The practice of nasal reconstruction dates to antiquity. Early efforts attempted soft-tissue coverage of nasal defects. Later attempts were made to reconstruct nasal form. Implant use in nasal reconstruction has a long and rich history. Various alloplastic materials have been experimented with, including cork, paraffin, ivory, gold, and silver [1]. Infection and extrusion limited the success of these early implants. In addition to development of sterile techniques and the discovery of antibiotics, the modern era ushered in new understandings of implant biology and host response. This knowledge, coupled with the availability of ever-evolving implant materials, has provided the nasal surgeon with a wide range of choices when nasal implantation is indicated.

Implants are classified by their source of origin; autologous grafts or autografts are harvested from the same patient, homografts derive from a donor within the same species, xenografts originate from another species, and alloplasts are manufactured from synthetic or semisynthetic materials. Xenografts are not used in nasal surgery.

The goals of implantation for nasal augmentation are numerous. The most common site requiring augmentation is the nasal dorsum, which may be congenitally low or malformed by prior surgery or trauma. Augmentation of the nasal tip may include changes in projection or definition that may be accomplished with columellar or tip grafts. Nasal obstruction caused by an incompetent nasal valve may be addressed with spreader grafts or alar batten grafts. Volume augmentation is used to ameliorate an acute nasolabial angle.

Before attempting to use implants for nasal augmentation, the nasal surgeon should be familiar with the various options currently available, the attendant risks and benefits of each implant type, the expected host response, and the technical considerations applicable to working with each implant material.

Clinically, two general scenarios are encountered in which augmentation using nasal implants is indicated. First is the platyrrhine nose, which is characterized by a low, wide dorsum, poor tip projection and definition, and an acute nasolabial angle.
angle. Second, the over-resected nose is characterized by a scooped-out dorsum and a narrow tip, and symptomatic nasal obstruction caused by incompetent nasal valves [2].

The ideal nasal implant does not exist. Although some implant choices exhibit many of the qualities of the ideal implant, no implant satisfies all requirements. The ideal nasal implant should be readily available, inexpensive, inert, nontoxic, noncarcinogenic, sterilizable, easy to sculpt, easily camouflaged, and able to provide volume and mechanical support. Furthermore, the ideal implant should interact favorably with surrounding tissues, maintain its form over time, resist trauma, infection and extrusion, and remain easy to remove [3–5].

**Autologous implants (autografts)**

Autografts satisfy many of the requirements of the ideal nasal implant. Their advantages are numerous: no disease transmission or biocompatibility issues, low rates of infection, resorption, rejection, and extrusion, favorable graft–host interactions, and minimal inflammatory response elicited. The greatest limitations of autografts hinge on the limited quantity of available tissue and the morbidity associated with tissue harvest. Despite their limitations, autografts remain the gold-standard material for nasal implantation and the one against which all other materials are measured.

Cartilage, bone, fascia, and skin may be harvested and used as autografts. Each of these tissues exhibits unique characteristics that may be applied favorably, depending on the needs of the nasal surgeon in a given reconstructive case. Each of these materials will be discussed in greater detail.

**Cartilage**

Cartilage is the preferred autologous tissue for nasal reconstruction. Cartilaginous autografts may be harvested from the septum, concha, or rib. Cartilage can provide volume and structural support. It may be easily cut, crushed, or molded to a desired size and shape. The rate of resorption is low. The greatest limitation of cartilage is a susceptibility to warp over time.

Reliable long-term results have been achieved using autologous cartilage grafting. Tardy reported 17 years of experience with more than 2000 autogenous cartilage grafts [6]. He reported no graft rejection or evidence of graft loss caused by infection. Complications that did occur were attributed to technical error. Similarly, Collawn reported 10 years of experience with autologous cartilage grafts in nasal augmentation. Complications requiring reoperation occurred more frequently early in the study and were attributed to operative technique. The complication rate decreased to 2% of cases during the final 4 years of the study [7].

**Septal cartilage**

Nasal septal cartilage is the preferred cartilaginous grafting material for nasal reconstruction (Fig. 1). It is easily harvested from the same surgical field and causes minimal donor site morbidity. The amount of available septal cartilage, however, is limited and often insufficient. This is especially true when a large amount of graft material is required or if the patient’s nasal septum has been compromised by prior surgery or trauma.

**Conchal cartilage**

A frequent second choice for autologous cartilage grafting is auricular conchal cartilage. Its quality is more pliable and less rigid than septal cartilage. It may be harvested using an anterior or a posterior incision. Two distinct anatomic regions of conchal cartilage are used frequently in rhinoplasty: concha cavum and concha cymba (Fig. 2). Concha cavum is concave in shape and is particularly useful for tip grafts and dorsal onlay grafts. Concha cymba’s shape approximates the contour of the lateral crura of the lower lateral cartilage. As a grafting material for previously resected lower lateral cartilage, concha cymba is a favored option [4].

The advantages of auricular conchal cartilage include its close proximity to the nose and the larger quantity available in comparison with septal cartilage. It may be prepped in the same surgical field for easy harvest and imparts minimal donor site morbidity. To some patients, however, the
associated donor site morbidity may be unacceptable. A notable disadvantage of conchal cartilage is its numerous contour irregularities. Adamson recommends suturing auricular cartilage grafts back-to-back to minimize that irregularity [8].

When used for dorsal augmentation, Toriumi recommends removing the bulk of the perichondrium to minimize the risk for warping. He recommends leaving the perichondrium intact when used in other areas of the nose because of the unlikelihood of warping in areas other than the nasal dorsum [9].

**Costal cartilage**

When the amount of cartilage available from the septum and the auricular conchae is insufficient or when bone is also desired, costal cartilage and bone are additional options. This is particularly relevant when dorsal augmentation is undertaken. Adamson notes that the quantity of cartilage required for nasal dorsal augmentation presents the major challenge in material choice [8].

The use of costal tissue has two distinct disadvantages: a susceptibility to warp and significant donor site morbidity. First, experience has demonstrated that rib cartilage is highly predisposed to warping [7]. Certain handling techniques can minimize warping: removal of the outer perichondrium and the use of a symmetric carving technique. This technique involves carving the same amount of cartilage from all surfaces of the graft in an effort to harvest the central portion of the costal cartilage, which is least likely to warp [9,10]. Second, the attendant donor site morbidity may be considerable, including postoperative donor site pain, incisional scarring, chest wall deformity, temporary atelectasis, and the small but significant risk for pneumothorax. In addition, operative time may be extended significantly with costal cartilage harvest. Finally, rib cartilage may be calcified in elderly patients, rendering the tissue unsuitable for carving.

**Bone**

Like cartilage, bone may be used for structural grafting. Limitations of bone grafts include their rigidity and susceptibility to fracture. Another drawback is the requirement for a prolonged period (weeks) of immobilization to allow for graft fixation. Toriumi cites the primary drawbacks of bone grafting in the nose to be difficulty in sculpting and a predilection to become visible as scar contracture occurs during the healing process [9].

When bone grafting is used, the surgeon has several donor site options including calvarium, rib, and iliac crest. Calvarial bone is preferred for several reasons: it may be prepped in the same operative field, graft harvest imparts minimal donor site morbidity, and finally, calvarium provides membranous bone [11]. Membranous bone is superior for grafting because of endochondral bone’s greater predilection for resorption [12]. Disadvantages of calvarial grafts include rigidity, susceptibility to fracture, an unnatural feel, and a tendency to create a noticeable step-off. Also notable are the
infrequent but potentially serious donor site complications of intracranial sequelae or brain injury (Fig. 3) [13].

For all of its relative limitations, endochondral bone may also be used in nasal reconstruction. It is available for harvest from the rib or iliac crest. A noteworthy disadvantage of endochondral bone is greater resorption in comparison with membranous bone. Specific donor site morbidity of iliac crest grafting includes substantial donor site pain and decreased mobility postoperatively. These drawbacks have limited the popularity of iliac crest as a donor site. Today, iliac crest bone grafting is uncommonly used in nasal reconstruction.

Soft-tissue grafts

Alternative autologous materials available for nasal grafting include dermis, fascia, and fat. Each of these soft-tissue grafts may be useful for volume augmentation or to camouflage minor irregularities. Soft-tissue grafts cannot provide the structural support often sought in a nasal implant.

Temporalis fascia is a popular choice for use as an onlay graft, typically over other implant materials, to smooth contour irregularities. Specifically, the layer desired is the superficial layer of the deep temporal fascia. It is harvested using a postauricular incision to gain access to the temporalis muscle, which it overlies.
Homografts

Homografts are another option for nasal grafting material. Irradiated rib cartilage and cadaveric dermal grafts have been used as nasal implants with consistent and dependable results for several years. These homografts are the preferred materials used by some nasal surgeons. Irradiated rib cartilage is harvested from cadavers and is used primarily for structural grafting. To eradicate potential pathogens, it is irradiated with 30,000 to 40,000 Gy of ionizing radiation. The benefits of irradiated rib cartilage include low infection and extrusion rates, minimal host immunogenic response, and no reports of disease transmission associated with its use [14]. Its limitations include a susceptibility to warp over time and a variable rate of resorption when used in the head and neck region (Fig. 4). When used for nasal implantation, however, low resorption rates have been demonstrated [14]. As described previously for autologous rib cartilage grafting, to decrease the risk of warping, the perichondrium and outer cortex of rib should be removed and the technique of symmetric carving should be employed.

Another homograft used frequently in the nose is cadaveric dermal grafts. Purified human acellular dermal graft (AlloDerm, Life Cell Corp., Woodland, TX) has been available since 1992. Dermis is harvested from cadavers and subjected to a process that removes the epidermal and dermal cellular components without disrupting the extracellular architecture of the dermis. The result is a dermal matrix graft that acts as a template for dermal regeneration. This homograft is typically used as a soft-tissue overlay graft to camouflage other implants and for the correction of minor contour irregularities or soft-tissue defects.

A noteworthy advantage of cadaveric dermal grafting include its favorable safety and compatibility profiles. In the 15 years since it was introduced, there have been no reports of graft rejection or infection transmission. The drawbacks of this material are its inability to provide structural support and its high rate of resorption. Volume reduction of 30% to 80% at 1 year has been reported [15].

Alloplasts

Autologous implants remain the preferred material for nasal implantation. These autographs are not without their limitations, however, including resorption, donor site morbidity, warping, increased operative time, and insufficient donor material [1]. Similarly, homografts may not be preferred in all cases. A third option for nasal implantation that may be used in some cases is alloplastic implantation.

Modern alloplasts are chemically composed of polymers: macromolecules of repeating units. The physical properties of these polymers are altered by various manufacturing methods. Depending on the chemical composition of the polymer substrate and the properties imparted by the manufacturing process used, implants with unique characteristics are produced.

Implant characteristics relevant to their use as a nasal implant include pore size, consistency, and malleability.

In vivo, the biologic behavior of these polymers is predictable. On implantation, alloplastic materials are coated with extracellular host proteins. These host proteins are then denatured by the hydrophobic implant surface. The denatured proteins elicit an inflammatory response that attracts various cell types, including neutrophils, macrophages, and fibroblasts. Implant materials that are degraded by the body’s inflammatory response release particle fragments into the local milieu. Particles up to 60 μm in diameter are phagocytized by macrophages. Particles greater than 20 μm, however, cause macrophage death, with a subsequent release of toxic metabolites into the local environment, which in turn propagates the inflammatory process [3,16–18].

The pore size of an implant affects tissue–graft interaction in two additional ways: the potential for bacterial colonization and fibrovascular host tissue ingrowth. Bacteria can enter pores larger than 1 μm in diameter. Significant host tissue ingrowth requires pores greater than 100 μm [17]. This ingrowth is important for two reasons: infection control and implant stabilization. Host tissue ingrowth minimizes dead spaces and facilitates the transport of inflammatory cells to counteract bacterial colonization and potential infection [19]. Furthermore, implant migration or extrusion is minimized by
tissue ingrowth, which stabilizes the implant with respect to the surrounding tissues [20].

**Implant types**

**Silicone implants**

Silicone has been the most commonly used solid facial implant in the last several decades. Medical grade silicone is a polymer (polydimethylsiloxane) comprised of repeating units of silicon (Si) and methyl groups (CH₃). The solid form of this polymer (Silastic, Dow Corning, Midland, Michigan) is soft and smooth in quality, imparting a natural feel. It is used in the nose for soft-tissue augmentation but it cannot provide structural support. Silastic implants are not porous and do not interact directly with host tissues. The body's response to the presence of solid silicone is to form a capsule around the implant. This encapsulation may be disadvantageous. If the silicon implant is not secured in place by surrounding tissue, chronic inflammation may result. Over time, chronic inflammation leads to seroma formation and implant extrusion. The risk for extrusion remains for the lifetime of the implant and is influenced by where in the nose the silicone implant is used. Rates range from 0.5% to 10% for dorsal implants and up to 50% for columellar implants [21]. In the nose, the use of silastic implants has been limited by excessive mobility and high extrusion rates [22].

**Meshed implants**

Meshed implants are composed of various synthetic polymers that are interspersed with large interstices of empty space. Meshed implants offer several advantages. They are easy to customize into a desired size and shape. Unlike silicon, graft–tissue interaction is extensive. Host tissue ingrowth of the implant imparts stability and also minimizes infection. The disadvantage of meshed implants is the difficulty encountered when graft removal is undertaken. Meshed implants are not easily removed from the body once host ingrowth has occurred. Often a cuff of surrounding tissue must be taken along with the implant. The thin quality of nasal skin in some areas precludes ready removal of a cuff of surrounding tissue.

Polyamide mesh (Supramid, Ethicon, Somerville, NJ) is one of the first meshed nasal implants. High rates of resorption were encountered with this material, however. It is no longer considered a viable implant alternative in the nose [13]. Polyester mesh (Mersilene, Ethicon, Somerville, NJ) is more resistant to the resorption seen with polyamide mesh. Polyester mesh has emerged as the preferred meshed nasal implant. Its uses include dorsal augmentation and tip refinement. The chief disadvantage of polyester mesh is its 3.5% to 8% infection rate [23].

**Porous implants**

Like meshed implants, porous implants interdigitate solid synthetic polymer with empty spaces. The relative proportion of empty space is generally smaller with porous implants in comparison to meshed implants. For this reason, porous implants bridge the gap between solid and meshed materials. Implant porosity allows host tissue ingrowth to provide stability with respect to surrounding tissues, but not so much ingrowth that implant removal is overly difficult.

Host–implant interactions depend on several variables endowed by the manufacturing process, including chemical composition, pore size, and percent porosity. Each individual porous implant type demonstrates unique characteristics as a function of those variables.
**Porous high-density polyethylene**

Porous high-density polyethylene (PHDPE) (Medpor, Porex Surgical, Inc., College Park, GA) is manufactured through a process of sintering in which small particles are fused at high temperature and pressure. PHDPE is 50% porous by volume and contains pores ranging from 100 to 250 µm in size, with an average pore size of 150 µm. That large degree of porosity enables significant host–tissue ingrowth (Fig. 5).

PHDPE has seen widespread use as a nasal implant. Additionally, PHDPE has been used extensively in other areas of the face for chin and malar augmentation and for orbital reconstruction. It is easily sculpted and can be readily molded into a desired shape after placement into hot water. Once the material is cooled, the implant retains its new shape [4]. It is safe and effective for use in soft-tissue augmentation and for structural support [24]. Unlike silastic, bone resorption under the graft is minimal [18]. Ready-made PHDPE implants are available as dorsal grafts, columellar struts, and alar battens (Figs. 6–8).

The disadvantages of using PHDPE include a prerequisite for wide tissue undermining during

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**Fig. 7.** (A, C, E, G) Preoperative and (B, D, F, H) postoperative views of a patient who underwent revision rhinoplasty using multiple porous polyethylene implants.
surgical implantation, implant rigidity, difficulty in implant removal, and a documented infection rate. Overlaying the implant with AlloDerm provides a more natural contour to the implant that can improve the unnatural, rigid quality of the PHDPE material. The senior author of this article has used this material extensively for more than 14 years in more than 1200 nasal reconstructions. He has found it to be an excellent alternative implant material when autogenous grafts are unavailable or insufficient. The most common cause for implant removal is infection, the rate of which ranges from 3% to 4% [25].

**Expanded-polytetrafluoroethylene**

Expanded polytetrafluoroethylene (e-PTFE) (Gore-Tex, W.L. Gore, Flagstaff, AZ) is composed of a polymer arranged as solid nodes attached to fine fibrils in a grid-like pattern (Fig. 9). For more than 20 years e-PTFE has been used safely and reliably as a vascular implant. The pore size of e-PTFE ranges from 10 to 30 μm, allowing some host tissue

![Figure 8](image-url)
ingrowth, but to a significantly lesser degree than allowed by PHDPE or meshed implants. Soft-tissue ingrowth is sufficient to stabilize the implant relative to surrounding tissues, while still allowing for graft removal if desired.

e-PTFE is soft and pliable in quality. In the nose, it is used for soft-tissue augmentation and is not recommended as a structural graft [26]. In a long-term follow-up study of 309 rhinoplasty patients over a 10-year period, Godin reported an overall complication rate of 3.2%. Notably, a higher rate of complication was observed in the revision rhinoplasty group (5.4%) compared with the primary rhinoplasty (1.2%) group. Furthermore, nasal septal perforation was delineated as a predisposing factor for complications [27]. In a review of 705 implants, Schoenrock demonstrated higher rates of inflammation and rejection in cases in which e-PTFE implants were used in direct contact with dermis [28]. Adamson has reported several techniques to decrease infection rates with e-PTFE in nasal surgery, including the use of intravenous antibiotics, implant irrigation with antibiotic solution, and the use of an 18-gauge needle to create holes in the graft to promote additional host tissue ingrowth [8].

A new formulation of e-PTFE reinforced with fluorinated ethylene propylene (FEPRePTFE) was designed to enhance pliability and firmness. An animal model has demonstrated favorable graft–host interaction, including favorable vascular migration and limited capsule formation [2]. Safety and efficacy for use in humans has not yet been reported. Previously, e-PTFE was available as prefabricated facial implants called GORE Subcutaneous Augmentation Material (S.A.M) (Gore-Tex, W.L. Gore, Flagstaff, AZ) available in sheets, blocks, strands, and preformed shapes. In late 2006 the manufacturer announced that these e-PTFE SAM facial implants would be withdrawn from the market for nonmedical reasons. The future of e-PTFE as a nasal implant is uncertain.

Autologous implants remain the preferred grafting material for nasal implantation. Autografts are not without their limitations, however, including absorption, donor site morbidity, warping, increased operative time, and insufficient quantity of donor material. Homografts may be appropriate for nasal implantation in some cases. Alloplasts provide an additional grafting option that may be used in specific situations. The choices available to the nasal surgeon will doubtless expand as implant technology continues to evolve. The surgeon should be informed about the various options available for nasal implantation and grafting and the relative benefits and disadvantages of each option.

References


