without disrupting the growth centers on the nasal septum. Septoplasty in the pediatric population is generally delayed till adolescent except for patients with severe deviated nasal septum and nasal obstruction resulting in obstructive sleep apnea. In these cases, a conservative approach is key with minimal cartilage resection and attempts to preserve the bony-cartilaginous junction if possible. One should approach management of pediatric nasal injury in a conservative fashion to avoid disrupting the growth centers on the nasal septum.

**Management of the Saddle Nose**

The treatment of saddle nose deformities depends on the degree of saddling and the presence of structural septal support. Various classifications for saddle nose deformities have been described in the literature for mild to severe deformities, but none has been universally accepted. We describe a simple algorithm in the management of saddle nose that we believe is applicable for majority of these patients (Fig. 11). They can be broadly divided into two groups. The first group comprises patients with mild saddle nose deformity with intact dorsal and caudal septal support and without nasal obstruction. These can be treated with dorsal augmentation to camouflage the deformity. The onlay grafts used consist mostly of autografts such as the temporalis fascia graft, septal cartilage, auricular cartilage, or the “Turkish Delight.” Alloplasts can be considered as a last resort.
Common implants include silicone, high-density porous polyethylene (Medpor, Stryker Corporation, Kalamazoo, MI), and expanded-polytetrafluoroethylene (Gore-Tex, W.L. Gore Associates, Inc., Newark, DE). Generally, alloplasts are prone to infection and extrusion with rates of up to 8% after 10 years, especially when used as a rigid structural graft that imparts tension on the overlying skin, such as a large tip graft. The porous nature of these grafts allows tissue ingrowth that can help with fixation but also makes retrieval more challenging. They remain widely used, especially in Asia, as dorsal augmentation grafts.

The second group consists of patients with severe saddle nose deformity and who are usually associated with poor septal support mechanism. They usually require middle vault reconstruction to reconstitute the dorsal and caudal septal support mechanism in addition to a dorsal onlay graft. A rib or bony autograft in an L-strut fashion is commonly used for this purpose.

**Mild Saddle Nose with Intact Structural Septal Support**

For mild saddle nose where augmentation of 1 to 2 mm is needed, deep temporalis fascia can be used for dorsal augmentation. The advantages are the pliability of the temporalis fascia. It can be easily contoured to fill the mild saddling and almost never shows through the skin. It can be harvested from a small, 3 cm incision hidden within the temporal hair. The mobility and stretchability of the temporal skin allows an almost $5 \times 5$ cm size of temporalis fascia to be harvested with minimal donor site morbidity. To achieve more dorsal augmentation, diced cartilage can be used wrapped in temporalis fascia. Diced cartilage are believed to have longer survivability than crushed cartilage and are believed to fuse together with

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**Fig. 11** Working algorithm for management of saddle nose deformity.

**Fig. 12** (A) Poor dorsal support with scooped appearance on side view. (B) Dorsal onlay graft comprising of septal and auricle cartilage sutured together. This is carefully tucked into a tight periosteal pocket created to minimize chance of migration postoperatively. Sutures can be used to anchor this to the upper lateral cartilage to enhance its stability.
time to form a self-containing conglomerate. This is believed to be an improvement of the “Turkish Delight” as described by Errol who wrapped the diced cartilage in Surgicel (Ethicon, Somerville, NJ), a resorbable oxidized regenerated cellulose product frequently used as an intraoperative hemostatic adjunct. Diced cartilage wrapped in temporalis fascia is believed to have longer survivability as the Surgicel can potentially incite an inflammatory reaction resulting in increased cartilage resorption. Cartilage obtained from the septum, concha, or rib can be diced into 0.5-mm cubes with fresh size 11 blades. The temporalis fascia can be used to wrap the diced cartilage and closed with a 4-0 plain gut. This can be used as a dorsal augmentation much like a silicone implant. It can be secured in place with a percutaneous stitch running through the graft and through the skin of the glabella. The stitch can then be removed 1 week postoperatively.

Septal cartilage is advantageous due to its resilience compared with auricular cartilage. It is relatively straight, lacks of donor site morbidity, has less chance of warping compared with costal cartilage, and has ease of harvest. However, it may be deficient in revision rhinoplasties and in patients with large nasal septal perforations. Auricular cartilage, commonly from the concha bowl, is an alternative option though its intrinsic curvature makes it less ideal. The septal and conchal cartilage can be used together with the straight septal cartilage sutured firmly to the conchal cartilage to splint it and keep it straight. It is crucial to ensuring that the edges of this graft are gently beveled laterally to minimize chance of show through the skin.

After the graft has been fashioned, a tight periosteal pocket is created over the nasal bones just sufficient to admit the graft and to minimize chance of lateral migration postoperatively. The sides of this graft can be sutured to the upper lateral cartilage to further minimize chance of movement.

Severe Saddle Nose with Poor Septal Support
Middle vault reconstruction with the use of rib cartilage of calvarial bony autograft in the form of an L-strut is used to treat patients with severe saddle nose and poor septal support. This autograft provides both dorsal augmentation and dorsal and caudal support. The rib autograft is commonly harvested via a 3- to 5-cm incision over the seventh, eighth, or ninth rib. A subperichondrial dissection especially on the deep surface of the rib prevents pleural injury, and a central segment of a relatively straight costal cartilage is obtained. This helps prevent subsequent warping of the rib. Soaking the rib graft in saline at regular intervals during the carving phase will allow it to warp and the carving of the rib graft can be tailored accordingly. The greater rigidity of the rib mandates judicious contouring, especially of the edges, and is necessary to avoid show of the autograft below the skin. The site where the caudal strut meets the dorsal strut correlates to the ideal anterior septal angle for the patient and the base of the strut is suture-fixated to the periosteum of the nasal spine. The cephalic end of the rib autograft is tucked snugly into a conservative subperiosteal pocket to minimize chance of migration. Calvarial bone grafts from the parietal bone have been described for the same uses as above; however, it carries a potential risk of intracranial injury during the harvesting process, albeit a small one. The benefits of a calvarial bone graft is its longevity, superior strength, and relative abundance. It is much less prone to resorption compared with cartilages graft. Because of its strength, calvarial bone can be thinned to 1 mm and arranged in a hinged, interlocking fashion with an L-configuration for caudal and dorsal support of the nose.
Conclusion

Management of the posttraumatic crooked and saddle nose is a challenging problem the surgeon faces in his practice. A careful preoperative assessment of the patient and a thorough understanding of the underlying anatomical causes for the deformity are important for surgical planning. The crooked and saddle nose can have varying degrees of functional and aesthetic concerns to the patient, and it is vital to elucidate this clearly prior to embarking on a definite treatment plan.

References

Cosmetic Concerns Related to the Posttraumatic Nose without Nasal Obstruction

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Abstract

Because of its prominent position on the facial skeleton, the nose is commonly injured. Though significant trauma can result in nasal obstruction, there is also considerable concern for potential cosmetic deformity. Repairing traumatic deformities is complex and can involve all aspects of the nose, including the bony and cartilaginous framework as well as the soft tissue envelope. Trauma can result in deflection, asymmetry, and deformity of the bony nasal dorsum, midvault, and nasal tip. Any serious nasal trauma places patients at risk for complications that may include nasal septal hematoma, septal perforation, and possible cerebral spinal fluid leak. Unrecognized or untreated septal hematomas can result in cartilaginous septal necrosis followed by saddle nose deformity. Though damage to structural scaffolding is often the cause of cosmetic deformity following nasal trauma, the nasal soft tissue envelope is also commonly affected. This can result in lacerations, avulsions, and traumatic tattooing. The following will discuss the evaluation, diagnosis, and management of these cosmetic concerns relating to nasal trauma.

Keywords
- nasal fracture
- nasal deformity
- crooked nose
- saddle deformity
- nasal laceration

Nasal trauma is common due to the prominent position it has on the face. In fact, the nasal bones are the most commonly fractured facial bone.1 Though it is common to associate nasal trauma with nasal bone fracture, it can also affect the cartilage framework and nasal soft tissue. Nasal trauma can be accidental or iatrogenic. Iatrogenic trauma may be the consequence of some other medical or surgical management that may have damaged the nose. This could lead us to the subject of revision rhinoplasty that is beyond the scope of this chapter. It is not uncommon to come across a patient with significant external nasal deformity despite denying nasal obstruction. Such deformities warrant surgical correction. Comprehensive nasal analysis is paramount to obtaining satisfactory results. Structural deformities should be broken down into components to ensure that all aspects of the nasal deformity are addressed.1 None functional nasal deformities may also encompass soft tissue injuries.

Though some aspects of traumatic nasal deformities can be repaired acutely, it is often necessary for patients to undergo more definitive repair remotely. Nasal bone fracture and nasal deviation are extremely common with nasal trauma. Deformities of the bony nasal vault are typically repaired with osteotomies. Careful analysis of the bony deformity is necessary to ensure adequate reduction and realignment.2 Minor traumatic deformities of the midvault are preferably reconstructed with structural intranasal grafting and camouflage onlay grafts.

Severe trauma to the nasal midvault and collapse of the nasal septum can lead to saddle nose deformity.3 Traumatic septal hematoma with resultant septal abscess and septal necrosis can result in the same deformity. The severity of this deformity varies significantly. Though minor irregularity that
does not violate structural integrity can be treated with cosmetic onlay grafts, more severe deformity requires more complex reconstruction with structural cartilage grafting. Soft tissue trauma can also contribute to cosmetic deformity. Skin resurfacing can be used for treatment of unsightly scars. However, scar contracture of the nose can lead to more serious nasal deformity which will require more extensive repair (Fig. 1A, B). It is important to evaluate all aspects of the appearance of traumatic nasal deformities prior to embarking on repair.

**Diagnosis**

As with any evaluation of a new patient, a detailed history and physical examination should be obtained. The initial assessment should include the mechanism of injury and the direction of force. Timing of injury is also documented along with a history of epistaxis following the event. Any history of previous nasal trauma should be elicited as well as any previous nasal or facial surgery. It may be useful to review preinjury photographs of the patient. Also, a standard series of nasal photographs should be obtained prior to surgical intervention.

Critical analysis of the nose is an essential aspect of the initial assessment. The most common changes to nasal aesthetics following nasal trauma are nasal deviation and an obtuse nasolabial angle. General inspection should note the patient’s skin characteristics, including thickness, presence of lacerations, or other soft tissue trauma. As with all nasal analysis, the width and height of the nose should be assessed with respect to the rest of the face. The face is typically divided into vertical fifths. The nasal base should equal one-fifth and should correlate with the intercanthal distance. The width of the upper two-thirds of the nose should equal 75% of the width of the base of the nose.

Facial asymmetry should be brought to the patient’s attention prior to any surgical correction. It is also important to establish the patient’s true midline. A vertical line can be drawn from the glabella through the philtrum, upper incisors, and mentum. The nasal dorsum should follow a smooth, gentle curve from the medial eyebrow to nasal tip, known as the brow-tip aesthetic line. The nasal tip defining points should be symmetric and the columella should be visible just inferior to the alar rims.

When viewing the nose from the patient’s profile, nasal projection should follow a 3–4–5 right angle triangle. Nasal projection should equal 60% of the nasal length. The nasal dorsum should follow a line parallel and slightly posterior from nasion to the nasal tip. The nasofrontal angle should fall between the ranges of 115 and 130 degrees. The nasolabial angle depends on gender. In men an angle between 90 and 95 degrees is acceptable, whereas in women a slightly more obtuse angle, between 95 and 115, is desired. The relationship between the alar rim and columella should also be evaluated. Typically 2 to 4 mm of columellar show is acceptable. Though intranasal examination is a critical aspect of complete nasal analysis, its nuances are beyond the scope of this article.

**Nasal Bone Deformity**

Traumatic deformity of the nasal dorsum will interrupt the smooth contour of brow tip aesthetic line. The deformity can originate at the bony nasal pyramid, the cartilaginous midvault, or the nasal tip. Nasal bone fractures are often the root of these deformities. Nasal bone fractures can be managed in the acute or subacute setting. For acute nasal bone fractures, with no preexisting deformity, closed nasal reduction can be performed. Adequate reduction can be difficult to achieve and comes with a rate of persistent nasal deformity ranging from 14% to 50%. Pitfalls of this technique include timing between injury and intervention, persistent edema masking inadequate reduction, and occult septal fracture.

![Fig. 1](image_url) (A) Alar Retraction and side wall collapse after lateral rhinotomy and skull base surgery for malignancy without a functional component requiring reconstruction for purely cosmetic reasons. (B) 2 weeks status postreconstruction with side wall turn in flap, costal cartilage structural reconstruction of the bony, and cartilaginous side wall and cheek advancement.
For patients with preexisting or persistent posttraumatic nasal deformity or those who did not undergo acute management will require osteotomy for straightening the bony nasal dorsum. Prior to performing any osteotomies, any dorsal hump should be reduced. Any cartilaginous aspect of the hump can be reduced sharply. The bone can be reduced with either an osteotome or rasp. It is often necessary in traumatic nasal deformities to remove the dorsal asymmetrically. This is typically the case when the bony vault is shifted to one side (Fig. 2A). To prevent overaggressive reduction less, bone should be removed from the side of the deviation, the convex side of the nose (Fig. 2B, C). As with most bony hump reductions, an open roof deformity can be created at the time of removal.

Further straightening of the nasal dorsum will require osteotomies. Indications for osteotomies include closure of open roof deformities, as well as narrowing, widening, or straightening the bony nasal vault. Careful evaluation of the bony nasal vault is required to determine which types of osteotomies are necessary to achieve straightening of the nasal dorsum. Medial osteotomies should be performed to control back fracture and avoid green sticking of the nasal bones. They should be considered when the nasal dorsum is wide or deviated with severe traumatic deformities and thick nasal bones. The senior author prefers a straight medial osteotomy with a transverse osteotomy to a medial oblique osteotomy when there is a deviation of the bony complex, as it has more reliable and consistent results in the deviated bony nose (Figs. 3 and 4). When combined with lateral osteotomies, it creates a reliable site of back fracture. The osteotomy is performed using a 3-mm osteotome starting at the caudal aspect of the nasal bone at the midline and paralleling the nasal septum up to the nasal process of the frontal bone. This will allow a purchase, fulcrum, to complete the fracture of the central complex. For oblique osteotomies, the osteotome is allowed to diverge following the path of least resistance to a 15-degree angle laterally and continued cephalad to later be joined by the planned lateral osteotomy (Fig. 5).

Fig. 2 The need for asymmetric hump reduction in the severely deviated nose with relatively greater reduction in the concave side wall. The medially displaced side of the nose.

Fig. 3 Asymmetric bony contour with a convex and concave side to the nose may require multiple osteotomies and fracture of the central complex to straighten the nasal dorsum.
Lateral osteotomies are needed to straighten and narrow the bony nasal dorsum, as well as close open roof deformities. The typical pattern for the lateral osteotomy is a high-low-high trajectory. This allows for preservation of a small triangle of bone at the pyriform aperture, which leaves the lateral suspensory ligaments of the nose undisturbed to help maintain a patent nasal airway. The osteotomy can be performed in a linear or perforating technique. The senior author prefers a perforating osteotomy inferiorly and a linear technique in the superior half of the lateral osteotomy. A 2-mm straight osteotome is directed almost perpendicular to the bone of the pyriform aperture at the level of the inferior turbinate. The osteotome is then redirected cephalad and follows the nasal facial groove superiorly to the level of the medial canthus. The osteotomy is completed by performing a back fracture by either lifting the osteotome or manual pressure.

Intermediate osteotomies can be a crucial technique for straightening traumatic bony nasal deformities. Their primary indications are to narrow wide nasal vaults, correct deviations when the contour of the nasal bones are asymmetric, and when they are broad and convex or concave to an abnormal degree. Intermediate osteotomies should be performed prior to lateral osteotomy as precision and control are lost if the bone is mobile laterally. The trajectory of the intermediate osteotomy should parallel the nasal dorsum at the height of the junction of the nasal process of the maxilla and the nasal bones (Fig. 6A, B). Placement of the osteotomy will depend on the deformity. It is important to leave soft tissue, periosteal, attachments to the nasal bones to prevent collapse and nasal obstruction.

Midvault Deformities

Significant deformity and deflections of the nasal midvault can also cause significant traumatic nasal deformities. Septal fractures can cause buckling of the nasal midvault and disruption of the brow tip aesthetic line (Figs. 3 and 6). The mainstay of reconstruction of the midvault is the spreader graft. Spreader grafts can be used to straighten the cartilaginous midvault, can assist in reattaching the upper lateral cartilages to the nasal dorsum, and bolster the strength of the middle vault.

Spreader grafts can be placed through either an endonasal or open approach. The open approach allows increased precision of graft placement (Fig. 7). Septal cartilage is harvested as the preferred grafting material. The design of the spreader graft should take the nature of the nasal deformity into consideration. Bilateral spreader grafts should...
be used to straighten a severely deviated midvault and to assure symmetry. Typically each spreader graft should be 1 to 2 mm in width and should extend beneath the bony cartilaginous junction to below any deflection in the dorsal quadrangular cartilage (Fig. 7). However, if there is significant asymmetry, a wider spreader graft or laminated (double) spreader may be used on the more deficient side to obtain better symmetry. The spreader grafts are beveled at their cephalic edge to tuck under the distal edge of the nasal bones. The dorsal edge of the graft is aligned with dorsal edge of the nasal septum and secured with horizontal mattress sutures.

An alternative technique is to use the medial aspect of the upper lateral cartilage as an autospreader graft. Here the lateral edge of the upper lateral cartilage is scored, turned onto itself, and then secured with suture. The use of the autospreader in the crooked nose may maybe difficult and unreliable because of the asymmetric nature of the deformity and upper lateral cartilages.

Mild collapse of the midvault can be reconstructed using a butterfly graft. This is an oval-shaped onlay graft over the nasal dorsum typically using auricular cartilage. The graft spans the distance of the cartilaginous nasal dorsum and is typically tapered laterally to avoid palpable irregularities. It is anchored to the lower lateral cartilages. Potential downfalls of using the butterfly graft include broadening of the nasal dorsum and fullness of the supratip.10

**Dorsal Augmentation**

Traumatic deformities of the nasal dorsum can also be reconstructed with dorsal grafting. Grafting may be structural or strictly camouflage. Dorsal augmentation can be used when there is severe injury and deflection, as well as in the weak or cartilage depleted nose.3 Dorsal augmentation aims to improve the dorsal profile as well as conceal traumatic deformities (Fig. 8A–C). Grafting material can be septal cartilage, auricular cartilage, or costal cartilage. Split calvarial bone, osseocartilaginous rib grafts, and homologous costal cartilage have also been used as dorsal onlay grafts.11–13 Diced cartilage wrapped in fascia has gained recent popularity for dorsal augmentation (Fig. 9A, B).14

One instance in which structural augmentation is critical is in the setting of patients with posttraumatic saddle nose deformities. These deformities are caused by collapse of the dorsal and/or caudal nasal septum following traumatic septal dislocation from the bony nose due to high-impact trauma or necrosis of the cartilage from septal hematoma nasal.3 Reconstruction of saddle nose deformities is challenging. It is...
important to determine the severity of the saddle nose deformity. Severity of deformity will dictate treatment options.

Some patients may present with minor depressions of the cartilaginous midvault or excessive supratip depression without significant compromise of supporting nasal structure. For these patients dorsal onlay grafts can be used as cosmetic concealment. These options have been previously discussed above. Patients with more severe injury will start to have associated structural collapse with compromise of septal support, midvault collapse columellar retraction, and loss of nasal tip support. Repair of these deformities typically require extended spreader grafts and caudal septal reconstruction. The extended spreader grafts span the entire distance of the nasal dorsum and are anchored to both sides of the caudal septal reconstruction graft. The angulation of the extended spreader grafts will determine nasal projection. Available septal cartilage can be used for grafting material, although it is often necessary to use costal cartilage.

Fig. 6 Nasal bone deviation requiring medial, intermediate, and lateral osteotomy. (A) Preoperative—frontal view. (B) Preoperative—three-quarter view. (C) Preoperative—profile view. (D) Preoperative—base view. (E) Postoperative—frontal view. (F) Postoperative—three-quarter view. (G) Postoperative—profile view. (H) Postoperative—base view.

Fig. 7 Spreader grafts used to stabilize the midvault, split dorsal septal deflections, and preserve midvault contour avoiding inverted V deformity.
Increasing severity of saddle nose deformities demonstrates flattening of the nose that is noticeable from all views. This represents complete absence of septal support for the midvault, columella, and nasal tip. For reconstruction of such deformities, it is often helpful to use intranasal grafting as described previously in the form of extended spreader graft and a caudal septal reconstruction graft. However, an additional overlying L-shaped strut may be necessary to reestablish height of the nasal dorsum as well as nasal projection and nasal tip support (Fig. 10). The most common grafting material is autologous costal cartilage. Reconstruction of the nasal tip in this setting can be achieved with either suturing techniques, onlay grafts, or shield tip grafts. It is often necessary to add support to the ala to avoid collapse. This can be achieved through alar rim grafts, lateral crural strut grafts, or alar batten grafts. While addressing the issue of internal lining is important, it is beyond the scope of this article.

Camouflage

Further efforts can be taken at the time of surgery to correct subtle traumatic deformities of the nasal dorsum. Onlay grafts of the nasal dorsum can be used to camouflage collapse of the lateral nasal wall or unilateral depression of the upper lateral cartilage. Autologous septal, auricular, or costal cartilage can be used. Irradiated homograft rib is also an option to reduce potential donor site morbidity.

For even more minor irregularities of the dorsum, morselized cartilage or diced cartilage can be used for coverage. Another option is harvesting temporalis fascia to cover the nasal dorsum. Using temporalis fascia can camouflage minor irregularities without adding bulk and width to the nasal dorsum.

Some surgeons advocate correcting postrhinoplasty deformities with soft tissue fillers. The most frequently used soft tissue fillers are hyaluronic acid derivatives, calcium hydroxyapatite gel, and silicone. Injection of soft tissue filler should be in the
Goal of injections should be smooth out minor irregularities and asymmetries of the nasal dorsum and nasal sidewall. As with soft tissue filler in other locations, augmentation is transient and reinjection will be necessary to maintain correction. It has been observed that the effect of hyaluronic acid filler in the nose can remain for longer periods than in other areas of the face. Use of soft tissue filler in the nose can lead to significant complications. Severe granulomatous reactions can occur with silicone injection. Infection, thinning of the nasal skin envelope, and skin necrosis can occur with use of any soft tissue filler in the nose. As such, this technique should be approached with great caution.

Others propose autologous fat grafting for correction of dorsal and nasal sidewall irregularities as well as augmentation of the supratip. Autologous fat grafting has the advantage of permanent correction. However, autologous fat grafting is not without potential serious complications. Intra-arterial injection can cause retrograde arterial emboli leading to sudden-onset permanent blindness.

Soft Tissue Deformity

Also of importance is trauma sustained to the nasal soft tissue envelope. As a result of facial trauma abrasions, lacerations and avulsions can affect the nasal skin. All nasal soft tissue injuries should be meticulously irrigated and examined to determine the extent of injury. Copious irrigation of such wounds both prevents potential infection and removed foreign debris. For nasal skin abrasions wound debridement followed by strict posttraumatic wound care may be all that is necessary. Persistent traumatic tattooing or unsightly scarring of the skin can be treated with early dermabrasion 6 weeks following initial insult.

In the acute setting, every effort should be made to close lacerations meticulously. All nasal lacerations should be
Fig. 11  Alar notching. (A) Preoperative—frontal view. (B) Preoperative—base view. (C) Postoperative—frontal view. (D) Postoperative—base view.

Fig. 12  Severe traumatic avulsion. (A) Postinjury—frontal view. (B) Postinjury—profile view. (C) 1 week following supraclavicular full-thickness skin grafting—frontal view. (D) 6 months following full-thickness skin grafting for repair—frontal view.
explored and closed in layers. If the internal lining is damaged, it should be repaired with long-lasting dissolvable sutures. Intranasal stenting should be considered with violation of the internal nasal lining to prevent nasal scar contracture and potential stenosis. Fractured or damaged cartilage should be reapproximated at time of injury and every effort should be made to restore the natural structure to prevent distortion. Cartilage grafting should be considered for severely damaged or absent cartilage.

Nasal scars lead to wound contraction and possible nasal deformity as a result. This can be particularly problematic at the alar rim. Scar contracture can cause alar notching and retraction. Alar notching that is less than 1 cm in diameter can be reconstructed with an auricular cartilage composite graft (Fig. 11). Larger traumatic deformities typically require soft tissue transfer for reconstruction. Reconstruction of the entire alar subunit is often achieved with a superiorly based melolabial interpolated flap.19

Soft tissue avulsion should be treated conservatively at first by removing foreign debris and meticulous wound debridement and replacement of the avulsed segment if it has been recovered. If the segment is not recovered, wound care to allow the area to granulate and subsequent grafting or acute grafting with a full thickness or composite graft as necessary. Depending on the location, reconstruction may be necessary (Fig. 12). Options for reconstruction include full-thickness skin grafts, composite grafts, and soft tissue flaps. These potential repairs have been well documented elsewhere and are beyond the scope of this article.

Conclusion

Traumatic nasal deformities are complex reconstructive challenges. It is of utmost importance to fully evaluate all aspects of the deformity. Surgical repair should focus on restoring alignment and symmetry. Small irregularities should be camouflaged to achieve acceptable refinement. The fundamental principles of wound management, layered primary closure, reestablishing structural support, and delayed repair when necessary may need to be used to solve the reconstructive dilemmas that can result from nasal injuries with or without airway compromise.

References

Management of Posttraumatic Pseudotelecanthus

John L. Frodel, Jr., MD

Abstract

Injuries to the nose and perinasal region are common. Though the nasal fractures are commonly recognized and properly addressed, injuries to adjacent structures such as the orbit, medial canthus, and midface skeleton can be missed or misdiagnosed leading to improper primary treatment and subsequent secondary deformities. In this discussion, we focus on secondary deformities of the medial canthal region injuries that result from inadequate primary repair of the displaced medial canthal tendon apparatus in naso-orbital-ethmoidal fractures. Emphasis is placed on the difference in complexity of the secondary pseudotelecanthus deformity relative to primary fracture treatment. Case examples are used to discuss the complexity of the correction of such deformities.
regarding the origin of the nasal deformity, especially noting if they had midfacial trauma requiring surgical intervention. It will frequently be the case that either an NOE fracture was not properly diagnosed at the time of the initial fracture management or it was inadequately treated at that time.

Physical examination will demonstrate lateralization of the canthus and “rounding”; the latter appearance is caused by a more vertical orientation of the upper canthal limb of the eyelid, or a combination of vertical orientation of both upper and lower limbs. The canthus may be lateralized alone, but it is often positioned inferiorly as well. There may be epiphora due to lacrimal obstruction, but this is not always the case. Palpation often reveals bony fullness, due to lateralization of fracture fragments. This is a key component to the deformity as it contributes to the lateralization of the canthus and, without correction, will lead to inadequate medicalization of the canthus at the time of corrective surgery. A flattened and widened nasal pyramid is commonly, but not necessarily, present. Orbital deformities, such as enopthalmos, hypophthalmos, and lid malposition may be present. Lower lid ectropion or even restricted lower lid movement due to scarring are important to recognize as lid restrictions can also limit an effective canthal reconstruction. Additionally, noting whether the deformity is unilateral or bilateral is important, as symmetry is key to the perception of normal appearance. For example, I have seen patients with symmetric bilateral posttraumatic pseudotelecanthus who were not aware of it causing a deformity. Conversely, and most commonly, there is a disconcerting unilateral deformity or a bilateral deformity where both medial canthi are displaced in completely different fashions creating a complex evaluation and treatment problem.

All specific deformities are then reviewed with the patient. Like many posttraumatic deformities, correction is difficult as cicatricial contraction of scarred canthal; eyelid and medial orbital tissues make secondary correction much more difficult than in the primary setting. Accordingly, complete correction to proper symmetric position is not always possible and/or more than one surgery is not uncommon. These issues need to be stressed to the patient. The complexity grows and the likelihood of complete correction in one surgery further diminishes with the addition of other deformities (e.g., globe malposition, lid malposition, etc.).

Computed tomography (CT) scans are obtained in almost all cases. These assist in defining the bony anatomy of the medial orbit and maxillary regions. In particular, one looks for lateral displacement and fragmentation of the medial orbital rim and lacrimal area, displacement of the nasoaxillary segments (Manson type I or II), and orbital floor and wall displacement.

Prior to proceeding with surgery, the above limitations and concerns must be reviewed with the patient in detail. Besides the possible inability to completely correct the canthal malposition, other risks and complications should be reviewed. These include additional scarring, no improvement or worsened eyelid malposition, epiphora due to lacrimal obstruction, and related nasal and orbital issues (include visual changes and/or blindness if working on the orbit).

Surgical Treatment

After treatment plans, goals, risks, and complications have been extensively reviewed with the patient, one can proceed with surgery. We prefer the coronal approach to the medial canthal region in literally all patients. Though it is tempting to due limited local incisions (e.g., Lynch or transcaruncular), particularly in more limited unilateral canthal dystopias, we have found that these limited approaches commonly result in limited improvements. Our experience suggests that rarely is the source of the pseudotelecanthus simply due to detachment and lateral displacement of the medial canthus (i.e., a Manson type III NOE fracture scenario), but rather displacement at least in part caused by malposition of densely healed medial orbital and nasomaxillary bone segments. Accordingly, these malpositioned bony segments must either be repositioned or removed to create space for movement of the canthus into a more medial and superior position. Furthermore, experience has demonstrated that the cicatricial forces of the scarred canthal region tissues tend to move all repaired tissues back toward their deformed positions during the lengthy healing process. Therefore, it is extremely important to overcorrect the repaired canthal tendon as superiorly and posteriorly as possible, as the medial canthal region will contract laterally and inferiorly over time. This is best done by producing forces away from the medial canthal region, which is optimally performed with trans-nasal wiring (or use of any apparatus that can produce an appropriate transnasal force). In our hands, such manipulations are best performed with the excellent visualization of both medial orbital regions provided by the coronal approach (Fig. 1A).

Once the medial orbits are fully exposed, osteotomies are performed to either move or remove obstructive medial orbital bone. Unlike in primary repairs where the goal is to reposition fracture fragments, in the secondary setting these bones are stable and less important to either structural integrity or cosmesis. On occasion, in what was originally a pure Manson type I fracture, where the nasomaxillary segment is not comminuted but displaced inferiorly, an osteotomy of the segment (aided by an intraoral approach) at the lateral nasal buttress and infraorbital rim allows upward and medial repositioning of the segment, thus facilitating proper medial and superior positioning of the medial canthus. However, we find this to be uncommon. More frequently, there has been comminution in the medial orbital region with lateral displacement of healed bony fragments into the anterior medial orbital region, thus literally presenting an obstruction to medicalization of the malpositioned medial canthus. Therefore, rather than attempting to reposition this bone, it is commonly removed (osteotome or drill) to create space in the anterior and central medial orbital region. This actually facilitates narrowing of nasal bony pyramid width, while still allowing adequate reconstruction of the important posterior medial orbit in cases with combined globe malposition.

Once space for medicalization is created in the medial anterior orbit, the medial canthal tissues are identified. The medial canthus is often densely scarred and not easily
isolated. Accordingly, tissue is grasped that when the coronal flap is repositioned, one can see good movement of the medial canthal region when the grasped tissue is manipulated. This canthal tissue is then secured, either with wire or strong permanent suture. The capture should be retested by firmly pulling on the tissue from above to ensure that it will not tear through when pulled under tension to the contralateral side. The next step is critical. As the medial orbit has now been “excavated” of obtrusive bone, there is no ipsilateral lever point to produce a posterior and superior pull: If the wire is pulled directly medially to the contralateral side, it will be too anterior. The canthus must be pulled to a position that would equate to the area of the posterior lacrimal crest, and a minimum, because of the expected “spring back” that will occur during healing. Therefore, a cantilever point must be created to produce the proper medial and posterior pull. Some authors have described, for primary NOE repairs, placement of a plate to produce a posterior cantilever on the ipsilateral side. We have found that this limits the medialization that is necessary to correct the canthus position. Accordingly, using a small awl (or drill), a hole is carefully placed in the septal perpendicular plate of the ethmoid bone (making sure preoperatively where the location of the cribiform plate is on CT scan) as far posteriorly as possible. The wire that had previously been secured to the medial canthal tissues is now passed to the contralateral medial orbit, where the medial orbital soft tissues have been reflected and protected. The wire is then pulled under tension and secured to a screw placed in the superior-medial orbital rim or lateral glabellar region. Fig. 1 (B–F) demonstrates this process in a cadaver, noting the position of the perpendicular plate hole and the significant tension that is created and the overcorrection produced. Fig. 2 shows an example of the amount of overcorrection that should be produced to optimize results, noting that there will be lateral and inferior drift during healing in literally all patients. Fig. 3 serves as a simplistic model view of the principles of overcorrection in the proper direction.

As it is difficult to work in the orbit or lateral nose after the medial canthus has been medialized and secured to the contralateral side, any internal orbital, orbital rim, and nasal reconstructions should be completed prior to securing the wire to the screw. Finally, if nasal reconstruction is simultaneously being performed for a widened bony pyramid, transnasal compression is recommended. This is essentially what was showed in old literature where compression of the pyramid was performed with “lead plates.” We use silicone...
sheets placed on the external nasal sidewall, and then use a strong suture on a large needle that secures and gently compresses the sheets transnasally. We leave these in place for 1 week, finding that the technique assists in eventual narrowing of the nasal pyramid.

**Case Examples**

The following four cases demonstrate some of the above principles of posttraumatic pseudotelecanthus repair.

**Case 1:** This 22-year-old man was involved in motor vehicle accident, sustaining a central facial soft tissue avulsive injury, with bilateral LeFort level fractures, orbital fractures, and type III NOE fractures (►Fig. 4A). After primary repair (by myself) and subsequent healing, he presented with what appeared to be right-sided canthal displacement (►Fig. 4B, C). However, on close examination, he was noted to have good canthal position, but a soft tissue canthal web mimicking pseudotelecanthus. ►Fig. 4D shows intraoperative design of double Z-plasties, whereas ►Fig. 4 (E, F) shows his postoperative improvement. This case illustrates the importance of peri-canthal soft tissue analysis and that a pseudotelecanthic appearance can result from soft tissue scarring alone.

**Case 2:** This 28-year-old woman was involved in a severe motor vehicle accident sustaining central midface fractures, including nasal fracture, midface, LeFort-type fractures and bilateral orbital fractures, evaluated, and treated at another institution. She apparently did not have significant midface displacement and so attention on the repair was for the orbital rim and orbital fractures. She was referred for evaluation of her posttraumatic nasal deformity and nasal obstruction. On physical examination she was noted to have a collapsed bony and cartilaginous nose with retroposition of the bony dorsum and limited tip ptosis without structural support of the cartilaginous portion of the nose (►Fig. 5A, C). Intranasal examination showed an obstructed deviated septum. Striking was the lower eyelid ectropion, right...
telecanthus, and a transglabellar/nasal scar from the “butterfly” type of incision chosen by the initial operating surgeons. Though it appeared that she might have enophthalmos, measurements did not confirm this and it was felt that here right upper lid was ptotic. She was also noted to have brow asymmetry in the regions of the supraorbital extensions of the brow incisions. During this evaluation I pointed out to her that though her nasal deformity was significant and certainly needed to be addressed, I felt that without addressing some of the perinasal soft tissue problems she would not be satisfied with her outcomes. Unfortunately, our experience told us that it was extremely difficult to improve the abnormal scars created by the butterfly incisions and she was counseled to this effect. However, I felt that with medialization of the lateralized right medial canthus as well as attempted elevation of the lower lid, it might lessen these deformities. It was decided that the ptosis of the right upper lid could be addressed secondarily after final healing as this was a delicate and precise procedure. Preoperative CT scans showed inadequate position of the right orbital implant, but she wished to defer orbital reconstruction. Accordingly, she underwent structural reconstruction of her nose using autogenous rib grafts through an external approach along with open septoplasty. At the same time, through a new coronal approach she underwent transcanthal wiring of the right medial canthus, a right midface lift through her previous subciliary incision, and adjustment of her eyebrow position on the left. Postoperative photographs at 12 months (►Fig. 5B, D) after surgery show improvement of all aspects of the perinasal deformities that were addressed, including improved right canthal position, right lower eyelid position, and right and left medial brow position.

In review of her case one could point to several errors both in the decision-making process as well as technical errors. First and perhaps foremost was the decision to use a butterfly incision. This is particularly the case on the younger patient who is more apt to scar suboptimally. In our hands this incision is never used even the face of open wounds in this area. We feel that wounds should not be extended as the scar sequelae are often worse in the elective scars than in the accidental traumatic scars. Accordingly, a coronal approach should have been used to address the reconstruction of the medial orbit.

**Fig. 5** (A, C) Preoperative photos of patient with nasal, lid, and canthal deformities, along with iatrogenic “butterfly” scar. (B, D) Postoperative views after rhinoplasty and canthopexy.
and canthal regions. Perhaps the next error, which is far more debatable, was the use of the supriliary approach to the orbit. That on the left side certainly healed better than that on the right. However, to be constructively critical, though there is some lid retraction of both lower lids, it is just that it is worse on the right side and is more noticeable. We prefer the transconjunctival approach with or without lateral canthotomy and have found very few deformities with this approach. Finally, it is important to remember to properly reposition all periorbital structures such as noting the proper position of the eyebrow at the time of reposition of either the coronal or in this case the butterfly incision approach. With the coronal approach we have not had much trouble with brow malposition, but it certainly can occur. In this particular case it is possible that the eyebrow was inferiorly displaced inadvertently at the time of closure. Our correction, again to be constructively critical, probably led to an overelevated eyebrow, but at least it is more symmetric and draws less attention to itself. In the end, she still requires correction of her right upper lid ptosis. What is noticeable, however, is the butterfly scar. We are in process of attempting to individually revision limbs of the scar followed by the use of dermabrasion, but we are not optimistic that this will optimally improve these very deforming scars. Also, some limited left canthal malposition and webbing was unmasked by the procedure.

Case 3: This case is that of a 42-year-old man with a history of a self-inflicted gunshot wound 20 years previously. He presented with a several year history of increasing fullness in the left medial orbit and CT scans suggested a mucocele. On examination, besides this left upper medial fullness, he was noted to have other sequelae of the initial injury, including bilateral canthal dystopias, along with an upper lip deformity (Fig. 6A). CT scan confirmed a small ethmoid mucocele (the frontal sinuses were aerated), as well as significant lateral displacement of bony fragments in each medial orbit (Fig. 6B). After preoperative discussion, he requested removal of the mucocele and agreed that he would like to have his eyes look better by improving his pseudotelecanthus. He wished to defer lip reconstruction.

He subsequently underwent surgery where, via the coronal approach, the mucocele was removed, followed by medial orbital bone excision, and bilateral transnasal medial canthopexies. Fig. 6C shows his improvement 6 months after surgery.

This case demonstrates that though he had a significant deformity, the bilateral canthal dystopia was relatively symmetric, thus likely better tolerated by the patient until the mucocele growth led to the more asymmetric appearance.

Case 4: Fig. 7A shows the preoperative photo of a 50-year-old man who approximately 15 years earlier sustained a self-inflicted transoral gunshot wound. This remarkably did little damage to the anterior and external nose but led to severe orbital and intracranial injuries and fractures. He apparently underwent craniotomy through a coronal approach and repair of the injuries. This repair included fixation of midface fractures and reconstruction of the left orbital region. Repair of presumed right orbital fractures was apparently not performed. He was referred years later because of an extruding foreign body in the left upper maxilla that was likely the plate that was improperly positioned in the left medial orbit with a large bulk of plate material over the infraorbital rim. CT scan showed this plate along with other fixation devices throughout the maxillofacial skeleton (Fig. 7B). He was noted to have bilateral expanded orbital cavities leading to bilateral globe malposition. The examination and CT scan confirmed the abnormal position of medial orbital/ascending process of the maxilla bone on the left, which likely was in part responsible for the left canthal malposition. Obvious cranial and temporal deformities also existed. He denied any breathing problems. After multiple discussions with the patient, his principal priority was addressing the open wound in his left maxilla, and so to address this particular problem, the plan was to move the plate followed by tissue advancement to close the cheek wound. Upon further questioning, it became clear that he was bothered by the numerous cranial deformities as well as the deformities of his periorbital regions. He was counseled that if symmetry could be improved that he would likely be more satisfied. Accordingly, the decision was made to address both medial canthal regions but only to address the left globe displacement with the goal being to attempt to elevate the left globe to match the level of that on the right side. If there was persistent asymmetry after the first surgery, the right side could be addressed as well, but it was felt that the bilateral canthal medialization and symmetry was equally, if not more, important. Accordingly, he was taken to the operating room, and through his previously poorly positioned coronal incision, he underwent cranioplasty with hydroxyapatite bone...
substitute to address the majority of his cranial deformities. The left orbital plate was removed and soft tissue repaired in the left infraorbital cheek with attempt made to elevate the midface tissues at the same time to support the left lower eyelid. Excess bone was excavated from both the right and particularly the left medial orbit to allow for bilateral transnasal wiring. The severe displacement of the left medial canthus (~1 cm displacement laterally) caused by the severe contracture and cicatricial forces in this region made it impossible to adequately medialize it, but it was attempted regardless. Postoperative photographs, 9 months after surgery showed generalized improvement of all the areas that were addressed (~Fig. 7C). There was improved globe symmetry to the point that he felt that no further intervention in that respect was necessary. As expected, he had a persistent left canthal displacement, but there was satisfactory improvement.

This patient demonstrates many of the soft tissue complications that can occur from inadequate primary repair. Understandably, the likely principal focus at the time of the initial surgical intervention in what would have been a very serious injury was the intracranial repair and repair of the severe mandibular and midface fractures. However, one can be critical of numerous omissions in the primary repair. These include the placement of the coronal incision. It is likely that the patient was undergoing hair recession at the age of his injury yet the surgeons placed the incision somewhat anterior. Unfortunately, with further hair recession, this linear incision has moved onto the temporal extension region of the forehead. The incision should have been placed more posteriorly, and in our opinion, a geometric design would be less evident. Next, the orbital repairs were inadequate; even though we do not have the original CT scans, it is likely that he had a right orbital injury as well as a left. Obviously the left orbital repair was inadequate even though plate was positioned while nothing was placed on the right side, thus leading to severe bilateral enophthalmos and hypophthalmos. The next mistake was that of inadequate reduction in the paranasal bony fractures. The severe bony displacement in the left lateral nose/medial orbit obligated the poor position of the left medial canthus. As there is no wire present in our CT scans, either there was no attention given to the medial canthal displacements or it was done with resorbable suture as no foreign materials were found during our repair. The other issue that was likely not appreciated was the resuspension of the midface tissues at the time of the primary repair. It is likely that he underwent both eyelid and intraoral approaches to the midface, and it is quite possible that the surgeons did not resuspend the midface leading to traction on both lower eyelids. This is why a midface lift was performed on the left side during our repair.

**Case 5:** The final case is that of an unfortunate woman who at age 20 was involved in a motor vehicle accident in manner that her injuries were the result of a tree branch protruding through the window and then puncturing between her eyes into her skull base. One globe was ruptured while the optic nerve on the other was severed. Initial management involved intracranial stabilization and skull base reconstruction. Her presentation after that is shown in ~Fig. 8 and clearly demonstrates a variety of complex problems not the least of which was her severely deformed nose, along with bilateral pseudotelecanthus, and cranial deformities. After extensive consultation, a plan was made to reconstruct her nose while simultaneously addressing her periorbital deformities including bilateral posttraumatic pseudotelecanthus. Additionally, we recommended cranioplasty to improve her cranial irregularities. On examination she was noted to have only thin scar in the upper dorsal region with overrotation of the tip. It was obvious at the time of this evaluation, which was augmented by the use of endoscopy that there were no soft tissue layers remaining in the upper dorsum of the nose just an open cavity from the initial injury intranasally. We felt that this would not support traditional placement of augmentation material both in terms of inadequate external skin and...
internal lining coverage as well as the inability to expand the skin in the upper dorsal region. Accordingly, the decision was made to recommend the use of adding external soft tissue by placement of a forehead myocutaneous flap using either de-epithelialized residual or turn-in flap for lining. At the time of surgery, to expand and derotate the contracted tip, the residual skin at the superior dorsum necessarily required full-thickness release creating the composite defect in the nose. The distal dorsal nasal skin was then turned internally being based superiorly to restore internal lining to the nose. A calvarial bone graft was then fashioned and placed over the turn-in flap for cutaneous coverage. Prior to reconstruction of the orbit, the medial canthal areas were dissected and excavated followed by transnasal wiring to at least secure the medial canthus in more optimal positions. I have had the ability to follow this patient for nearly 15 years and along the way further cranioplasty reconstruction and other minor revisions have taken place primarily unrelated to the surgery I just described. Unfortunately she had developed brow malposition, particularly noticeable with the overelevated left medial eyebrow that has been refractory to attempts to lower it (Fig. 8).

This case was illustrative of the severe deformities that can occur with nasal perinasal trauma. On rare occasions is there a need to bring in more soft tissue, but this was certainly a good example of a situation that it was not only necessary, but that has maintained relatively stable nasal and canthal appearance over a long period of time. As noted, such severe trauma can be difficult to manage and made frustrating by seemingly minor soft tissue issues such as her left medial eyebrow that are refractory to improvement due to scar tissue changes. However, awareness of such deformities is key both in counseling and in surgical planning.

Cases 3 through 5 demonstrate the severity of potential problems that can occur with avulsive injuries. Granted, a blast injury is likely worse than even a severe avulsive soft tissue injury that does not originate from a blast, but we believe that these cases are analogous in terms of the severity of the soft tissue injuries. Great attention to intricate of the bony anatomy in such bony perinasal/midface fractures is critical, as is attempted adequate repair of the soft tissue. Additionally, these are the kind of cases that will almost always optimally require some sort of secondary procedure and counseling to this effect is important.

Summary

These cases have been used to demonstrate how perinasal fracture scenarios can result in posttraumatic canthal dystopias. We have attempted to make it clear that the secondary correction of canthal and orbital deformities is extremely
difficult and fraught with predictable failure in many if not most cases. The cases presented further emphasize the importance of understanding the principles of proper primary correction. When such complex secondary deformities present, proper evaluation leading to proper planning and counseling is key. It such situations the appreciation for the severity of the deformities and the need for sometimes invasive techniques must be appreciated. Rarely is a “minimalist” approach in even modest secondary canthal deformities adequate. Keys to acceptable outcomes include good exposure of the canthal and medial orbital regions, complete release of the scarred canthal soft tissue elements, removal of obtrusive medial orbital bone, and strong fixation of the canthi via cantilever compression wires through the septal perpendicular plate.

References
Dorsal Augmentation in Rhinoplasty: A Survey and Review

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Rhinoplasty remains one of the most complex and nuanced procedures in facial plastic surgery. Debate surrounding best technique and outcomes remains a vital part of our literature. Augmentation of the nasal dorsum is a prevalent topic in the literature on rhinoplasty regarding different techniques and graft materials to achieve success.

Understanding current trends in rhinoplasty is imperative to master the most efficacious techniques and improve outcomes. There is a wide range of acceptable practices regarding dorsal augmentation; surgeon preference may vary based on expertise. For this reason, we conducted a national survey to investigate the practices of rhinoplasty surgeons regarding dorsal augmentation.

An anonymous survey was sent to the members of the AAFPRS. The survey queried the predominance of rhinoplasty in the surgeons practice, as well as specifics related to use of dorsal augmentation techniques.

Methods

A brief six-question survey was created and dispersed via e-mail to the current attending and fellow members of the

Abstract

Understanding the nuanced practices and grafting options of dorsal augmentation will improve outcomes and results in rhinoplasty. To better understand the practices of dorsal augmentation among our colleagues. To review the current literature regarding the indications, safety profiles, and outcomes of different materials used in dorsal augmentation. A PubMed search was performed to capture current articles containing reviews or large series regarding the safety and efficacy of various grafting materials used for dorsal augmentation. Of the many options available, autologous cartilage grafts maintain widespread use for dorsal augmentation and other techniques in rhinoplasty. Homologous cartilage grafts, namely irradiated rib, are a preferred alternative. Irradiated costal cartilage has been shown to have low complication rates and is unique in its abundance of supply, particularly in the revision rhinoplasty. Alloplastic implants, particularly silicone, are prevalent in Asian countries where they are a popular first-line choice. ePTFE has a favorable complication profile in primary rhinoplasty; however, caution is recommended when using ePTFE in revision cases. Porous polyethylene has a higher risk of associated complications than the other alloplastic implants listed, and therefore should be considered thoughtfully. Although cartilage is often the preferred graft for dorsal augmentation, there are many other autogenous, homologous, and alloplastic materials that have been shown to be safe and effective choices when applied in the proper setting.

Keywords

► rhinoplasty
► dorsal augmentation
► revision rhinoplasty

Rhinoplasty remains one of the most complex and nuanced procedures in facial plastic surgery. Debate surrounding best technique and outcomes remains a vital part of our literature. Augmentation of the nasal dorsum is a prevalent topic in the literature on rhinoplasty regarding different techniques and graft materials to achieve success.

Understanding current trends in rhinoplasty is imperative to master the most efficacious techniques and improve outcomes. There is a wide range of acceptable practices regarding dorsal augmentation; surgeon preference may vary based on expertise. For this reason, we conducted a national survey to
AAFPRS. The survey was sent to a total of 1,300 surgeons via e-mail. The questions were listed in multiple-choice, checkbox format with single or multiple answers available depending on the questions presented. Free text responses were allotted for two of the questions to gather more information. Questions 1 and 2 inquired about the prevalence of rhinoplasty within the surgeons practice. Questions 3 and 4 asked about the surgeon’s practices related to dorsal augmentation. Questions 5 and 6 asked about preferred grafting/implant material for dorsal augmentation.

**Results**

Of the 1,300 surveys dispersed, 290 responses were received for a survey response rate of 22%. Responses were collected over a 2-month period from August through September of 2013. The data were analyzed anonymously and independently using the Survey Monkey Web site and data analyzer.

Our survey showed that approximately one-third (32%) of our participants have a surgical practice in which rhinoplasty represents more than half of their overall case volume. Approximately one-fourth (23%) of our responders reported that more than half of their rhinoplasty cases are revision or secondary surgeries (Fig. 1).

**Primary Rhinoplasty**

An overwhelming majority of responders (93%) report that they perform dorsal augmentation in less than 25% of primary rhinoplasties. For the surgeons who perform dorsal augmentation in the majority of their primary cases, 83% reported that rhinoplasty represented less than half of their overall surgical case volume.

Our findings are consistent with current literature advocating septal cartilage as the graft of choice for primary cases, with 70% of surgeons indicating so in our survey. Alloplastic implants were the first-line choice in primary cases for 11% of responders; ePTFE being the most popular alloplast (8%), followed by silicone (3%), and porous polyethylene (<1%). Diced cartilage wrapped in fascia is the autogenous graft of choice for 8% of responders. Costochondral grafting (both autologous and cadaveric) was the first choice for 6% of surgeons (autologous rib 4%, cadaveric rib 2%) in primary cases.

**Revision and Secondary Rhinoplasty**

The majority of surgeons (57%) perform dorsal augmentation less than one-quarter of the time in revision and secondary rhinoplasty. For the surgeons performing dorsal augmentation in the majority of their revision/secondary cases, we found a wide range in the percentage of their surgical practice that is made up of revision/secondary rhinoplasty.

Interestingly, we found an equal number of surgeons electing septum and rib as their first-choice graft material for revision/secondary cases, 30% chose septum and 30% elected rib. Autogenous rib comprised 21% and cadaveric rib 9% of responses. Diced cartilage wrapped in fascia is first-line graft for 11% of responders. Alloplastic implants garnered first choice in 10% of responders with ePTFE representing 9%, a large majority, for use in revision/secondary cases.

**Discussion**

This brief survey reveals the widespread practices of dorsal augmentation among rhinoplasty surgeons. Proper and safe management of the nasal dorsum is imperative to achieving desirable aesthetic outcomes, and must be considered on an individual basis. Mastering techniques in dorsal augmentation require advanced skill and a large armamentarium of knowledge about different options in grafts and implants.

We conducted a literature review on the various types of materials used in dorsal augmentation, and the historical complication rates associated with each. An ideal graft is one that is readily available, biocompatible, inexpensive, harvested with low donor site morbidity, and bearing a low complication rate. The current literature reports separately on the use of autogenous, homologous, and alloplastic grafts for dorsal augmentation. We present a concise article to compare all types of grafting material together, with their associated successes and failures, as well as the patient population for which each is most suitable (Table 1).

This survey did not query surgeons on rhinoplasty approach as it was considered extraneous to the aims of this study. Whereas an open versus closed rhinoplasty approach can alter tip shape and projection, it is not considered to affect the outcome of dorsal augmentation. However, we acknowledge that this is an unlikely but potential confounding issue with our data. This study focused on the unique issues related to varying graft materials in dorsal augmentation.

**Autologous Grafts**

Autologous grafts are considered by many to be the most desirable material for grafting in rhinoplasty. Autologous grafts offer clear advantages of low rates of infection or graft extrusion and favorable patient acceptance. However, the well-known disadvantages of autologous grafts include availability of graft volume, irregular shape, absorption, donor site morbidity, and aesthetic results—all of which may prohibit use in revision or more extensive cases.

Autologous cartilage is the preferred grafting material for dorsal augmentation as shown in our survey, and has been widely documented as a successful technique in the literature. Autologous cartilage is sourced from the nasal septum, conchal bowl, costal cartilage, and lateral crura of the lower lateral cartilages. Cartilage grafts can be used en bloc or diced and wrapped in autogenous temporalis fascia or other biocompatible materials such as Surgicel® (Ethicon, Inc., Somerville, NJ). When using diced cartilage techniques, the surgeon must ensure encapsement with temporalis fascia versus surgical and other biocompatible materials. Surgicel wrapped cartilage is also referred to as a “Turkish Delight” based on the original author’s publication and heritage. The complication rates of autologous cartilage are infection (1.5–5%), implant migration (1–12.5%), graft resorption (0.5–5%), and warping (2.5–5%). There are no reported cases of graft exposure. Particular care must be taken in cases of...
revision or secondary rhinoplasty, where availability of autogenous cartilage may be inadequate.

There are reports of autologous bone and other soft tissues successfully used in nasal augmentation as well. Bone grafts have been described for augmentation of moderate to great dorsal defects. However, bone grafts may be difficult to carve into an aesthetically pleasing nasal dorsum as well as requiring fixation. Soft tissue grafts for refinement and augmentation of mild to moderate dorsal defects have also been reported. Although the data are limited thus far, there are

Fig. 1  Survey results.
no reports of graft extrusion, infection, or displacement. The most common complication encountered with soft tissue grafts was under-augmentation, suggesting this may play a more appropriate role in contour refinement.

**Homologous Grafts**

Irradiated rib has gained widespread popularity with a particular advantage in secondary or revision rhinoplasty, where autologous cartilage may be scant or inadequate for use. Irradiated rib has unique benefits for use in augmentation of the nasal dorsum in that it is an abundant resource to provide ample grafting material while reducing operative time and donor site morbidity as compared with harvesting autologous costal cartilage. Reported complications of irradiated rib include infection (0.87–7.4%), resorption (1–7.4%), displacement (0.3–5.9%), warping (1–14.8%), and graft exposure (3.6%). Human acellular dermal matrix grafts, AlloDerm, is an alternative homologous graft. Used either alone or in conjunction with other graft materials, AlloDerm is incorporated into surrounding tissue and therefore may cover small contour irregularities. Resorption, has been shown to be between 20% and 30%, occurring within the first year post-op.

### Table 1 Review of graft material complications

<table>
<thead>
<tr>
<th>Author</th>
<th>Graft material</th>
<th>Cases</th>
<th>Follow-up</th>
<th>Complication rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cervelli et al²</td>
<td>Autogenous costal cartilage</td>
<td>33</td>
<td>1–8 y</td>
<td>Revision surgery 9.1% Resorption 3%</td>
</tr>
<tr>
<td>Herman and Strauch³</td>
<td>Irradiated costal cartilage</td>
<td>56</td>
<td>1–14 y</td>
<td>Exposure 3.6% Resorption 1.8% Displaced 1.8% Removal 1.8%</td>
</tr>
<tr>
<td>Kridel et al⁴</td>
<td>Irradiated costal cartilage</td>
<td>20,1</td>
<td>4 d–24 y</td>
<td>Overall complication 3.25% Infection 0.2%</td>
</tr>
<tr>
<td>Jackson et al⁵</td>
<td>AlloDerm</td>
<td>15</td>
<td>6–24 mo</td>
<td>None</td>
</tr>
<tr>
<td>Lam and Kim⁶</td>
<td>Silicone</td>
<td>1,079</td>
<td>N/A</td>
<td>Infection 2.6% Removed 2.6% Cosmesis 2.96%</td>
</tr>
<tr>
<td>Tham et al⁷</td>
<td>Silicone</td>
<td>355</td>
<td>3 mo–3 y</td>
<td>Infection 5.3% Extrusion 2.8% Cosmesis 7.8%</td>
</tr>
<tr>
<td>Wang et al⁸</td>
<td>Silicone</td>
<td>27</td>
<td>2 y</td>
<td>Poor cosmesis 3.7% Extrusion 3.7% Infection 3.7%</td>
</tr>
<tr>
<td>Conrad et al⁹</td>
<td>Gore-Tex</td>
<td>264</td>
<td>12–17 mo</td>
<td>Overall complication 1.9%</td>
</tr>
<tr>
<td>Godin et al¹⁰</td>
<td>Gore-Tex</td>
<td>309</td>
<td>5 mo–10 y</td>
<td>Infection 3.2% Removed 3.2% Cosmesis 0.32%</td>
</tr>
<tr>
<td>Jin et al¹¹</td>
<td>Gore-Tex</td>
<td>853</td>
<td>18 mo</td>
<td>Infection 2.1% Removed 2.2% Cosmesis 1.9%</td>
</tr>
<tr>
<td>Chen et al¹²</td>
<td>Medpor</td>
<td>32</td>
<td>25 mo</td>
<td>Infection 6.25% Removed 6.25%</td>
</tr>
<tr>
<td>Romo et al¹³</td>
<td>Medpor</td>
<td>187</td>
<td>6–42 mo</td>
<td>Infection 2.6% Removed 2.6%</td>
</tr>
</tbody>
</table>

**Alloplastic Implants**

Alloplastic implants are well studied and in widespread use, and are particularly favored in Asian countries for augmentation in rhinoplasty. The reported complications associated with silicone implants include extrusion (2.1–3.7%), infection (3.7%), and displacement (3%). There were also reports of graft dislocation; however, there are no published rates of this complication.

Expanded polytetrafluoroethylene (Gore-Tex; Implantech, Inc., Ventura, CA) has also been used with good results in augmentation rhinoplasty, alone and in combination with autologous cartilage grafts. Complications observed with ePTFE include extrusion (1%) and infection (3.2%). Of note, the published literature notes a higher complication rate with ePTFE use in cases of revision surgery, thereby heeding special attention and care to this subset of patients.

Porous polyethylene (Medpor; Porex Surgical, Inc. Newnan, GA) is also used in dorsal augmentation rhinoplasty; however, the reported complication rates of porous polyethylene are somewhat higher than the other alloplastic choices. Porous polyethylene was shown to extrude from 3.1% to 10.7% of the time, and infection rates run from 1 to 6.25%. Some surgeons also find that with
advantageous property of excellent tissue in-growth with Porous polyethylene implants can also be a detriment if this implant requires removal for infection or displacement.

One potential issue to consider is the long-term duration of augmentation materials based on their varying complication profiles. Alloplasts, namely silicone, remain at potential risk for delayed extrusion at any time after implantation, as there is no tissue incorporation. There is no literature to suggest if the same risk applies to porous polyethylene or pETFE. This potential downside must be weighed against the added benefits that alloplasts incur by requiring no further surgical morbidity from a donor site surgery that may be associated with harvesting rib or ear cartilage. The authors do not advocate any particular graft material; rather they present a review of the benefits and downsides to enhance the understanding in the field.

These findings, as well as our survey results, confirm cartilage as the preferred graft for dorsal augmentation when it is available in sufficient quantity. However, familiarity with other graft material is imperative to success in a wide range of case complexity, and a necessary tool for the masterful rhinoplasty surgeon. This literature review validates autogenous, homologous, and alloplastic materials as safe and effective choices when applied in the proper setting, as illustrated in our survey results.

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Handheld-Level Electromechanical Cartilage Reshaping Device

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Abstract

We have developed a handheld-level multichannel electromechanical reshaping (EMR) cartilage device and evaluated the feasibility of providing a means of cartilage reshaping in a clinical outpatient setting. The effect of EMR on pig costal cartilage was evaluated in terms of shape change, tissue heat generation, and cell viability. The pig costal cartilage specimens (23 mm × 6.0 mm × 0.7 mm) were mechanically deformed to 90 degrees and fixed to a plastic jig and applied 5, 6, 7, and 8 V up to 8 minutes to find the optimal dosimetry for the our developed EMR device. The results reveal that bend angle increased with increasing voltage and application time. The maximum bend angle obtained was 70.5 ± 7.3 at 8 V, 5 minutes. The temperature of flat pig costal cartilage specimens were measured, while a constant electric voltage was applied to three pairs of electrodes that were inserted into the cartilages. The nonthermal feature of EMR was validated by a thermal infrared camera; that is, the maximum temperate of the flat cartilages is 20.3°C at 8 V. Cell viability assay showed no significant difference in cell damaged area from 3 to 7 minutes exposure with 7 V. In conclusion, the multichannel EMR device that was developed showed a good feasibility of cartilage shaping with minimal temperature change.

Keywords

► electromechanical reshaping
► multichannel EMR
► cartilage reshaping
► facial cartilage

Reshaping facial cartilages of the head and neck through open surgery is demanding for the surgeon and resource intensive for the hospital. Doctors who perform such procedures undergo years of training and education. The cost of operating room including staff and overhead is an economic burden to both the hospital and patient. More importantly, it is cumbersome for patients who elect such procedures.

Though the open surgery remains as the gold standard for reshaping cartilage, alternative methods to reshape cartilage have been developed. The first and most researched method is using heat to reshape cartilage, which can be accomplished with laser or radiofrequency (dielectric heating) sources. Although this technology has been studied for more than a decade, a huge disadvantage to this method is the application and uncontrolled diffusion of heat to the surrounding tissue.1–3 The second method to reshape cartilage and main topic of this paper is the use of electric energy to reshape tissue called, electromechanical reshaping (EMR). To perform EMR, the tissue is bent into the desired shape and while in that shape a voltage is applied through electrodes in contact with tissue. The direct current that passes through the material elicits redox reactions that modify the internal
structure of the tissue, thereby releasing the internal stresses under deformation. A major advantage to EMR is that it is a nonthermal and noninvasive technique with applications to the head and neck as well as in tendon.6-8

The evidence and usefulness of EMR applications within the head and neck have been reported in ex vivo as well as in vivo studies; however, this work has been done using laboratory setups. To progress this technology from bench to bedside, the device and software need to be constructed and tested. The objective of this study is to produce a turnkey, multichannel EMR device and to evaluate its performance on ex vivo pig costal cartilage. A thermal infrared camera (FLIR SC 660) is used to validate the nonthermal effect of EMR. A live-dead assay is used to determine the extent of cellular viability dependent on EMR voltage and time settings. Herein we provide details of the electronic architecture and operating functions of the device as well.

Materials and Methods

Multichannel Electromechanical Reshaping Devices

A handheld-level electromechanical reshaping (EMR) cartilage device has been developed for the office or bedside operations, as well as replacing the conventional benchtop EMR that is direct current (DC) power supply-based instrumentation. Fig. 1A shows the system overview of the handheld-level multichannel EMR for cartilage reshaping. The device is designed for three primary tasks: (1) applying direct current (DC) voltage to the positive needles (i.e., anode); (2) feeding the current from the negative needles (i.e., cathode); and (3) controlling the system, including chart display, data logging, and various parameter setup by a universal serial bus (USB) connected tablet computer.

The following lists the system requirements required for our portable cartilage reshaping device. First, the multichannels are composed of six positive-negative pair needles (i.e., six pairs of electrodes) to cover the wide area of the facial cartilage in a minimally invasive manner. Second, the output voltage of the positive needles can be programmed between 5 and 8 V at 1 V steps. Third, the current during applying the voltage.

Voltage Source Selection

According to the DC-power supply-based EMR instrument, reshaping the rabbit septal cartilage is required the range of voltage from 2 to 8 V.6,7 However, below the voltage threshold of 4 V, clinically significant reshaping was not observed. Hence, the voltage range and application time for the handheld-level EMR cartilage device is determined from 5 to 8 V.

The voltage output that is controlled in the physical layer of the EMR device is accomplished by using a boost DC-DC converter with an adjustable output-voltage function through built-in feedback routine. In more detail, the DC-DC converter has voltage reference of 1.23 V, which is compared with the attenuated output voltage by external resistor divider R1, R2, R3, and R4. The attenuated output voltage physically feeds back into the boost DC-DC converter though the feedback (FB) pin, and then adjusts the output voltage following the equation as:

\[ V_{out} = 1.23V \times \left(1 + \frac{R1 \cdot R4}{R2 \cdot R3} \right) \] (1)

where R1~R4 can be selected by turning on or off the N-channel metal–oxide–semiconductor field-effect transistor (MOSFET) as shown in Fig. 2A. For example, when the user chooses the applied voltage of 5 V using web-pad, the gate of Q1 is turned on (i.e., logic = 1), then other gates of Q2 ~Q3 become off (i.e., logic = 0). In this case, the Eq. (1) is to be

\[ V_{out} = 1.23 \times (1 + R1/R5) \]

because R2, R3, and R4 are disconnected.

Current Sensing Technique

While applying the voltage between positive and negative needles, the current flows that through the cartilage elicits electrochemical reactions.6,7 There is a threshold at which these reactions occur that facilitate tissue reshaping. To figure out optimal EMR settings (V, t) for cartilage reshaping using this device, it is necessary to measure the electrical current during applying the voltage. The current shunt monitor is placed between applied voltage and each positive needle. Fig. 2B delineates the circuit diagram for one of the current shunt monitor channels. The current monitor can sense voltage drops across shunt resistor, which can be translated into the amount of electrical current. In other words, the current monitor indicates the amount of electric current though output voltage, then analogue-to-digital converter (ADC) equipped with the controller part of our developed system is able to read the level of output.

![Fig. 1](image-url) Multichannel electromechanical reshaping (EMR) cartilage device: (A) system architecture, (B) developed handheld-level EMR device.
Four cartilage specimens were used for each group, while for the cartilage thermograph, four cartilage specimens were used. For the shape change and cell viability assay, five cartilage specimens were used for each group, while for the cartilage thermograph, four cartilage specimens were used.

**Tissue Preparation**

Fresh pig costal cartilage was obtained from a local distributor and it was cut with a dimension of 23 mm × 6.0 mm × 0.7 mm using a sharp blade. To reduce the inherent tendency of the warping in pig costal cartilage, only the central portion of the costal cartilage was used. For the shape change and cell viability assay, five cartilage specimens were used for each group, while for the cartilage thermograph, four cartilage specimens were used.

**EMR Protocol**

During temperature measurement tests for the thermograph, three pairs of electrodes were penetrated into the middle location of the pig costal cartilage and measured the temperature for seven minutes at the applied voltages 5, 6, 7, and 8 V, respectively, by the infrared FLIR camera. The camera was focused at the center needle among three positive needles to record the temperature variation of the cartilage during voltage application.

For the shape change and cell viability assay, the specimen was mechanically deformed 90 degrees and fixed to a plastic jig. Platinum needle-based electrodes were inserted into the cartilage through the jig. Three negative needles and three positive needles were placed parallel across the bend. The electrodes were connected to the developed handheld EMR device through the female needles ports as shown in Fig. 1B. The voltage of exposure duration can be set using a touch screen of the controller and displays as a chart diagram in the tablet graphical user interface.

The cartilage was sliced into cross sections 400 μm thick. They were stained with calcein AM and ethidium homodimer-1 (EthD-1; Molecular Probes, Eugene, OR) to calculate the proportion of live and dead cells. Calcein AM is an indicator of living cells that have intact cell membranes and esterase activity and Eth-D-1 is an indicator of dead cells. It can only permeate cells with compromised membranes. Stained specimens were inspected with a confocal microscope at 10× magnification (LSM 510 META, Carl Zeiss, Jena, Germany).

**Quantitative and Statistical Analysis**

The thermographs of the cartilage were measured by the infrared camera (FLIR SC 660). The current and voltage through the cartilages were plotted on the web-pad using the selectable voltage and current sensing technique in subsections 2.4 and 2.5. The shape and cell viability data were analyzed using ANOVA among groups and a t-test was used for analysis of data between two groups. Significance was set at p = 0.05.

**Results**

To validate the functions of the handheld EMR device, we conducted experiments using pig costal cartilage. Four metrics determined the performance of the handheld-level EMR device: analysis of cartilage shape change at different voltages and application time, thermograph of cartilage during each applied voltage, current measurement depending on various voltages and thickness, and cell viability assay by a confocal microscope at 10× magnification.

**Shape Change Depending on Voltage and Application**

We measured the bend angle of cartilage created by EMR with different voltage (5, 6, 7, 8 V) and exposure time (1, 3, 5, 7 minutes). The bend angle created in pig costal cartilage were 41.7 ± 11.0, 50.3 ± 16.2, 60.9 ± 10.8, and 70.5 ± 7.3 degrees when 5, 6, 7, and 8 V were applied for 5 minutes, respectively, showing linear relationship between bend angles and voltage used (p < 0.01; Fig. 3A, B). The bend angle also increased with increased application time. The angles created were 37.6 ± 11.0, 60.8 ± 10.8, 54.0 ± 29.4, and 76.3 ± 11.6 degrees with 1, 3, 5, and 7 minutes of exposure, respectively (p < 0.05; Fig. 3A, C). The results in shape change are in accordance with those of the previous benchtop EMR instrumentation.4,5

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**Fig. 2** Voltage selection and current sensing scheme: (A) Circuit diagram for the selective voltage, (B) current sensing technique.
Thermograph for Cartilages
To verify that heat is not a main factor to reshape the cartilage, we conduct experiments using the infrared camera (FLIR SC 660). The peak temperature is measured during applying the voltages 5, 6, 7, and 8 V for 7 minutes. In addition, the anode needles generated more heat than the other cathode electrodes. According to Fig. 4, temperature increased with increasing voltage. In addition, the increase in applied voltage causes to reduce the application time to reach the peak temperature. When applying 8 V to the pig’s costal cartilage, the peak temperature is measured by 20.3°C in 45 seconds at the positive needles. After approaching the peak temperature of 20.3°C, the temperature on the cartilage begins to decrease.

Current Flow
Fig. 5A demonstrates the current measurement plot in the developed EMR device during application of 5, 6, 7, and 8 V for 7 minutes. As soon as turning on the system, the current is rapidly initiating to flow through the cartilage and increasing up to the peak current. Once the electrical current is approaching the peak point, the current is slowly going down. The peak current is increasing when the applied voltage is increasing; that is, increasing applied voltage results in a corresponding increase in peak electric current. However, maximum electric current does not exceed 2.2 mA for any voltage during application time up to 7 minutes with 0.5-mm-thick cartilage specimens. In fact, the current measurement results reveal that if we increase the voltage, we can...
reshape the cartilage within shorter time. The effect of EMR on cartilage tissue thickness was also investigated. Fig. 5B shows the measurement results at different cartilage tissue thickness: 0.5, 1, 1.5, and 2 mm for 7 minutes. The thicker cartilage can increase the peak electric current.

**Cell Viability Analysis**

Confocal microscopy in conjunction with a live/dead assay is a well-known method used to determine acute chondrocyte viability. After measuring bend angles, cell viability assay was performed with a confocal microscope to identify the extent of chondrocyte injury after EMR. Fig. 6A shows the results of the live dead assay as a function of EMR voltage application. The length of damaged cell was statistically different when 8 V was applied for 5 minutes compared with those when 5, 6, or 7 V were applied (p < 0.05; Fig. 6B).

In terms of application time, 1 minute showed less damaged area compared with those of 3- to 7-minute exposure and there was no significant difference in damaged area from 3 to 7 minutes exposure with 7 V of our developed EMR (p < 0.05; Fig. 6C). In these results, optimal EMR dosimetry values and needle placement could limit cell injury and intersperse the areas of tissue damage within areas of normal tissue. Furthermore, unlike the laser cartilage reshaping, the chondrocytes surrounding the regions of EMR-induced injury can potentially aid in the repopulation of the damaged areas with viable chondrocytes.

**Discussion**

The cartilage reshaping results (Section “Shape Change Depending on Voltage and Application”) can demonstrate the relationships between voltage, application time, and resultant shape change all of which can be associated with total amount of electrical charge passed through the tissue. In this sense, the shape change of the cartilage can be correlated with total amount of charge. In theory, more than one combination of voltage and time can achieve the same degree of cartilage reshaping.

To verify the thermal performance of electromechanical (EMR) reshaping cartilage, we use the thermograph that can be a suitable way to show the correlation between the temperature of cartilage and the current flow during the cartilage reshaping. In fact, other cartilage reshaping techniques such as lasers, radiofrequency, and contact heating (e.g., hot saline, iron) are used for the thermal effect to change shape of the cartilage. In general, the thermoforming methods generate heat to change the shape of cartilage; leads to increased tissue injury by uncontrolled diffusion of heat. On the contrary, electromechanical reshaping (EMR) cartilage is not the thermoforming methods but electrochemical reactions. The thermograph shows that when the current flow is decreased, the temperature of the cartilage is also reduced.

The current flowing through the pig costal cartilage is proportionally increasing depending on the thickness. In fact, according to the Ohm’s law, the voltage across a resistor is directly proportional to the current flowing through the resistor; that is, Ohm defines the constant of proportionality for a resistor to be the resistance, R. The resistance R of any material with cross-sectional area A and length L can be expressed as

$$ R = \frac{\rho L}{A} \quad (2) $$

where $\rho$ is known as the resistivity of the materials. Considering the Eq. (2), the distance between positive and negative needles is the length L and the thickness of cartilage means the cross-sectional area; therefore, the increase in thickness can raise the electrical current flow.

However, the limitation of this study is that we only consider the cartilage without any surrounding tissue such as perichondrium to validate the performance and show the feasibility of the developed EMR device. Future work includes a long-term in vivo efficacy experiment and short-term ex vivo experiment evaluating the damage of cartilage and perichondrium. The soft tissue around target cartilage will also be explored to identify the biomechanical properties after using our EMR device and confirm the efficacy of the EMR cartilage. Because soft tissue has different tissue resistance, it is necessary to validate the thermal effect and current flow with the consideration of the surrounding soft tissue. Besides, the long-term in vivo implantation can show the tendency according to the direction of bending and tendency of warping. Also,
because the main origin of cartilage regeneration is from the stem cells in perichondrium, we are going to prove that the perichondrium of dead zone is not injured by electric stimulation using the long-term in vivo implantation.\textsuperscript{7–9}

In conclusion, we developed a handheld EMR cartilage device with multielectrode channel operability and demonstrated the feasibility to be used as a medical device in a clinical outpatient setting. This study serves as a significant starting point, allowing EMR to be performed using a handheld-level device, three pairs of needle electrodes, a user convenient tablet control, and a rechargeable battery-based operation. In accordance with benchtop-based EMR studies, shape change increased with both voltage and application time. The thermographs reveal that the EMR do not involve thermoforming methods. Instead of them, it is associated with spatially limited cell injury. The developed EMR device would convert operating room procedure to office-based or bedsides service care.

Conflict of Interests
Electromechanical reshaping has been patented by the University of California Irvine, and licensed by Aerin Medical, Inc Santa Clara, CA. Dr. Wong is an inventor on the patent and related intellectual property, Praxis Biosciences licensed the technology to BLI Korea, Dankook University, and Dr. Mauel is a consultant for Praxis Biosciences.

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Injection rhinoplasty is a medical procedure in which injectable fillers are used to modify the nose without the need for invasive surgery. Commonly this comprises filling depressed areas, lifting the angle of the tip or smoothing the appearance of bumps on the nose bridge. Injection rhinoplasty offers an attractive alternative to surgical rhinoplasty as it is reversible if the results do not meet patient requirements. Furthermore, there is little downtime, with the most common adverse effects comprising bruising, swelling, and redness that usually resolve within 1 week. It is a much cheaper procedure than surgical rhinoplasty, although it is important to remember that repeat treatments may be needed every 1 to 2 years. In addition, it can provide a patient with a stepping stone before fully committing to permanent surgical rhinoplasty and it can also provide a solution for those who have undergone unsuccessful earlier surgical rhinoplasty procedures. However, there are some disadvantages as it is not a permanent solution, the administration of fillers means injection rhinoplasty can increase the size of the nose, and there are also limitations in terms of what can be achieved, with some patients having unrealistic expectations. Attitude to longevity plays an important part in the patient's decision to opt for injection rhinoplasty. In our practice, we exclusively use degradable synthetic fillers, and therefore many patients reject treatment for this reason. Thus, a carefully
considered treatment plan with a clear outline of realistic results is crucial for patient satisfaction. In this study, we aimed to assess the outcome, longevity of beneficial effects, adverse effects and patient assessment of injection rhinoplasty using degradable synthetic fillers.

**Patients and Methods**

All patients provided written informed consent for treatment. Because the study was a retrospective review of patient’s treatment, no Ethics Committee approval was needed; however, the principles of the Declaration of Helsinki were followed. Informed consent was obtained from all patients for off-label treatment with hyaluronic acid (HA) or calcium hydroxyapatite (CaHA) for soft tissue augmentation at least 1 day prior to the treatment.

Photographic assessment was performed using the standardized Canfield imaging system that allows matching of pre- and postoperative frontal view images at 45- and 90-degree angles (Omnia, Canfield Scientific Inc., Fairfield, NJ). Preoperative images were compared with simulated images indicating realistically achievable treatment results so that an informed decision could be made by the patient as to whether to opt for filler injections or surgical rhinoplasty (—Fig. 1). In some cases of surgical rhinoplasty, we have observed low levels of patient satisfaction because preoperative simulation for surgery did not sufficiently match the actual result. This is not generally the case with injection rhinoplasty as predictability using photographic simulation in most cases, especially for hump camouflage, augmentation, and columella elevation, is very high.

We selected the type of filler to be used based on levels of viscosity and elasticity. CaHA seemed initially to be the most appropriate agent, particularly for structures such as the nasal dorsum that has thin connective tissue and firm adhesion to the underlying structures and thus requires greater extensibility. Furthermore, some investigators highlight the importance of low hydrophilic properties for application in the nasal area to reduce the risk of compression of dermal and subdermal vessels, thereby favoring use of CaHA rather than HA.

However, we observed two adverse effects in our first 20 patients, comprising filler displacement and erythema of the nose tip, which caused us to start using HA fillers as well (Juvéderm 4 and VOLIFT). Sixteen patients were treated with Juvéderm 4 and four patients with VOLIFT. Although the properties differ significantly between these two HA fillers—the former comprising a cohesive, 3D HA matrix dermal filler with local anesthetic; the latter using VYCROS technology, comprising an innovative combination of low- and high-molecular-weight HA to improve the cross-linking efficiency of HA chains—they were not separately evaluated due to the small number of patients in the VOLIFT group. The decision as to whether to treat with CaHA or HA was reached according to the region to be treated. If augmentation of the columella was desired, we chose CaHA due to the higher-viscosity gradient that was believed to result in greater stability, while pure dorsum augmentation was performed with HA. However, a major complication associated with use of CaHA at the end of the observational period (see “Adverse Effects” section) led us to treat our remaining cases exclusively with HA.

Anesthetic ointment (i.e., 23% lidocaine-alkaline, 3.5% tetracaine-alkaline, 3.5% tetracaine—HCl, paraffin, Lipothene 133) was applied for 15 minutes prior to the procedure to the target treatment region; no other anesthetic measures were performed. The patient was then taken to the operating room, the anesthetic ointment was removed, and the skin area disinfected with Cutasept F (Propan-2-ol). The patient was placed horizontally with the upper part of the body slightly elevated. No marking of the treatment areas was performed to avoid camouflaging any irregularities. Visualization of the target zone was optimized by binocular head Loupes glasses (Eye Mag Smart Zeiss x2.5). Injection was performed either with a 23-gauge needle for CaHA or a 27-gauge needle for HA fillers. In both cases, fillers were injected craniocaudally deep into the superficial musculoaponeurotic system (SMAS) and sub-SMAS area. After positioning the needle, the syringe was aspirated to eliminate any intravascular placement. Injection was performed retrogradely while simultaneously controlling the effect on the tissue volume. After needle removal, molding of the tissue was performed to achieve maximum homogenous distribution of the filler. This procedure was repeated if required and the patient was also involved by controlling the desired effect using a hand mirror.

After the procedure, cool packs were applied to the treated area for further 15 minutes and the patient was instructed to use ibuprofen and bromelain to mitigate against potential bruising for 3 days. A follow-up visit was scheduled for 1 week later, at which time volume was assessed and a repeat filler injection was administered if appropriate.
Finally, patients were issued with a questionnaire 3 weeks and at least 9 months posttreatment asking them to rate their satisfaction with injection rhinoplasty according to a 5-point scale (“not at all” to “completely”).

**Results**

Forty-six patients were treated over 3 years, 9 of whom underwent more than one treatment, up to a maximum of three consecutive treatments. Some patients were treated in more than one area, each of which were separately evaluated, so in total 88 areas were treated. Regarding the type of filler used, Radiesse (CaHA) was administered in 26 patients, and Juvederm 4 or VOLIFT (HA) in 20 patients.

Patients were questioned about their motivation to undergo the procedure. Thirty-two wanted to improve an aspect of their nose but did not wish to undergo surgery, seven patients presented following unsuccessful surgical rhinoplasty, whereas seven patients were considering rhinoplasty but wanted to try a nonsurgical procedure before committing. Four patients elected to undergo surgical rhinoplasty at this point. Indications for treatment were as follows:

- Correction of a hump (radix and/or dorsum augmentation): 48 treatments
- Columella elevation, nose tip elevation, shortening of the nose: 16 treatments
- Camouflage of a twisted nose: 5 treatments
- Adjustment of grooves due to cartilaginous bony irregularities: 7 treatments
- Nose augmentation and/or tip molding: 12 treatments

**Hump Reduction and/or Columella Elevation**

Hump camouflage was performed in 12 patients and was combined with a nose tip elevation or nose shortening in 16 patients. For 17 patients, CaHA was the filler of choice and HA was used in 11 patients. The needle was introduced craniocaudally below the radix nasi and the injection was performed retrogradely. Care was taken to preserve a reasonable amount of the nasofrontal groove so that the hump was resolved completely (→ Fig. 2). Management of pollybeak deformation (i.e., overprotection of the cartilage dorsum in relation to the bony dorsum) was achieved by columella elevation and equalization of the cartilage bony transition using 0.7- to 1.3-ml filler (→ Fig. 3).

**Camouflage of Twisted Nose**

Harmonization of a twisted nose requires equalization of the concave side of the deformity. The needle entry point is positioned cranially of the concavity, the skin is elevated, and the needle inserted deep into the sub-SMAS, just superior to the periosteum or perichondrium. After aspiration, the needle is gently withdrawn and injection is performed caudocranially in a retrograde manner. The volume of filler required is evaluated by direct vision with the binocular Loupes glasses and palpation. Five patients were treated for
this deformity and the amount of filler used varied between 0.5 and 0.9 mL (►Fig. 4).

Adjustment of Grooves due to Cartilaginous Bony Irregularities
Equalization of the grooves between the cartilage skeleton is an effective indication for harmonizing the nose, particularly because the surgical alternative is difficult and does not generally lead to a successful outcome. Five patients were treated for this indication using between 0.6- and 1.1-mL filler (►Fig. 5). Bony irregularities occurring following rhinoplasty were treated in two cases.

Augmentation of the Dorsum (Saddle Nose)
Three patients presented with a saddle nose that is effectively treated with injection rhinoplasty, resulting in a smooth, even surface. We administered between 0.7- and 0.9-mL filler volume (►Fig. 6).

Nose Augmentation, Tip Augmentation, and/or Optical Nose Thinning
We performed this procedure in five patients. The nose tip is treated together with the columella by inserting the needle between the medial crura of the alar cartilage, then moving on to the tip defining point. Again, the filler material is inserted retrogradely, and placement between the medial crura allows a firm encapsulation of the filler within a defined structure, resulting in a stable correction and projection of the nose tip. The total amount of filler administered was between 1.3 and 1.7 mL. Tip molding was performed in combination with columella elevation and adjustment of cartilage grooves in seven patients (►Fig. 7).

Patient Satisfaction Questionnaire
All 46 patients provided feedback within 3 weeks of undergoing treatment. Sixty-three percent were completely satisfied, 22% were satisfied, and 15% were dissatisfied with...
treatment. Thus, 85% of patients were satisfied with the short-term treatment results. Only 15 patients returned the questionnaire 9 months or later after treatment, 87% of whom confirmed they were very or completely satisfied with the results of injection rhinoplasty, regardless of the type of filler used. Ten patients confirmed they would repeat the procedure (four were undecided and one would not undergo repeat treatment). In those cases where patients were dissatisfied or not completely satisfied, this was commonly due to loss of volume that had occurred since treatment (73%). Indeed, treatment longevity varied considerably, ranging between 6 and 30 months (mean 13.5 months) (Fig. 8). Eight patients (53%) said they would recommend treatment to others, four (27%) were likely and three (20%) would probably recommend treatment.

The overall positive evaluation was mainly due to the high level of predictability of the result and the ability to simulate the desired outcome to meet patient expectations. This is particularly the case for refining the nose profile, that is, humps, saddle nose, and columella elevation. Of the 35 patients treated for nose profile correction, 27 were completely satisfied (77%), 7 were moderately satisfied (20%), and 1 patient was dissatisfied (3%). Least patient satisfaction was associated with nose augmentations, molding of the nose tip, and isolated columella elevations in which eight patients (66%) were dissatisfied and four patients (33%) were only averagely satisfied.

Regarding patient assessment of the injection procedure, 29 patients were fully satisfied and stated that the procedure met the expectations completely, especially with respect to the preoperative counseling and simulation tool (63%)(10 patients [22%] were satisfied; 7 patients [15%] were dissatisfied).

**Adverse Effects**

Reported complications after nonsurgical rhinoplasty are generally restricted to minor adverse effects, such as erythema, local inflammation, swelling, and bruising. Local erythema after injection is almost unavoidable, and administration of anti-inflammatory drugs and application of cool packs usually leads to prompt recovery within hours.

Minor adverse effects in this study comprised one case of filler dislocation, two cases of visible hematoma, and one case of subcutaneous nodules persisting for up to 8 weeks after CaHA injection. However, we also observed one moderate and two severe complications, all following CaHA treatment. The first was a 35-year old man treated for a hump, cartilaginous grooves, and abnormal projection of the columella who presented with a painless red nasal tip 2 weeks posttreatment. Treatment was given with topical corticosteroid (Ecural [Mometasone 17-(2-furoate)]) and cefuroxime antibiotics and resulted in complete remission after 4 weeks (Fig. 9). The second case was a 48-year-old woman presenting for a dorsum correction after rhinoplasty 15 months previously. We administered 0.4 mL CaHA in the area between the alar and lateral cartilage of the dorsum. As the patient lived some distance from the clinic, we recommended cefuroxime 250 mg as prophylaxis, but she rejected this advice. She presented the following day with local infection at the injection site and punctate skin lesions were observed. Local treatment comprised disinfection with Octenisept and hydrogen peroxide 4%, and Aureomycin antibiotic ointment. The patient insisted on returning home, but 72 hours later she sent photographs that indicated skin necrosis. We arranged a consultation at a local ENT and facial plastic surgery department whereupon necrosis was not confirmed, but extensive infection was diagnosed.

**Fig. 7** Nose augmentation and thinning of the nose tip (pre- and postoperative), injection of 1.3 mL Juvederm 4 in the radix area, dorsum nasi, tip of the nose, and the columella.

**Fig. 8** Treatment longevity of up to 30 months, injection of 0.7 mL Juvederm 4 in the radix area.
and it was recommended that in-patient treatment was required. The patient rejected this advice and no further information on follow-up was available (►Fig. 10). The third case was a 53-year-old man who underwent several CaHA injections for nose augmentation over the past 5 years, the last of which was with 0.4 mL CaHA 12 months ago. He also underwent corrective surgical rhinoplasty that involved insertion of a polyethylene Medpor splint. There were no reported infections following these treatments. He presented with a history of a blocked nose persisting for approximately 2 weeks, with no obvious signs of infection. Endoscopic inspection revealed a dislocated splint that had protruded through the mucosa of the left nasal cavity and the nose tip revealed a subdermal abscess with skin necrosis (►Fig. 11). The abscess was incised, pus removed (microbiological examination indicated staphylococcal infection), and the cavity was cleaned with hydrogen peroxide 4% and ciprofloxacin. This treatment was repeated daily for 10 days, together with oral ciprofloxacin 750 mg twice a day. The splint was shortened under local anesthesia but not removed as per the patient’s request. Following treatment, the infection resolved completely and the splint was covered by a layer of mucosa.

**Discussion**

Injectable biodegradable fillers are a safe and effective alternative to surgery for correction of minor nasal deformities or irregularities either as primary procedure (primary rhinoplasty) or secondary to surgical rhinoplasty with residual unevenness (revision rhinoplasty). In this study, 46 patients were treated (26 with CaHA, 20 with HA). There was a high level of patient satisfaction 3 weeks posttreatment (85%); however, only 15 patients returned the questionnaire 9 months or later posttreatment, but of these, 63% indicated they would repeat the procedure and 80% would recommend the procedure to others. Lack of satisfaction was largely due to complete or partial loss of the initial volume over time (73%). The overall positive assessment was related to the very fast and mostly painless (62%) procedure, which offsets the temporary nature of the result. Treatment longevity was very variable, ranging between 6 and 30 months.

Most practitioners agree that biodegradable fillers should be used in preference to permanent fillers for safety reasons, although some authors still favor permanent fillers. In our study we assessed safety of the procedure, as there are potential disastrous complications that can occur, such as amaurosis after injection of fillers, fat, or local anesthesia, probably due to accidental intra-arterial injection with subsequent occlusion of the central retinal artery or its branches. Similar complications have been reported following septoplasty and rhinoplasty. Therefore, it is important not to exert excess force when injecting and attention should be paid to the needle size, as well as the viscosity and particle size of the filler. This is a particular issue when comparing CaHA and
HA fillers, as CaHA is harder to inject due to its higher viscosity, and therefore higher pressure has to be applied than with HA fillers, resulting in use of thicker needles. In our study, 23-gauge needles were used to inject CaHA, whereas 27- and 30-gauge needles were used to inject HA.

All authors concur about injection technique that comprises syringe aspiration, retrograde injection, reduction in injection pressure, avoidance of bolus injection, application of topical vasoconstrictors pretreatment, use of blunt needles, sub-SMAS injection, and compression of the angular artery.10 We would also recommend a superior-inferior injection technique into the nasion and dorsum of nose following the longitudinal vessels of the dorsum from the fixed (superior) to the more flexible (inferior) region. This technique means that vessels tend to be pushed away by the needle so it is unlikely they will be punctured accidentally, whereas the subcutaneous areas of the nasion and the lateral walls of the pyramid have a distinctly firmer adhesion that reduces the ability of the arteries to shift away. It is important to document the technique used in case of subsequent complications.11 In the unlikely event of microembolism and vision loss following HA treatment, hyaluronidase should be the first-line treatment as it is an enzyme that catalyzes the hydrolysis of HA and has been shown to degrade intravascular HA.12 There is no similar dissolving agent known for CaHA, with most practitioners favoring reperfusion of the occluded vessels with oxygen, topical application of Nitropaste,2 intravenous diuretics, corticosteroids and antibiotics, carbogen and hyperbaric oxygen inhalation, plus lysis therapy.13

Infections or necrosis have been reported following application of HA in the glabella and nose.14,15 In this study we observed three cases of infection after CaHA administration; no infection/necrosis was observed in patients treated with HA. Two cases resolved completely following treatment, but one case was lost to follow-up. However, because of the high number of complications associated with CaHA (10.7%), we decided to use HA rather than CaHA for future injection rhinoplasty, particularly because it has the potential for immediate degradation using hyaluronidase.

In conclusion, injection rhinoplasty with CaHA and HA biodegradable fillers for harmonization of minor nasal deformities, either as primary procedure (primary rhinoplasty) or secondary to rhinoplasty with residual unevenness (revision rhinoplasty), produces excellent results with high levels of patient satisfaction.

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Fig. 11 Pus penetrating through the nasal tip (left), and residual scar (arrow) after local treatment, multiple previous injections of Radiesse in the dorsum nasi, and surgical rhinoplasty.
Safety Approach to Otoplasty: A Surgical Algorithm

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Abstract

An algorithm was developed through an evolution of refinements in surgical technique with the goal to minimize risk and morbidity in otoplasty. Key principles were avoidance of cartilage incisions and transections and the use of multiple surgical techniques to distribute the “surgical load” evenly among these techniques. The present retrospective study was designed to test safety and efficacy of the concept in 100 consecutive patients and to discuss the results in light of the literature. Data detailing the surgery, preoperative, and postoperative period were extracted from the record and during patient interviews. Patients were contacted to complete a questionnaire to rate the postoperative pain and their satisfaction with the final outcome on a 6-point visual analog scale (VAS). An expert and a lay panel assessed preoperative and postoperative frontal-view photographs, using the same VAS. Pain in the postoperative was rated as minor (pain level VAS average score, 2.33) and patients’ satisfaction was excellent (satisfaction level VAS average score, 1.82). The assessment by the panels of expert and lay evaluators paralleled these outcomes with a postoperative average VAS score of 1.69 and 1.87, respectively. Cartilage incision and transection can be effectively avoided in otoplasty. Even distribution of the surgical load among multiple techniques avoids the problems associated with “overload” of a single technique. The innovative technique of cortical mastoid drill-out is described. High satisfaction with the results, excellent patient comfort, and a favorable safety profile are associated with the present algorithm.

Keywords
► otoplasty
► prominent ears
► external ear

With an incidence in the Caucasian population of ~5%, prominent ears are the most common congenital deformity of the external ear. Prominent ears represent a source of distress and diminished self-confidence, especially for children. Anatomically, otoplasty may be performed as early as 5 to 6 years of age. Goals of the procedure include improving quality of life and avoiding the above-mentioned harms.1,2 Protruding ears may result from a multitude of anatomical contributors including an underdeveloped antihelical fold and overdeveloped conchal wall.3

Otoplasty can be a highly satisfying procedure for patients when complications are avoided and an excellent result is achieved. Complications may be categorized as early (within the first 14 days following otoplasty surgery) and late complications. Pain, bleeding, skin necrosis, wound dehiscence, hematoma, and infection are classified as early complications; suture extrusion, hypertrophic scarring, keloid or granuloma development, hypo- and hypersensitivity, narrowing of the external auditory canal (EAC), and unsatisfactory aesthetic results are late complications. Among the
cosmetic complaints are inadequate correction, asymmetry, overcorrection, recurrence, creation of a sharp antihelical fold, inadequate correction of the lobule, and telephone ear deformity.\textsuperscript{4–6}

To avoid an unfavorable result and to achieve a successful, harmonious, and natural-appearing outcome, the surgical plan should be tailored to the individual pathology.\textsuperscript{7} More than 200 surgical otoplasty methods have been described.\textsuperscript{5,8–11} These can be classified into techniques used to accentuate the antihelical fold, to correct the conchal hyperplasia, to modify lobule positioning, and others. Reconfiguration of the cartilage may be achieved by incisional techniques, scoring techniques, suturing, or a combination of these.\textsuperscript{3,12} Incisional techniques and aggressive anterior scoring can be associated with deformity, sharp edges, pain, and other unfavorable sequelae.

The purpose of this article is to describe the evolution of our current surgical concept, to present, analyze, and discuss outcomes in a series of 100 consecutive patients treated with the described concept, and to compare the results with the literature.

**Methods**

**Surgical Technique**

The present surgical concept was developed through a continued evolution of techniques, based on analysis of the surgical results and the quest to eliminate imperfections and optimize outcome. The surgical techniques and maneuvers have evolved as follows.

The first measure is to address the conchal bowl. Rotation of the conchal bowl is an effective maneuver as it carries the upper two-thirds of the ear without distortion. We aggressively resect the postauricular muscle and identify the EAC skin. To minimize the risk of perforation of the EAC, especially in teaching cases, we mark the skin from the luminal side with a needle and dye. Two conchal set-back sutures are placed from the mastoid periosteum to the lateral aspect of the conchal bowl. To minimize the risk of EAC stenosis, these sutures are placed with a posterior vector and the EAC is observed while they are tied. When this is insufficient, we drill the mastoid cortex for improved conchal rotation (\textsuperscript{–}**Fig. 1A**). After placement of testing knots, the sutures are left untied until all other maneuvers have been completed.

The second maneuver following the conchal set-back is modification of the antihelical fold with the Stenström technique. This is based on the observation by Gibson and Davis that injured cartilage warps away from the treated surface.\textsuperscript{3} We initially utilized direct scoring of the anterior antihelical surface with a Brown–Adson forceps, after an anterior incision and the creation of a skin tunnel. Because of the considerable ecchymosis, the less predictable effect, and the risk of cartilage injury, we changed to multiple percutaneous needle perforations, as described by Fritsch.\textsuperscript{13} This resulted in reduced operative time, avoidance of an anterior incision, and reduced ecchymosis. Occasionally, microfractures of the cartilage were observed. Because of that, we changed from a 23- to a 26-gauge needle. Ecchymosis was further minimized and injury to the cartilage no longer observed. The observation of an accentuated edge along the antihelical fold led us to change our technique and produce multiple parallel scoring lines (\textsuperscript{–}**Figs. 1B and 2**). This has resulted in consistently smooth, harmonious, and reliable folds.

**Fig. 1** (A) When postauricular muscle resection and conchal rotation set-back sutures are not sufficient to improve conchal rotation, the mastoid cortex is drilled. (B) Modified Stenström technique (multiple parallel scoring lines). (C) Modified Mustardé technique (marking mattress sutures). (D) Modified Mustardé technique (permanent Mustardé sutures).
We routinely combine the Stenström technique with Mustardé sutures. To accurately place the mattress sutures, we used to mark the new antihelical fold percutaneously with needles lined with blue dye. The markings were not always precise because the dye would run. Moreover, the creation of the fold was simulated with a finger pinch, which also introduced variability. The placement of anterior percutaneous marking mattress sutures (4–0 nylon, Resolon, Resorba, Germany) was in three ways advantageous: the marking became precise, the creation of the antihelical fold could be simulated more accurately, and the placement of the permanent Mustardé sutures could be completed without tension, thus rendering these sutures more exact and reliable (►Fig. 1C). Initial observations of occasional suture failure led to the placement of additional sutures. We now place one redundant “reserve” suture in the gap between each original Mustardé suture (►Fig. 1D). This usually results in the placement of a total of six Mustardé sutures.

Our initial choice of suture material for the permanent Mustardé sutures was 4–0 polyfilament nonresorbable Mersilene (Ethicon Inc, Johnson & Johnson Medical GmbH, Germany). As we observed suture granulomas, we switched to transparent monofilament 4–0 nylon (Seralon, Serag-Wiessner KG, Germany). With this suture material, no more granulomas were observed. The occasional suture extrusion is typically managed by simply cutting the inert suture at the level of the external skin. This is done in the office and no local anesthesia is required.

The protrusion of the supratragal portion of the helix may in some instances of pronounced conchal hypertrophy persist after the conchal set-back, Stenström, and Mustardé techniques, as shown in ►Fig. 3. We term this the “U-phenomenon,” as the outline of the helix and the contour of the temporal scalp form the shape of a “U.” In these cases, an additional high conchal set-back suture is placed.

When lobule position was not ideal after the conchal set-back approach, we initially corrected it by resecting postlobular skin. However, we did not observe consistently ideal results, because this technique is not capable of modifying

Fig. 2 Preoperative (A) and postoperative (B) clinical images of a pediatric patient, who was treated using only a single line of antihelical scoring and an incisionless placement of Mustardé sutures. The single scoring line created a visible sharp edge. Subsequently, multiple parallel scoring lines were employed (right ear).

Fig. 3 Persisting protrusion of the supratragal portion of the helix, after the conchal set-back, Stenström, and Mustardé techniques: the “U-phenomenon”; an additional conchal set-back suture is performed for correction.
the inherent shape of the lobule. The same applies to various suture techniques. To overcome these difficulties, we developed the fillet technique.\textsuperscript{14} This method consists of releasing the lobular soft-tissue insertions by “filleting” the anterior from the posterior surface. The posterior flap can be repositioned in a shearing motion, thus allowing correction of lobular shape in all three dimensions (\textit{Fig. 4}). Tension is eliminated.\textsuperscript{14} We now use a fine resorbable 5–0 Monocryl as anchoring suture; the technique can be adapted in a “cut as you go” manner. When all tension has been released, the suture may even become optional and the flaps may be adapted just with the external dressing. In over 3 years, consistently excellent results and no complications have been observed so far.

After completion of the conchal set-back sutures, the postauricular incision is closed with 5–0 Monocryl (Ethicon Inc) resorbable interrupted sutures. In cases where there is considerable skin excess, the excess is very conservatively reduced. Excess of \textasciitilde 3 mm is maintained and skin closure is performed with no tension at all. The ear is then covered with a mold formed of sterile cotton and Vaseline petroleum jelly and a light circular dressing over fluffs is applied. After 24 to 48 hours, the dressing is replaced by a headband, which is kept for 10 days, 23 hours per day, and then only at night for another 10 days.

\textbf{Selection Criteria and Data Collection}

A total of 100 consecutive patients who met the following inclusion criteria were included in the study:

- Surgery performed by the senior author (H. G. G.)
- The surgical algorithm applied as described above
- Follow-up at least 3 months

Details of the surgical and postoperative period were retrospectively obtained from the medical chart and the operative report. Data concerning demographics, duration of surgery, operated side(s), type of anesthesia, peri- or postoperative complications, length of hospital stay, use and duration of antibiotics, duration of dressing, missed school/work days, length of follow-up, and the need of revision surgery were gathered.

All patients were asked to evaluate their own postoperative pain level and satisfaction level with the cosmetic outcome on a 6-point visual analog scale (VAS) (pain level: 1 = no pain and 6 = extremely painful; satisfaction level: 1 = extremely satisfied and 6 = no satisfaction at all with the final outcome). This was performed by either mail or telephone.

Two otolaryngologists who were not involved in the study and two nonphysicians assessed preoperative and postoperative frontal-view photographs (>3 months follow-up), using the same VAS.

The study was approved by the institutional review board of the University of Regensburg (14–101–0046). Written informed consent was provided by all patients or their parents or guardians.

\textbf{Results}

Between January 2010 and February 2014, 100 patients (184 ears) met the inclusion criteria and consented to participate in the study. Mean patient age was 18.3 years (range: 6–70 years). Intraoperative and postoperative parameters are presented in \textit{Table 1}.

Response rate, pain level, and subjective outcome assessment scores are listed in \textit{Table 2 (A)}. Proportion of patients with available postoperative photographs and scores of expert and lay evaluations of postoperative results are listed in \textit{Table 2 (B)}.

In terms of complications, we observed six ears with recurrence of the deformity (3.3%) that needed revision surgery (those patients were satisfied with the outcome of revision with a follow-up of at least 3 months), six granulomas (3.3%; five of these six resolved after conservative treatment and/or removal of an underlying suture in the office without anesthesia, and one required surgical revision; treatment of all granulomas resulted in complete resolution), two hematomas (1.1%) that were treated with needle aspiration and did not require surgical revision, one keloid (0.5%), treated with steroid injections that resolved completely, and one hypertrophic scar (0.5%) that resolved after conservative treatment. In one patient, folds of skin excess were resected under local anesthesia in the office. No excessive bleeding, skin necrosis, wound dehiscence, infection, narrowing of the EAC, or sharp edges were observed.

\textbf{Discussion}

The presented algorithm relies on important principles: (1) avoidance of maneuvers and techniques that are prone to complications, (2) selection of maneuvers and techniques...
that produce favorable and dependable cosmetic outcomes, and (3) combination of multiple techniques with the aim to reduce the “corrective load” on each individual technique to create a more balanced and reliable result.

In terms of techniques and maneuvers that are prone to complications, we have identified the following from literature reports and referred secondary cases: aggressive anterior scoring techniques, cartilage incision, excision and transection, excessive skin resection, prolonged placement of pressure dressings, and reliance on and “overload” of a single surgical technique.

More aggressive Stenström techniques are associated with complications in up to 23% of cases (ecchymosis, cartilage injury, and sharp edges).

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Important deformities and irregularities may be associated with cartilage incision, excision, or transection. Those are rather invasive methods and need prolonged placement of a circular pressure dressing during the postoperative period, which can lead to pain, pressure ulcers, and skin necrosis. We avoid incisional techniques and do not require pressure dressings. We apply a gentle circular wrap and remove the bandage after 24 to 48 hours.

In terms of cosmetically unfavorable outcomes, we have observed a common theme: “overload” of a single surgical technique is frequently observed as the cause of an unfavorable outcome. When an anterior scoring technique is overdone, contour irregularities, sharp edges, and even disastrous deformities can be observed. We therefore avoid all cartilage fractures or incisions with our needle technique. When the Mustardé technique is overdone, the antihelical fold becomes too acute and linear, a hidden helix syndrome ensues, and recurrence may occur with increased tension on the sutures, especially with firm and thick cartilage. To minimize this risk, we reduce the load on this technique and place reserve sutures. Suture granulomas are observed in up to 4% of patients after otoplasty, according to the literature.

We utilize monofilament sutures in lieu of polyfilament sutures to decrease the chances of having this type of complication. When the conchal set-back suture is overdone, EAC stenosis and protrusion of the antitragus may be

### Table 1 Gathered intraoperative and postoperative parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (mean)</td>
<td>18.3 y</td>
</tr>
<tr>
<td>Gender (male:female)</td>
<td>40:60</td>
</tr>
<tr>
<td>Duration of surgery (mean)</td>
<td>94 min</td>
</tr>
<tr>
<td>Operated side(s)</td>
<td>Right ear: 7/100 Left ear: 9/100 Both ears: 84/100</td>
</tr>
<tr>
<td>Type of anesthesia</td>
<td>Local anesthesia: 24/100 General anesthesia: 76/100</td>
</tr>
<tr>
<td>Ratio outpatient versus admission</td>
<td>Outpatient: 24/100 Admission: 76/100</td>
</tr>
<tr>
<td>Length of hospital stay (mean)</td>
<td>1.7 d</td>
</tr>
<tr>
<td>Use of antibiotics; duration (mean)</td>
<td>10/100; 4.1 d</td>
</tr>
<tr>
<td>Duration of dressing (mean)</td>
<td>1.68 d</td>
</tr>
<tr>
<td>Missed school/work days (mean)</td>
<td>7.8 d</td>
</tr>
<tr>
<td>Length of follow-up (mean)</td>
<td>13.1 mo</td>
</tr>
</tbody>
</table>

### Table 2 Pain level and outcome assessment scores

<table>
<thead>
<tr>
<th>Section</th>
<th>VAS score (1–6)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Subjective pain and outcome assessment</strong></td>
<td></td>
</tr>
<tr>
<td>Subjective assessment of pain level</td>
<td>2.33</td>
</tr>
<tr>
<td>Subjective assessment of cosmetic outcome</td>
<td>1.82</td>
</tr>
<tr>
<td><strong>B. Objective outcome assessment</strong></td>
<td></td>
</tr>
<tr>
<td>Expert evaluation</td>
<td>1.69</td>
</tr>
<tr>
<td>Lay evaluation</td>
<td>1.87</td>
</tr>
</tbody>
</table>

Abbreviation: VAS, visual analog scale.

*Response rate: 67% of patients.

*Proportion of patients with available postoperative photographs: 72%.

*Pain level: 1 = no pain, 6 = extremely painful; satisfaction level: 1 = extremely satisfied, 6 = no satisfaction at all with the final outcome.
observed.\textsuperscript{17} We completely resect the postauricular muscle and allow the concha to gently rotate into the defect (the EAC is observed with placement of the set-back sutures). In cases of profound conchal hyperplasia, we drill the mastoid cortex for improved conchal rotation. No complications associated with the conchal set-back were observed in the present study.

For correction of the lobule, inconsistent results have been observed with skin resection and suture techniques.\textsuperscript{14} Both techniques reposition the lobule, but do not allow changing its inherent three-dimensional shape-memory. With the introduction of the fillet technique, shaping and positioning of the lobule has become consistent and reliable. In some cases, the ear piercing has to be sacrificed to obtain an optimal result. This can be redone 6 months after surgery.\textsuperscript{14}

Hematoma occurred in two ears (1.1%), hypertrophic scarring in one (0.5%), and keloid also in one ear (0.5%). Six ears developed granulomas (3.3%) and recurrence was also reported in six ears (3.3%). These complication rates reflect those reported in the literature (hematoma, 1.4–2.2%; hypertrophic scarring and keloid, 1.5–2.5%; granulomas, up to 4%; recurrence, 0–33%).\textsuperscript{2,4,6,16,18} A total of 4.4% of the ears had to be reoperated (literature 0–12%).\textsuperscript{6} No major early complications, such as excessive bleeding, skin necrosis, wound dehiscence, infection, narrowing of the EAC, or sharp edges, were observed.

Pain in the postoperative period was minimal to mild (pain level VAS average score, 2.33) and satisfaction with the outcome was high by the patients’ subjective rating (satisfaction level VAS average score, 1.82), with 50% of the patients rating it as 1.0 (extremely satisfied). Also the assessment by our panel of two noninvolved otolaryngologists and two nonphysicians evidenced a very pleasing aesthetic outcome with a postoperative VAS average score of 1.69 and 1.87, respectively.

Fig. 5 Preoperative (A, C) and postoperative (B, D) clinical images of a representative adult and a pediatric patient.
The present algorithm showed to be safe and reliable. ► Fig. 5 shows two representative patients with postoperative results. A limitation of our concept is the increased operative time (average time, 94 minutes), which is explained by the increased number of techniques and maneuvers performed.

**Conclusion**

The presented algorithm allows achieving excellent cosmetic results with high patient satisfaction, excellent safety, and reliable durability.

**References**

The Changes in Histopathology and Mass in Hyperbaric Oxygen–Treated Auricular Cartilage Grafts in a Rabbit Model

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ERRATUM

The publisher regrets an error in the above article in Facial Plastic Surgery, Volume 31, Number 2, 2015, page 172 (DOI: 10.1055/s-0035-1549041). The name of one of the authors, Meltem Akpınar, was missing from the original article. The correct listing of author names appears above.