An Overview of Nasal Dorsal Augmentation

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ABSTRACT

Structural deficiencies of the nasal dorsum most commonly derive from congenital, traumatic, and iatrogenic etiologies. Alternatively, dorsal deficiency may be a manifestation of a generally underprojected nose with otherwise appropriate relationships between the radix, dorsum, and tip. In analyzing dorsal deficiency, associated anatomic abnormalities leading to compromise of both aesthetic form and respiratory function must be recognized and incorporated into the reconstructive plan. The cornerstone of augmentation rhinoplasty employs either autologous graft or alloplastic implant material to restore dorsal height and structural support to the nasal skeleton. Many autologous and alloplastic materials are currently available to the rhinoplasty surgeon, each of which carries a characteristic profile of relative advantages and limitations. Although most rhinoplasty surgeons prefer autologous materials, the choice of material must be individualized to each patient. The reconstructive plan ultimately formulated emerges after thoughtful consideration of the extent of the dorsal deficiency, characteristics of the overlying skin–soft tissue envelope, history of prior surgery, associated structural abnormalities, preferences of the surgeon, and views of the patient. Regardless of the specific methods used to augment the nasal dorsum, optimizing the aesthetic profile and maximizing respiratory function in a sustainable manner with minimal patient risk and morbidity remain the primary objectives.

KEYWORDS: Rhinoplasty, dorsal augmentation, autologous, alloplastic, graft

In nasal surgery, there is a frequent need for structural augmentation to improve contour and respiration.¹ Among the more common findings is a deficient osteocartilaginous dorsum; in this situation, augmentation with graft material is required to achieve a desirable result. Establishing a symmetric and smooth nasal dorsum that fulfills the criteria of adequate form and function remains a principle challenge during primary or secondary rhinoplasty.^{2,3} This overview of dorsal augmentation rhinoplasty will illustrate the myriad factors contributing to the overall success of the reconstruction. The pertinent anatomic considerations will be discussed, as well as the manner in which the specific structural deficiencies contribute to the selection of a given approach to dorsal augmentation. A review of our

preferences for and experiences with the autologous and alloplastic materials available to the rhinoplasty surgeon follows, focusing on the relative merits and limitations of each. Ultimately, an understanding of the factors needed to maximize the success of the reconstructive effort should emerge.

NASAL ANALYSIS

In any given patient, the interplay of radix depth, nasal tip projection, and chin projection influences the ideal amount of nasal projection. On profile view, the nasofrontal angle typically ranges from 115 to 130 degrees. The proper depth of the radix is determined primarily by the aesthetic judgment of the surgeon. An excessively

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deep or shallow radix relatively shortens or lengthens the nose, respectively. As measured from the alar-facial crease to the nasal tip, nasal tip projection should approximate 60% of the nasal length from radix to nasal tip. Adequate tip projection occurs when 50 to 60% of the horizontal projection of the nose lies anterior to the upper lip. When a line is constructed from the radix to the adequately projected nasal tip, the dorsum should lie at or up to 2 mm posterior and parallel to this line. Dorsal augmentation is required when the dorsum is positioned significantly posterior to this line.⁴ A strong chin may mask an otherwise overprojected nose. Conversely, an adequately projected nose may appear overprojected in the setting of microgenia or retrognathia. Finally, despite appropriate interrelationships between the radix, dorsum, and tip, dorsal augmentation may be of benefit if the entire nose is underprojected.

Congenital, iatrogenic, and traumatic etiologies can produce a deficient or deformed nasal dorsum requiring correction with dorsal augmentation.⁵ Entities such as congenital hypoplasia or traumatic destruction of the nasal skeleton may also be associated with abnormalities of the skin envelope, endonasal lining, periorbital bones, and midface.⁶ Overresected dorsa and saddle nose deformities commonly require corrective augmentation.⁷ Reduction of a dorsal convexity can leave the tip projected beyond the height of the bridge, resulting in a scooped appearance.⁸ When excessive middle vault osteocartilaginous reduction results in inadequate dorsal septal support, the saddle nose deformity occurs.^{8,9} Functionally, the saddle nose often produces nasal valve constriction, which should be corrected during augmentation rhinoplasty.^{5,10}

Complete nasal analysis may reveal additional deformities associated with the deficient dorsum. These include a retracted columella, deficient caudal septum, acute columellar-labial angle, pollybeak deformity, septal perforation, hypoplastic premaxilla, and hypoplastic midface.^{8,11} Techniques that complement dorsal augmentation should be employed to achieve an optimal cosmetic and functional result. Such corrective measures include septoplasty, septal reconstruction, septal extension grafts, columella strut grafts, soft tissue grafts, endonasal lining grafts, premaxillary bone grafts, and chin and malar implants.¹¹

SURGICAL APPROACHES

Comfort with both external and endonasal rhinoplasty approaches is advisable. The external approach affords superior diagnostic capabilities, increased exposure, and better execution of precise maneuvers, especially when suture fixation of cartilage grafts is desired.^{12,13} Transcolumellar and infracartilaginous incisions prevent grafts from lying directly over openings into the nasal cavity. This approach also prevents grafts from traversing the

nasal cavity during inset.⁷ It is particularly important to separate incisions from alloplastic implants to reduce bacterial contamination.¹⁴ However, in the setting of decreased vascularity and a contracted skin-soft tissue envelope (S-STE), an endonasal approach with precise, limited tissue dissection may be preferred.¹³ Grafts may be introduced through intercartilaginous or marginal incisions. A supraperichondrial and subperiosteal pocket is then dissected to accommodate the graft without placing excessive tension on the overlying S-STE.¹⁰

If a coronal incision is performed for a synchronous procedure, it can be used for cephalad-to-caudad graft recipient pocket dissection and osseous fixation, if necessary.⁶ In rare circumstances, a vertical midcolumellar incision may be used. Lastly, although less commonly employed, the gingivobuccal sulcus approach affords ample exposure of the nasal dorsum, with no incisions lying directly over the graft.¹⁰

In general, we recommend placement of grafts from the radix to supratip region to minimize visible and palpable contour irregularities along the length of the dorsum. This technique may actually require reduction of dorsal projection in areas adjacent to known dorsal deficiency such that a straight dorsal line can be created. Superior seating of grafts at the level of the radix affords a measure of stability to the reconstruction that consequently reduces postoperative migratory tendencies. Prior to inset, graft fabrication requires an appreciation of the variance in S-STE thickness at the levels of the radix, rhinion, and supratip. The overlying S-STE must possess suitable intrinsic elasticity to accommodate the graft without creating excessive tension. Excessive tension can compromise the vascularity of the S-STE, increase the risk of visible and palpable dorsal irregularities, and promote graft extrusion.

AUTOLOGOUS GRAFT AUGMENTATION

Many autologous and alloplastic graft materials have been used for nasal dorsal reconstruction (Table 1).^{2,3} Autologous cartilage is the most commonly used and preferred graft material; it remains the gold standard against which other materials are compared.¹⁵⁻¹⁸ Autologous materials generally incorporate well into the

Table 1 Autograft Materials in Augmentation Rhinoplasty

Graft Source
Septal cartilage
Auricular conchal cartilage
Costal cartilage
"Turkish delight" cartilage
Split calvarial bone
Iliac crest bone
Costal bone

surrounding tissues, permitting permanence over time and the opportunity to replace “like tissue with like tissue.”⁶ Although autologous materials are more resistant to infection than are alloplasts, the possibility of resorption and various donor-site morbidities must be considered.¹⁶

Autologous septal cartilage and auricular conchal cartilage are the most commonly selected graft materials in limited augmentation rhinoplasty. However, in graft-depleted patients or patients with severely deficient dorsa, costal cartilage and bone, split calvarial bone, or iliac crest bone can be considered.^{2,3,16,18} Cartilage and bone possess the rigidity needed to maintain major nasal shape changes against the skin envelope and intranasal lining.^{6,16} Autologous cartilage is contoured with ease while its resilience lends good support to the reconstruction. Infection of autologous cartilage grafts are rare, but resorption, displacement, curling, and sharp edges can develop over time.^{14,19,20}

Although bone grafts confer great strength and support to the reconstructed dorsum,^{6,16} the donor sites are associated with various morbidities objectionable to some patients and surgeons.^{2,3} In addition, bone grafts may impart an unnaturally rigid feel to the reconstructed dorsum.

Septal Cartilage

Nasal septal cartilage is more rigid, easier to precisely shape, and usually straighter than auricular cartilage. Single- or multiple-layered grafts can be used for differing degrees of dorsal augmentation. Crushed cartilage can correct subtle dorsal irregularities and achieve slight degrees of augmentation. Bruised septal cartilage can be used as a radix graft to improve a deep nasofrontal angle. Septal cartilage can be harvested through a full transfixion, hemitransfixion, Killian, or external rhinoplasty approach.²¹ However, in the posttraumatic or secondary rhinoplasty patient, septal cartilage is frequently defective, insufficient, or missing.¹

Auricular Cartilage

Auricular cartilage is easy to harvest, yielding ~5 cm² of graft material. Donor site morbidity is low, although complete conchal cartilage removal can produce a slight medialization of the pinna.²¹ Conchal cartilage, owing to its more brittle nature, can be more difficult to carve than is septal cartilage.^{13,21} Like septal cartilage, conchal grafts can be used as a single-layered implant or sutured together to increase girth and rigidity.^{21,22} In the setting of a thin S-STE, including a portion of soft tissue on the posterior surface of the graft can provide some additional camouflage.²² Even morselized, though, it occasionally causes palpable and visible dorsal irregularities, due to its intrinsic memory and possibility for resorption.¹

Additionally, conchal cartilage is more curved and less rigid than is septal cartilage; structure and support, therefore, are better achieved with septal or costal cartilage.²¹ In their review of more than 1263 aesthetic rhinoplasties using stacked strips of auricular cartilage to augment the dorsum, Endo et al readily acknowledged that this method was not well-suited for the patient requiring extensive augmentation. Rather, it was designed to improve facial balance by effectuating a minor improvement of dorsal contour.²³

Costal Grafts

Autologous costal cartilage and bone grafts offer an abundance of material for augmentation of the severely deficient dorsum.^{15,21} These grafts permit simultaneous reconstruction of the dorsum and tip while maintaining a slim columella.⁶ Graft contouring creates a boat-like configuration that blends with the adjacent nasal anatomy.²¹ By replacing like tissue with like tissue, costal cartilage can impart a similar “feel” to the reconstructed nose. Disadvantages associated with the donor site include pain, conspicuous scarring, increased operating time (if performed by a single surgeon), risk of pneumothorax, and the need for a brief hospitalization.^{1,15,18} Despite careful technique, costal cartilage may nonetheless impart a stiffened feel to the reconstructed dorsum. Unpredictable warping and resorption continue to be the primary problems associated with costal grafts.^{1,15,18,21} However, in some series, such as that of Gurley et al, combined chondro-osseous costal grafts neither significantly resorbed nor lost projection during long-term follow-up of 32 pediatric rhinoplasty patients.⁶

Homograft Rib

Irradiated homograft costal cartilage (IHCC) is harvested from human cadaveric donors. The cartilage is readily available, semipliable, and easy to carve.²⁴ IHCC exhibits excellent tissue tolerance and good resistance to infection and extrusion.²⁵ The relatively acellular structure elicits minimal host tissue immunoreactivity.²⁶ The risk of disease transmission is nearly zero with the rigorous standards of donor testing and graft exposure to a maximum of 60,000 Gy gamma waves.^{15,21} IHCC grafts may be best suited for patients who would benefit from reduced operative time and elimination of donor-site morbidity.²¹

As with costal autografts, the stability of IHCC is highly variable. Some authors report minimal warping and resorption over time; others find resorption rates of 75 to 100% over extended periods. However, satisfactory results can occur even in the face of significant resorption due to replacement of cartilage with fibrous tissue.²⁴ Warping can be minimized with complete removal of the perichondrium followed by symmetric sculpting and

K-wire fixation of the graft.^{15,21} Delayed insertion of grafts beyond 30 minutes is also advocated to compensate for the effects of initial warping.²⁵

Multiple series have reported favorable results with IHCC reconstruction of the nasal dorsum. Murakami et al reported results of dorsal reconstruction with IHCC in 18 patients, 12 of whom had undergone previous rhinoplasty. All patients appeared functionally improved or stable except for one patient who required revision of a previous alar stenosis. Complications included two displaced caudal struts, one warped dorsal graft, and one fractured graft. In no patient was infection, extrusion, mobility, or significant resorption noted.²⁴ Clark and Cook used IHCC to immediately reconstruct 18 patients with extruded alloplastic nasal implants. After a mean follow-up of 26 months, all patients were satisfied with their cosmetic outcomes. There were no cases of graft extrusion or infection, and clinical resorption was minimal.¹⁵

Bone

Bone is a viable alternative to cartilage for nasal dorsal augmentation. Although bone grafts are usually well tolerated, they tend to impart an unnatural, rigid-appearing structure to the reconstructed nose.²¹ Donor sites most commonly include calvarium, ilium, and rib. The use of iliac crest is limited by perioperative ambulatory morbidity, pain, and a potentially permanent contour deformity. Moreover, fabrication of a dorsal "L" strut is difficult to achieve with iliac bone.⁶

Some authors believe that membranous bone, such as split calvarium, is less likely to resorb than is endochondral bone, such as iliac crest.²¹ When compared with costal grafts, calvarial bone harvest generally results in less postoperative pain and better scar camouflage.¹⁸ During rhinoplasty, split calvarial bone is available within the same operative field. Although calvarial bone provides excellent structural support to the dorsum, the rigid feel of the graft can be bothersome to patients.^{15,18} The intrinsic lack of a cartilaginous component makes reconstruction of combined osteocartilaginous dorsal defects less natural. In addition, the S-STE available to cushion the tip of the graft may be inadequate to prevent extrusion over time.⁶ Other disadvantages include the risk of dural tears, cerebral damage, and intracranial hemorrhage. Difficulty carving and contouring the grafts and the potential for heterotopic resorption also detract from the selection of this material.^{15,18} Finally, the risk of donor-site scar alopecia must be considered.¹⁸

"Turkish Delight"

The use of diced cartilage grafts in augmentation rhinoplasty was referred to as the "Turkish delight" by Erol.^{26,27} The technique employs multiple minute car-

tilage pieces cut to 0.5 to 1.0 mm in size, wrapped with Surgicel (Ethicon, Inc., Piscataway, NJ), and then inserted subcutaneously over the nasal dorsum.^{3,26,27} The Turkish delight graft becomes a pliable composite unit that can be molded with digital pressure in the first 2 to 3 postoperative weeks.^{3,26} This theoretically eliminates the need for a perfectly straight dorsal graft of 30 to 40 mm in length and reduces the risk of postoperative malposition or visibility.²⁶ Turkish delight grafts are designed to achieve dorsal augmentation and correct minor secondary dorsal irregularities.^{3,27} Warping does not occur, and because the grafts are neither bruised nor crushed, long-term survival is facilitated.²⁶ However, if the cartilage chips fail to incorporate into the residual dorsum, graft migration may occur.³

Erol's original series consisted of 2365 rhinoplasty patients (1850 primary, 350 secondary, and 165 post-traumatic rhinoplasty patients) followed for 1 to 10 years. The technique proved extremely satisfactory in obtaining a smooth, straight dorsal profile. Correction of over-resected dorsa, ski-jump, saddle nose, and short nose deformities was achieved with Turkish delight grafts 3 to 8 mm thick. In 11 patients (0.5%), partial graft resorption resulted in undercorrection.²⁷

The observation of extensive and premature graft resorption using Erol's technique led Daniel and Calvert²⁶ to substitute deep temporal fascia for Surgicel. No clinical or histologic evidence of absorption of diced cartilage grafts wrapped in fascia was observed. The authors postulated that Erol's success with Surgicel stemmed from applying the technique primarily for camouflage of dorsal irregularities in primary rhinoplasty patients. In the series of Daniel and Calvert, the grafts were used to augment the dorsum and thereby effectuate a significant volume change. In conclusion, Daniel and Calvert recommended use of diced cartilage grafts wrapped in fascia to fill the crucial 2- to 5-mm dorsal augmentation gap that occurs between the uses of septal cartilage for deficiencies less than 2 mm and osteocartilaginous rib grafts for deficiencies exceeding 5 mm.²⁶

AlloDerm

When nasal skeletal irregularities cannot be completely eliminated, augmentation of the S-STE can improve surface contour.²⁸ To this end, we have regularly used autologous crushed postauricular fibroconnective tissue grafts and mastoid fascia grafts to camouflage subtle dorsal irregularities, smooth the dorsal contour, augment a deep radix, and achieve a slight degree of dorsal augmentation. Whereas patients are always counseled about the possibility of significant postoperative graft resorption, our experience with these grafts leads us to conclude that this risk is exceedingly remote. Rather, long-term graft persistence has generally been the rule. We have

thus been quite pleased with the results of these fibroconnective tissue and mastoid fascia grafts when employed in the manners delineated above.

Acellular allogeneic human cadaver dermis (AlloDerm; LifeCell Corporation, Branchburg, NJ) has emerged as a popular alternative treatment option for augmentation of the dorsal S-STE. Acellular dermis is a biocompatible, nonimmunogenic, readily available, and relatively affordable material.^{2,28} After removal of the epidermis and cellular components, the dermis is freeze-dried to preserve the protein framework.²⁹ Rigorous processing removes bacterial and viral contaminants, and a freeze-dried collagen matrix sheet is ultimately produced that permits host tissue ingrowth.²

AlloDerm serves as a soft tissue alternative to fascia and perichondrium for dorsal augmentation and camouflage of minor contour irregularities.^{2,21,28,29} The grafts can be folded, rolled, layered, or combined with other grafting materials to achieve the desired tissue correction.^{21,29} However, the maximum achievable dorsal augmentation is ~3 mm with this material.² Unfortunately, the long-term persistence of acellular dermis is unpredictable, with implanted volumes falling to less than 50% within 3 months postoperatively in some reports. Cost considerations and the theoretical possibility of disease transmission have also periodically deterred its use.²⁸

Gryskiewicz et al used acellular dermis principally for dorsal augmentation in 58 nonconsecutive rhinoplasty patients, 37 of which were secondary procedures. The graft material remained soft and natural without shifting or developing unsightly irregularities over time. Partial graft absorption manifested in 45% of patients during the first postoperative year. Partial absorption was especially likely over the dorsum and in those with extremely thin skin. No contour changes occurred after the first postoperative year.²⁹ Gryskiewicz then reviewed acellular dermis graft reconstruction of acquired nasal defects in a second series of 25 revision rhinoplasty cases. The material again proved least durable over the bony dorsum, with loss of ~20 to 30% of the graft after a minimum 2-year follow-up period. Overcorrection to these extents was therefore recommended.²

ALLOPLAST GRAFT AUGMENTATION

A large variety of alloplastic materials have been used for nasal dorsal reconstruction. Selecting the optimal material continues to be challenging.³⁰ Most surgeons agree that alloplastic materials should be reserved for cases in which there is insufficient autologous tissue for grafting. Others who object to a variety of donor-site morbidities opt for alloplasts on a broader front.^{7,15,17} Implants are readily available and easy to sculpt, permitting rapid implantation with low perioperative morbidity.^{16,31} Major reasons to use an allograft include (1) an unlimited

supply of graft material volume that can be liberally shaped, (2) a need to fill a larger volume than is possible with septal or auricular cartilage, and (3) the difficulty in achieving aesthetic goals with auricular cartilage because of its irregularity or with costal cartilage because of its potential to warp.^{7,30}

In the nose, thin dorsal soft tissue and proximity to the nasal cavities pose challenges to the use of alloplasts.¹⁷ Generally, alloplasts should be restricted to relatively immobile areas, such as the nasal dorsum.²¹ The ideal implant should be inert, biocompatible, and incapable of inducing inflammation. It should be easily moldable yet structurally durable over time.^{17,21} Implants should mimic the color and consistency of the recipient area, permitting tissue ingrowth while resisting trauma.³¹ No single alloplast currently fulfills all of these requirements.¹⁷

When considering the use of an alloplast, the principle assets of donor-site avoidance and volume and shape preservation must be weighed against potential liabilities, including dislodgment, extrusion, infection, and uncertain durability.^{6,20} The most devastating complication, extrusion, varies with the technical experience of the surgeon, length of follow-up, and composition of the implant.¹⁵ Extrusion is also significantly influenced by the character of the recipient bed. A thin, scarred S-STE closed with tension over an alloplastic implant can be expected to carry a greater risk of extrusion. Relatedly, overaugmentation of the dorsum has also been implicated in the pathogenesis of implant extrusion. An excessively large implant causes undue tension on the overlying S-STE. This results in reduced perfusion, pressure necrosis, and eventual extrusion.^{16,31} Increased susceptibility to extrusion is also associated with alloplast placement in close proximity to the endonasal lining; chronic implant exposure to microbes and the relatively thin tissue barrier provided by the endonasal lining are implicated in this scenario.

Alloplastic materials used in rhinoplasty have included polytetrafluoroethylenes, such as Gore-Tex (W.L. Gore & Associates, Inc, Flagstaff, AZ) and (Proplast, ProMotus, Nyon, Switzerland); silicones, such as Silastic (Dow Corning Corp., Midland, MI); polyethylenes, such as Medpor (Porex Surgical Inc., College Park, GA) and PlastiPore (Richards Manufacturing Company, Memphis, TN); polyesters and polyamides, such as Dacron (Ethicon, Inc, Somerville, NJ), Mersilene (Ethicon, Inc.), and Supramid (S. Jackson, Inc., Alexandria, VA); hydroxyapatite; (Vicryl, Ethicon, Inc., Piscataway, NJ); and ivory.^{16,19,20} Table 2 provides a comparative overview of the key properties of these materials.

Silicone

Worldwide, silicone is the most commonly used implant material for nasal augmentation, especially in

Table 2 Alloplastic Implant Materials Available in Augmentation Rhinoplasty

Name	Trade Name	Handling	Biointegration	Primary Limitation
Silicone	Silastic	Easy	Extremely poor	Extrusion
Polyamide mesh	Supramid	Easy	Poor	Resorption
Polyethylene tetraphthalate mesh	Mersilene	Easy	Excellent	Infection
Expanded polytetrafluoroethylene	Gore-Tex	Easy	Excellent	Infection
Polytetrafluoroethylene–aluminum oxide	Proplast	Moderate	Moderate	Fragmentation
Porous polyethylene	Medpor	Moderate	Excellent	Rigidity
Granular hydroxyapatite	N/A	Easy	Excellent	Poor support

N/A, not applicable.

Asia.^{16,21,31,32} Silicone is practically inert, eliciting very little tissue reaction.^{32,33} Its firm consistency permits easy sculpting but can feel like a foreign body under the skin.^{19–21} The surface is slippery, which makes handling difficult.¹⁹ Its nonporous structure impedes bacterial colonization but also prevents tissue ingrowth and bio-integration.^{1,17,21,31} Instead, a thick fibrous capsule surrounds the implant.^{1,31} Implant stabilization depends upon this capsule formation. However, the capsule itself can predispose to implant malposition and deformation of overlying tissue. The capsule acts as a nidus for bacterial infiltration yet also serves as a barrier for antibiotic penetration.²¹

Widespread use of silicone has been limited by several complications including inflammation, migration, exposure, calcification, resorption of underlying bone, and abnormal skin color. Perhaps most disconcerting is the tendency for silicone to extrude over time.^{1,16,32} In the West, silicone implants have largely been abandoned due to complication rates ranging from 4 to 36%. Substantially lower complication rates in Asian patient series have been attributed to the characteristically thicker S-STE in the Asian nose.^{20,31} However, implant migration and/or misalignment can occur from the dissection of a large recipient pocket, constant midface movement, and repetitive microtrauma. Extrusions, seen most commonly with an L-shaped silicone implant, usually occur at the columella but can be especially devastating when located at the nasal tip.²⁰ Silicone therefore appears best-suited for those conditions in which there are no S-STE or mucosal restrictions.¹⁷

Supramid

Supramid is a polyamide mesh that resembles Mersilene in composition and appearance.²¹ Supramid, however, undergoes a high incidence of resorption within several years after implantation, thereby restricting its utility.³⁰ Histologically, Supramid elicits a moderate foreign-body tissue reaction that subsides over months as the implant becomes infiltrated and surrounded by fibrous tissue.³³ A fibrous shell may persist to maintain some of the implant's original volume and reduce susceptibility to dislodgment.^{21,33}

Mersilene

Polyethylene tetraphthalate mesh (Mersilene) is a stable and easily shaped material that has been used in the nasal dorsum with reasonable success. Infection rates of 4% and removal rates of 2% have been cited in some series.¹⁴ Others do not recommend the use of Mersilene under the dorsum. These authors cite prohibitive problems with infection and graft failure secondary to bacterial colonization of the mesh.²¹ Extensive fibroblast ingrowth stabilizes the reconstruction but makes removal extremely difficult when necessary.^{14,21} Although Mersilene resorbs less than does Supramid, its use has been largely supplanted by expanded polytetrafluoroethylene (e-PTFE).³⁰

Gore-Tex

Through the end of 2006, expanded polytetrafluoroethylene (e-PTFE, or Gore-Tex) has perhaps been the most reliable solid implant material available. The manufacturer has recently discontinued the fabrication of this material for plastic surgical applications. However, Gore-Tex sheets for use in general surgery and vascular surgery remain in production.

e-PTFE is a polymer of carbon bound to fluorine composed of solid pillar-shaped nodes connected by very fine fibrils in a grid pattern.^{7,14} It enjoys low tissue reactivity, outstanding biocompatibility, reasonable cost, and a long history of successful use.^{7,28} Bacterial adherence is inhibited by the hydrophobic composition of e-PTFE.²¹ Its microporous composition encourages tissue ingrowth that confers stability to the implant. Its greatest advantage over other alloplasts may be its ability to adhere to surrounding tissues firmly enough to prevent migration, but loosely enough to permit easy retrieval if necessary.^{7,14,21} e-PTFE can be easily shaped and exhibits no tendency to resorb, although it may slowly change shape and develop prominent edges over time.^{7,28} Delayed infection or immune reactivity is associated with a short-term extrusion rate of ~3%.²⁸ Similar to silicone, e-PTFE also tends to be slippery, causing possible displacement in the early postoperative period before tissue ingrowth has occurred. The whitish color of the material may become visible externally,

particularly in thin-skinned individuals.¹⁹ In sheet form, Gore-Tex can serve as a fill or contour graft but provides little structure. The block form offers more structural integrity but has had much more limited use.¹⁷

Godin et al reported a multicenter, retrospective study of 309 patients receiving Gore-Tex implants to augment the nasal dorsum with a mean follow-up of 40.4 months. Augmentation of the premaxilla was also performed in several cases. No displacement or resorption of any of the grafts was noted. Ten (3.2%) of the 309 grafts became infected and were removed. The only factor predisposing to infection was a preoperative nasal septal perforation.³⁴

Proplast

Proplast is a highly porous but firm alloplast prepared from PTFE polymer and vitreous carbon fibers. This porosity supports rapid host fibrous tissue ingrowth, creating stability and thereby minimizing implant migration and deformation.^{34,35} Its most significant advantage over other synthetic materials is its versatility, as it is flexible and easy to shape.³⁵ Proplast has some of the advantages of Supramid—moderate reactivity and tissue ingrowth. However, it is slightly less resistant to infection and extrusion. Its two advantages over Supramid are that (1) it is firm enough to support the nasal tip and (2) it is somewhat easier to shape.³⁴

The currently available formulation of this material, Proplast II, links PTFE to aluminum oxide fibers and hydroxyapatite to impart a white color and allow for bone compatibility.¹ In addition to prefabricated blocks, Proplast II is available in three shapes of prefabricated implants. Dorsal strip implants are designed for augmentation and for camouflage of bony and cartilaginous dorsal irregularities. The L-shaped dorsal-columellar implant is intended for repair of dorsal skeletal deficiencies in addition to increasing tip projection. Nasal dorsum implants are most commonly used for correction of partial saddle nose deformities.³⁵ However, the increased porosity associated with each of these Proplast II implants may explain its propensity to fragment and collapse when subjected to pressure and shearing forces.^{1,21} This material thus does not provide adequate structural stability under these circumstances.¹

Medpor

Medpor is manufactured from a linear high-density pure polyethylene that is sintered to create a somewhat flexible framework of interconnecting pores 160 to 360 μm in size. Polyethylene comprises 54% of the total implant volume; the remainder consists of pore space volume. This interconnecting pore structure permits rapid ingrowth of vascularized tissue with collagen deposition that ultimately forms a highly stable and

biocompatible complex resistant to infection, resorption, extrusion, and deformation.^{1,36} The firm nature of the material permits easy sculpting without compromising the pore structure. Submerged in hot sterile saline, Medpor implants can be bent to the desired shape, which becomes permanent after cooling. Because of its white color, Medpor will not show through the overlying tissue.¹ However, its stiffness can create an unnatural appearance over the nasal dorsum.²¹ Its surface is rough, which makes insertion cumbersome but displacement infrequent. This implant possesses long-term structural stability and does not resorb. If desired, additional fixation can be accomplished with sutures, surgical wire, or screws.¹

Multiple series have reported successful dorsal augmentation with porous polyethylene implants. Pham and Hunter achieved stable dorsal augmentation in 19 Asian patients. No infection, displacement, or extrusion occurred over the 3-month to 5-year follow-up period. Several factors contributed to the stability of the reconstruction: the thick S-STE of the Asian nose, use of appropriately sized implants to prevent excessive tension on overlying tissue, and fibrovascular ingrowth into the porous structure of the implant.³⁶ Niechajev reviewed 23 consecutive difficult nasal dorsal reconstructions and 4 chin augmentations using Medpor implants. Follow-up ranged from 1 to 3 years. All reconstructions produced an aesthetically pleasing straight nasal bridge. One patient developed implant exposure in the nasal valve area that responded to antibiotics and local wound closure. Another patient developed recurrent erythema of the nasal tip requiring removal of the distal third of the implant. The remaining 25 patients healed uneventfully.¹

Hydroxyapatite

Hydroxyapatite (HA) generated significant interest because its composition resembles human bone and permits bony ingrowth.¹⁷ Areas amenable to augmentation with HA grafts include the nasofrontal/glabellar area, radix, nasal dorsum, nasal sidewall, and the perialar or anterior maxillary platform. In block form, HA is particularly difficult to use in the nose and never garnered wide popularity as a result. It is extremely brittle, difficult to carve, and abrasive. Lastly, HA requires rigid fixation to the nasal skeleton for stability.^{1,17}

The granular form of HA is easily molded but provides little structural support. Accordingly, it is best used as a fill or contour substitute via a subperiosteal injection through a limited incision. The shape and amount of augmentation are controlled by precise dissection of the subperiosteal pocket and the amount of granules injected. No fixation is required postoperatively, except over the nasal dorsum. Here, a continuous subperiosteal pocket is difficult to maintain and, therefore, a

dorsal splint is used to stabilize the implant. The porosity of the granules allows fibrovascular ingrowth to enhance stabilization, render the implant vascularized, and thereby result in a low infection rate. Resorption and remodeling do not occur with HA.¹⁷

CONCLUSION

A soft, smooth nasal bridge with pleasing dorsal aesthetic lines is the anticipated end result of dorsal augmentation rhinoplasty.² Restoration of respiratory function through the provision of dorsal structural support and reconstitution of the nasal valves are equally important objectives. As described above, many materials and methods exist to realize these objectives. Because of excellent biocompatibility, the ability to reconstruct like tissue with like tissue, and the relatively low risk profile, autologous grafts are usually preferred when such material is available in sufficient quantity to achieve adequate augmentation. However, several reconstructive scenarios may be well-suited to the selection of an alloplastic implant. The reconstructive effort is thus influenced by the complex interplay of numerous variables including anatomy, availability of autologous graft material, prior surgical history, surgeon preference and experience, patient preference, and associated risks. Ultimately, an individualized treatment plan must be devised for each patient that offers an optimal opportunity for success.

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