Approach to Major Nasal Reconstruction

Benefits of Staged Surgery and Use of Technology

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KEYWORDS

• Nasal reconstruction • Hemirhinectomy • Subtotal rhinectomy • Complex facial defects • 3D printing • Free flap reconstruction • Technology

KEY POINTS

- In complex multi-subunit defects involving the nose and adjacent structures, the adjacent subunits should be reconstructed prior to nasal reconstruction.
- Anticipation of large nasal defects may allow for preparatory procedures like tissue expansion or prelaminated flaps.
- Technology like virtual surgical planning, 3 dimensional printing, and tissue engineering can help optimize outcomes for complex nasal defects.

INTRODUCTION

While all defects on the face pose unique reconstructive challenges, large nasal defects are among the most challenging to approach. The nose is the central element of the face, providing an important aesthetic focus, while also serving an important functional role in the upper airway. Patients with significant nasal deformity face social stigmatization and challenges with breathing, exercise tolerance, olfaction, and support for glasses and masks.[1]

Given its prominence on the face, the nose is a very common site for sun-related skin cancers. While lesions may appear small initially, they can be more extensive than anticipated and result in large defects even when approached with Mohs micrographic surgery. Tumors can extend intranasally without clinical symptoms for some time or malignancies which originate sinonasally can extend superficially to involve the cartilage and skin.[2] In some practice settings, limited access to care or psychobehavioral comorbidities may lead to presentation at an advanced stage with large destructive masses that obliterate not only the structures of the nose proper but extend to involve the cheek, lip, periorbita, nasal bones, palate, or skull base.[3]

The structure of the nose is complex, made up of 9 distinct aesthetic subunits, 3 layers, and a framework composed of both bone and cartilage. The overall structural integrity of the nose relies upon the "L strut" composed of the caudal and dorsal septum and nasal cartilages including the upper and lower lateral cartilages. Portions of the nose, like the lateral ala, are solely supported by fibrofatty tissue but may require non-anatomic structural support in reconstruction. While the septal cartilage can be used as easily accessible graft material, in large defects, this cartilage may

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Facial Plast Surg Clin N Am 32 (2024) 199–210
https://doi.org/10.1016/j.fsc.2023.11.001
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be insufficient or missing, requiring alternative autologous cartilage such as the ear or rib or the use of cadaveric donor tissue.[4]

The layers of the nose provide an additional reconstructive challenge. Unlike the cheek, there is little mobile skin on or adjacent to the nose which could easily be used as donor tissue for reconstruction of a large defect without risking significant distortion of adjacent structures. The framework of the nose must be reconstructed in 3 dimensions to provide support and contour, and the free structural grafts used in this framework require a bed of healthy vascularized tissue to survive. Perhaps the most troublesome layer of the nose to reconstruct is the lining of full-thickness defects. Intranasal mucosal flaps may be considered with smaller defects but subtotal or total rhinectomy defects leave little native tissue available for use and extensive framework that requires coverage.[5]

For all these reasons, the approach to major nasal reconstruction requires careful planning and consideration. Reconstruction can be particularly challenging in patients with multiple facial subunit involvement, scars from prior repairs, recurrent disease, aggressive or hard to clear disease, and those in need of adjuvant radiation. Repair is often approached in stages and technological resources like virtual surgical planning (VSP) and 3 dimensional (3D) printing are useful adjuncts when approaching these defects. There often is not a single correct answer when it comes to reconstruction and patient factors and goals play a large role in operative planning.

DISCUSSION

Multiple Facial Subunit Involvement

Large nasal defects often extend to involve the adjacent subunits including the cheek, upper lip, and orbit. In these cases, the sequence of reconstruction needs to be carefully considered in order to maximize function and survival of the reconstruction.

For all cases, reconstruction of surrounding subunits will be repaired prior to addressing the nasal defect to establish proper 3-dimensional (3D) position of the nose in relationship to the face. The medial cheek can often be repaired with local tissue advancement in older patients with greater skin laxity or by rotational advancement techniques like the cervicofacial flap in those with less redundancy. An upper lip defect can be approached in a similar fashion with primary closure for smaller defects as shown in **Fig. 1** or a variety of lip switch or complex rotational advancement flaps for larger defects. Co-existing cheek and lip defects may eliminate some nasal reconstructive options like a melolabial flap for alar reconstruction.[6] In cases of extensive loss of midfacial support, structural reconstruction with autologous bone flaps or implants is often required. When considering defects with associated orbital involvement, structural support for the medial orbit may need to be recapitulated prior to moving forward with nasal reconstruction to avoid migration of the globe and/or create a correctly sized and shaped orbit for prosthesis.

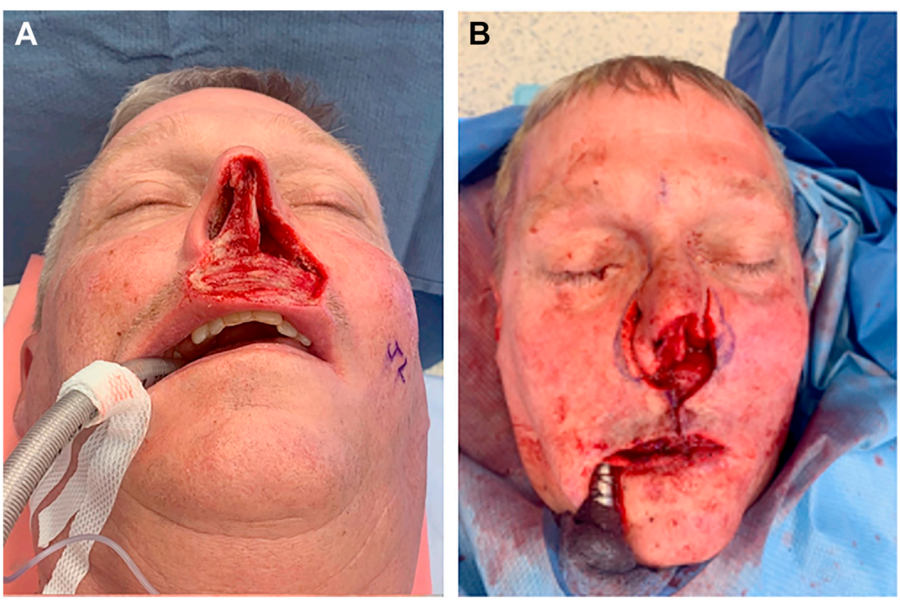

Fig. 1. (*A*) Combined lower third nasal and subtotal upper lip defect. (*B*) The lip was closed first to provide a base for the nasal reconstruction.

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In many cases, these multi-subunit defects will require a staged approach, creating a base of healthy tissue around the nasal defect before proceeding with reconstructing the nose itself.

Another consideration with nasal defects may be associated resection of the anterior skull base. These resections, often performed in conjunction with neurosurgery, are challenging in and of themselves and often require at least partial reconstruction immediately if the dura is involved. An example is shown in **Fig. 2**. The approach to resection may include a coronal dissection which limits the ability to use workhorse flaps like the paramedian forehead flap. An inferiorly based pericranial flap is commonly used to repair large dural defects and is robust enough to withstand radiation. This does, however, eliminate the periosteum as a source of nasal lining in a laminated forehead flap.[7]

Recurrent Disease or Prior Repair

Patients with recurrent disease or prior repairs are particularly challenging. Many of the most common reconstructive options may no longer be possible and a creative approach may be required. Advanced notice of resection can be helpful for planning with some preparatory measures taken prior to the ablative surgery if oncologically appropriate. In patients with prior paramedian forehead flap (PMFF), the contralateral side may be an option but the size of flap required and tissue laxity characteristics should be considered. In patients who will require a large amount of cutaneous coverage, tissue expansion may be an option as shown in **Fig. 3**.[8]

Grafting material options may also be limited. In patients with prior repair, septal cartilage may almost certainly be absent, as may auricular cartilage. In these settings, costal cartilage (autologous or cadaveric) or split calvarial bone grafts may be an option. Reconstructing the lining of the nose may be a particular challenge given the limited amount of mobile tissue available in the area at baseline. Some options in this case include a pericranial flap, a laminated free flap (**Fig. 4**), or a free flap with PMFF for skin reconstruction.[9–12]

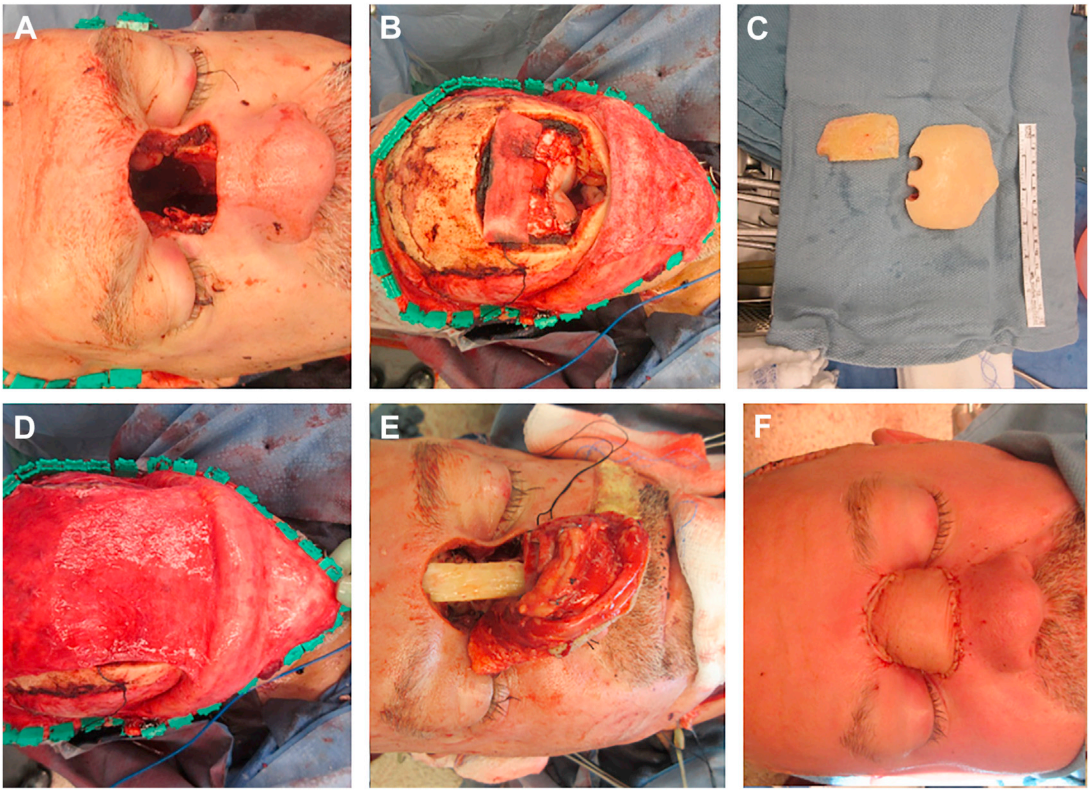

Fig. 2. (*A*) Upper and middle third nasal defect involving resection of the nasal bones and anterior skull base. (*B*) Anterior skull base defect exposed with dural onlay graft repair and bone flap removed. (*C*) Bone flap from frontal skull, part of which was used as bone graft for nasal dorsum reconstruction. (*D*) The pericranial flap was used to reconstruct the skull base and (*E*) a calvarial bone graft was used to reconstruct the nasal dorsum. (*F*) The structural reconstruction was wrapped in a radial forearm-free flap for both internal and external lining.

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Fig. 3. Patient with prior paramedian forehead flap and recurrent disease of the right nasal ala. A 120 cc rectangular base tissue expander was placed in the forehead to recruit tissue for a repeat paramedian forehead flap prior to his planned resection. In this photo, patient still undergoing expansion prior to partial rhinectomy.

Timing of Repair

Given the disfigurement associated with large nasal defects, the idea of immediate repair is attractive, but many factors should be considered regarding the timing of repair (**Table 1**). In some patients, the status of margins may not be clear at the time of resection or they may be at high risk for rapid recurrence due to aggressive disease. In these settings, it may be prudent to do a minimal repair immediately and delay more sophisticated work until the patient is known to be disease free lest early cancer regrowth destroy a complex repair effort. Medically fragile patients may not be suitable for the prolonged anesthetic time of a combined resection and repair.

The need for adjuvant radiation is a huge factor in timing of reconstruction. A classic concern with delayed repair, particularly in a field that will be radiated, is shrinkage of the soft tissue envelope and subsequent increased difficulty in repair. Radiated tissues have decreased elasticity, decreased perfusion, and increased risk of poor wound healing. Tissue planes are often distorted or obliterated, making dissection more difficult. Free grafts placed into radiated fields are at increased risk of necrosis and failure. On the other hand, radiation may cause a beautiful repair to fall apart over time and grafts to warp or become exposed. The reconstructive surgeon is then faced with the challenge of reconstruction in a radiated field with the additional handicap of a failed prior repair. Delayed repair also allows for completion of oncologic treatment with the tumor bed fully visible to assess for evidence of recurrence as shown in **Fig. 5**. Adjuvant treatment can be started without delay. A compromise between immediate and delayed repair may be a staged approach where vascularized tissue is transferred into the wound bed but section of the pedicle, graft placement, and refinements are performed after completion of and recovery from radiation.[13–15]

Discretion in Extent of Repair

In an ideal world, every patient would be able to achieve near normal nasal structure and function after repair. As any reconstructive surgeon knows, this is far from the case. All of the earlier discussed factors go into the feasibility of repair, with the most important factor arguably being the patient's goals. In some settings, there is just not enough local tissue available for a more sophisticated repair or a patient may be too ill to undergo multiple stages and refinements. In these cases, a free flap for soft tissue coverage may be the appropriate choice even if it is not aesthetically ideal to provide wound closure and a significant amount of soft tissue that may be utilized for delayed repair.[16–19]

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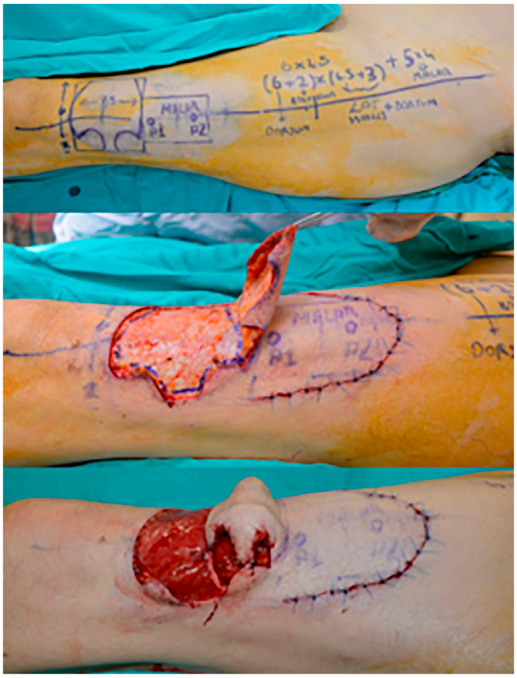

Fig. 4. Development of prelaminated anterolateral thigh-free flap for a combined total rhinectomy and medial cheek defect. The distal portion of the skin was used for the nose and the proximal for the cheek. The skin was raised in a suprafascial plane as the nasal skin layer. The fascia was then raised separately as the inner lining layer with a costal cartilage framework interposed between the 2 layers. From Bali and colleagues (2020),[11] used with permission.

Nasal protheses can also be an appealing option in patients who are either unwilling or unable to undergo the multiple surgeries required to refine a reconstruction. While this may seem like a missed opportunity to utilize the armamentarium of the reconstructive surgeon, the aesthetic result can be impressive and patients can be extremely happy.[20] A prosthesis can also be an option for patients who have failed prior reconstructions or who are at high risk of recurrence with need to more easily surveil the sinonasal cavity. While the cost of prosthesis has been prohibitive for some patients, there are some prosthetic artists who are starting to accept commercial insurance. Advances in 3D printing may also hold some promise on this front.[21]

Table 1
Pros and cons of repair before and after adjuvant radiation

	Pre-radiation	Post-radiation
Pro	• Limited duration of deformity for patient • Sustain soft tissue envelope • Well-vascularized bed	• Less risk if rapid disease recurrence • No delay of adjuvant treatment if healing difficulties • No potential for failed prior repair
Con	• Potential for hiding recurrence • Possible repair failure/graft exposure after radiation	• Radiated tissue (less elasticity, less perfusion, obscured tissue planes) • Risk of free graft failure • Contracted soft tissue

There are a number of options for type of prosthetics and means of retention as demonstrated in **Fig. 6**. The prosthetic can recapitulate part or all of the nose, with some designed for multi-subunit defects such as in orbital or palatal defects as well. They can be retained with adhesive, attached to glasses, or mounted to implanted posts similar to dental implants. When considering post placement, the risk of implant loss or hardware infection should be kept in mind, particularly in radiated beds.[22]

Use of Technology

Virtual surgical planning

VSP is an approach to reconstruction which utilizes computer-generated patient-specific models to provide the surgeon with an approach to the procedure which aims to optimize the aesthetic outcome while limiting the intra-operative time devoted to planning incisions or shaping hardware. This approach has been used for many years within the sphere of bony surgery; cutting guides for osteotomies are common in oncologic ablative surgery and osseous free flaps while virtual reduction of traumatic injuries is often used to develop pre-manufactured plates or plate bending guides. VSP services are often provided in conjunction with industry and utilize third-party engineers and proprietary software.

The use of VSP for non-rigid reconstruction is an emerging utilization of the technology. Soft tissue is easily deformable which makes modeling it much more challenging. The reliability of models may be affected by patient positioning, edema, pre-existing anatomic deformity, or imaging quality. This approach does, however, offer the opportunity to morph 3D models and create a perfected image as a goal for reconstruction or build constructs when multiple subunits are absent as shown in **Figs. 7** and **8**.[23,24] The perfected image can then be used to create a physical model for templating soft tissue flaps. This is a particular asset in complex 3D structures like the nose where estimating the tissue surface area required to

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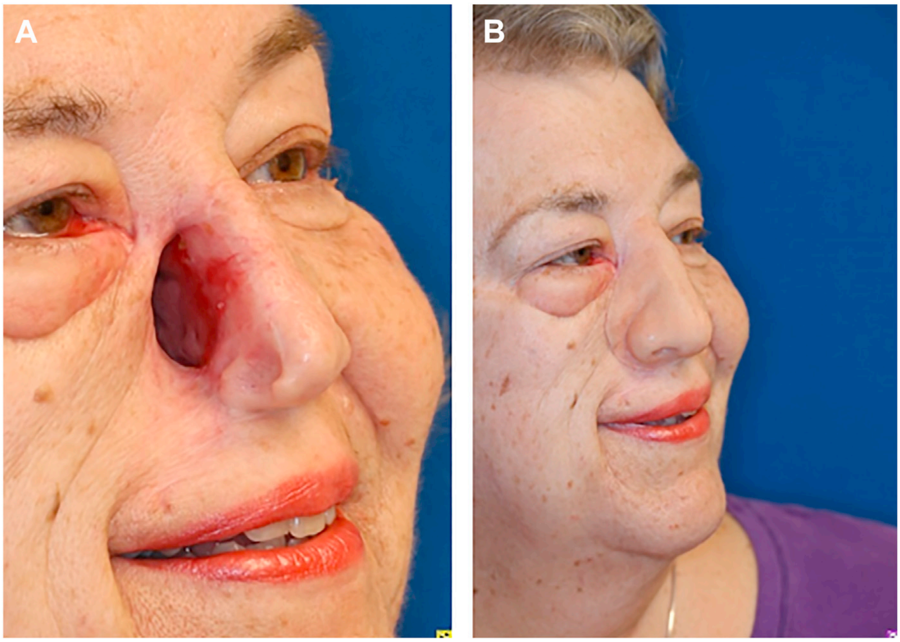

Fig. 5. Right hemirhinectomy defect in a patient with history of recurrent desmoplastic melanoma of the right nose with prior repair. After re-resection, she had a large combined cheek and nose defect. (*A*) The cheek defect was closed with local tissue advancement but the rhinectomy defect was left open for surveillance. (*B*) Adhesive-retained nasal prosthesis in place to cover the defect.

create alar contour or tip shape can be quite difficult and the contralateral side may be asymmetric or involved in the resection.[25]

The perfected images could also be used to develop nasal protheses that would rely less on the sculptural expertise of an artist, of which there are relatively few. As the technology progresses and modeling of the inherent deformational characteristics of the soft tissues and cartilage improves, this approach could be used to develop guides for framework cutting and incision planning.[26–28]

The reconstructive surgeon should keep in mind that VSP requires fine-cut patient imaging. This has likely been completed in the course of workup for extensive tumors or acute traumatic injuries but may not have been done prior to Mohs procedures or historical trauma. It may be advantageous to have pre-resection/injury images if the goal is creating a perfected soft tissue model. VSP is also relatively resource heavy and the relationships and infrastructure may not exist in all settings. Lead time for model building and delivery should be accounted for and forewarning of the need for repair would be helpful.

3D printing

3D printing is a technological adjunct to VSP and is growing in popularity, with many academic centers developing their own 3D printing labs in-house. Its use across medicine is broad, from developing custom prosthetic limbs, surgeon-specific instruments to bio-scaffolds for artificial organs. Within the realm of facial reconstructive surgery, 3D printed skulls are common in trauma and custom implants have been made for septal perforation reconstruction.[29] Stents for the nasal vestibule or internal nasal valve can be made to help with shaping of the reconstructed nose.[30–33]

This technology is rapid and customizable, with turn-around times as little as a day or 2 in settings with existing 3D printing set-ups. Relationships with bioengineers are required, as well as training with software and 3D printing machinery. In the time since this technology has come online, its accessibility has increased substantially with options for open source software and printers that are affordable enough for even home users. As with VSP, the source imaging needs to be considered when utilizing 3D printing. For patient-specific models, imaging is required and images acquired after resection or disfigurement will pose an additional modeling challenge. There are reports of the use of representative images from a database when patient-specific models were not possible.[34] Three D printing can also be used to make cutting guides for cartilage framework as shown in **Fig. 9**.[35] It should be kept in mind that 3D printed adjuncts are usually rigid or semirigid in nature

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Fig. 6. Examples of nasal prostheses for subtotal and total nasal defects. (*A*) Patient with prior failed free-flap reconstruction requiring second free flap. Prosthesis is secured with adhesive. (*B*) Patient with multiple failed prior reconstructions. Magnetic prosthesis retained with implant. Adjunct procedures including lip lift and filler injections were used to help with prosthesis positioning and blend.

which can be helpful when they are used as structural models but may not be realistic when used to stand in for deformational tissues like the cartilages and soft tissues of the nose.

Biocompatible materials

Major nasal reconstruction almost inevitably requires the use of graft material to recapitulate the structural framework of the nose. The most commonly used and easily accessible of these materials include septal cartilage, auricular cartilage, and costal cartilage. Other graft options include calvarial bone grafts, cadaveric rib, or osseous free tissue transfer. These options are often sufficient but very large subtotal or total rhinectomy defects may require the use of alternative biocompatible materials. While cutting guides could be made for autologous materials, the development of an extracorporeal framework can be complex and time consuming. In these settings, technology like VSP, 3D printing, and biocompatible polymers can be used to tandem to develop a framework.

When considering which material to utilize, the inherent nature of the nose should be considered. Rigid materials like metals would be unnatural and ceramics prone to fracture. Silicone is soft but may be too soft to provide support. The most commonly used biocompatible implants in this setting are biocompatible polymers. Porous polyethylene (Medpor®, Porex Surgical Inc, Newman, GA) has long been used in microtia repair, jaw augmentation, and midface implants. Manufactured dorsal implants, tip grafts, batten grafts, and nasal shells exist. Porous polyethylene allows for soft tissue ingrowth and graft incorporation which can be both an asset and a liability. Fracture of these grafts is a dreaded complication, as is infection and exposure. Other polymers like polycaprolactone and poly(L-lactic acid) have been used as implants and are easily printable.[36] Resorbable implants have also been used to maintain the soft tissue envelope and

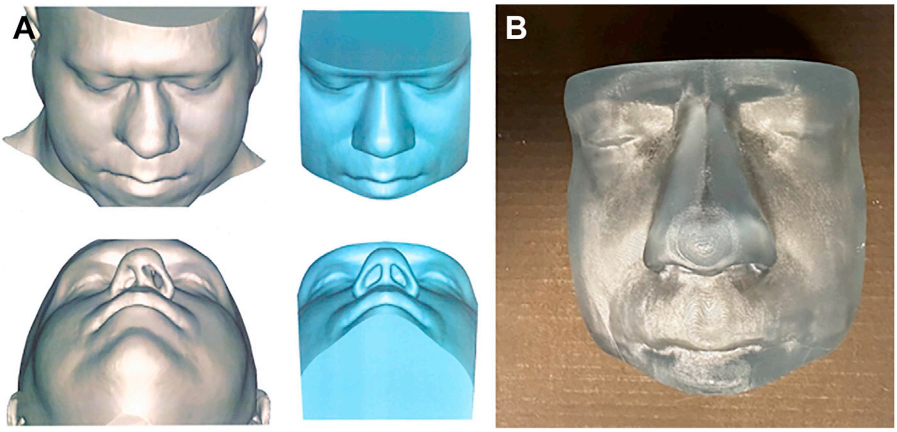

Fig. 7. (*A*) Pre-operative (gray) and perfected images (blue) generated in planning reconstruction for an anticipated hemirhinectomy defect in a patient with a prior paramedian forehead flap (PMFF). Generated in conjunction with Materialise and DePuy Synthes. (*B*) Printed model for use intraoperatively.

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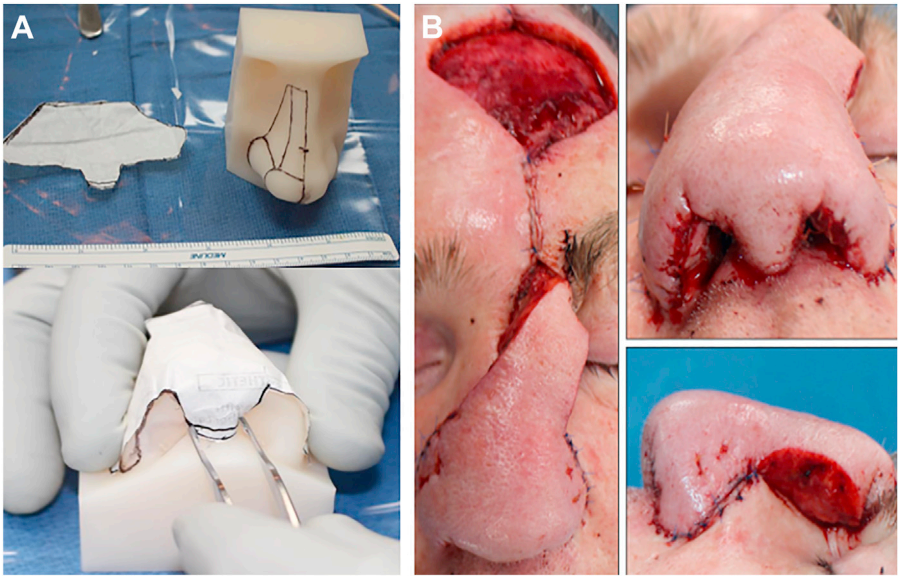

Fig. 8. (*A*) 3D printed model used to design template for PMFF. (*B*) The templated PMFF inset over the subtotal rhinectomy defect. (*From* Zeigler and Oyer (2021),[24] used with permission.)

nasal support in patients after near total septectomy with planned delayed reconstruction after radiation.[14,37]

Like all grafts, biocompatible implants require a healthy wound bed to decrease the risk of infection and implant extrusion so soft tissue flaps need to be planned. If no such wound bed is possible, repair should be considered in a staged fashion as outlined earlier prior to placing any non-native tissue in the field. If local soft tissue is insufficient to cover exposed bone, bio-scaffold material like Alloderm® (LifeCell Corp., Branchburg, NJ) or Integra® (Integra LifeSciences, Princeton, NJ) could be considered to encourage development of granulation tissue, mucosalization, or epithelialization in preparation for delayed reconstruction or prosthesis.

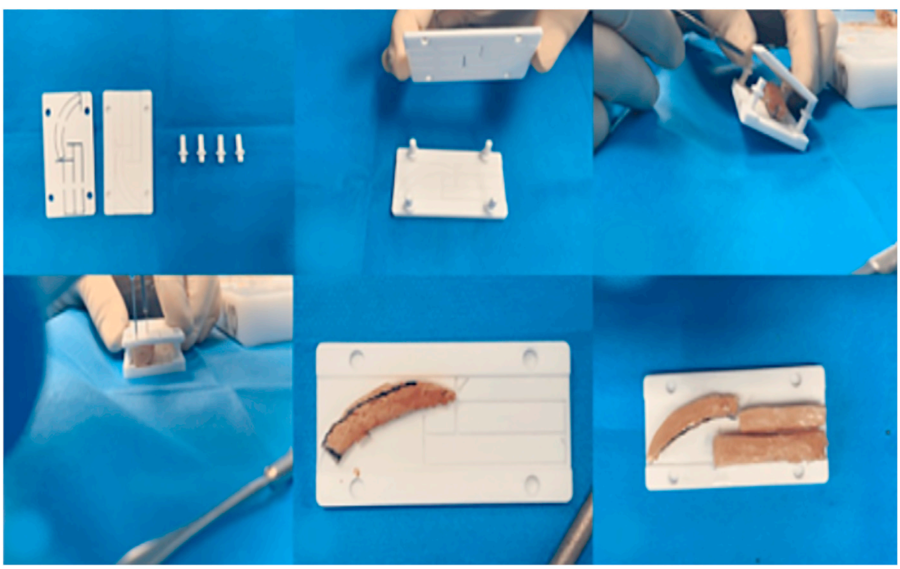

Fig. 9. A 3D printed cartilage cutting guide model developed from patient-specific virtual surgical planning. The guide was used to precisely carve costal cartilage when reconstructing a hemirhinectomy defect. (*From* Chiesa-Estomba et al (2022),[35] used with permission under Creative Commons international license CC BY 4.0.)

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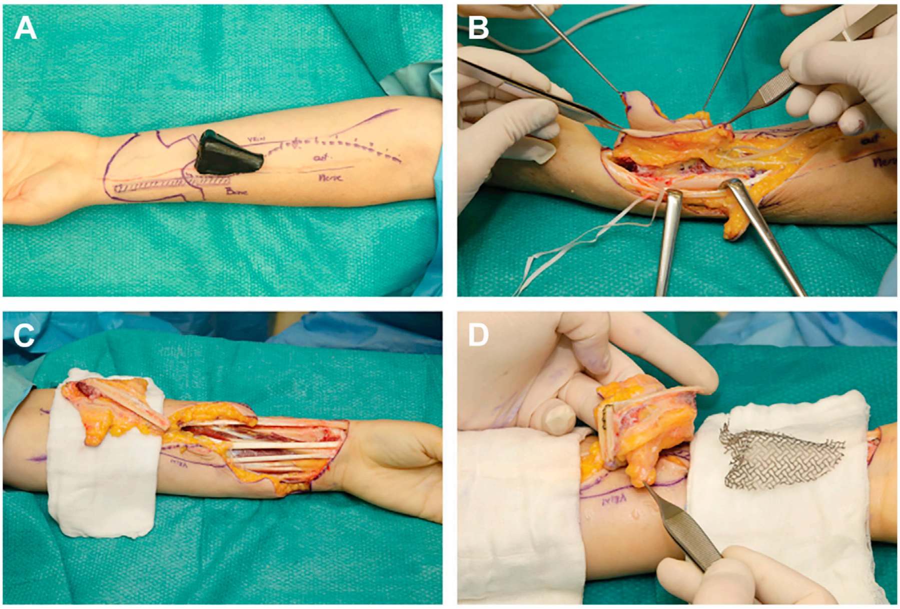

Fig. 10. Development of a laminated osteocutaneous radial forearm-free flap for a total rhinectomy defect. (*A*) A rubber model was used in planning. (*B-C*) The flap was raised with perforators intact. (*D*) The bone was then used to form the L strut framework and plated. The titanium mesh pictured was then laid between the bone and the skin to provide shape for the soft tissue. (*From* Ahcan and colleagues (2019),[42] used with permission under international license CC BY-NC 4.0.)

Lab-grown autologous material

Perhaps the most sophisticated and patient-specific option for reconstruction of major nasal defects would be lab-grown autologous material. Tissue engineering is a booming field of medical research with work on-going regarding development of autologous nasal cartilage from patient stem cells and biocompatible frameworks. This could provide large volumes of graft material without the potential donor site morbidity for patients or the immunostimulatory potential of non-native tissue.[25,38] Most of the research on this front has been focused on repair of nasal septal perforations.[39,40]

This technology obviously requires a significant infrastructure and scientific expertise. Tissue engineering labs are often under the direction of a PhD investigator with extensive laboratory research expertise. The growth of patient cell populated graft requires donor cells which have to be harvested days to weeks before the intended reconstruction. This could be obtained at the time of biopsy of a suspect lesion or at the initial stage of a multiple stage reconstruction.[41]

The ultimate technological advance in nasal reconstruction would be the development of a complete nasal graft with a developed 3D structure and all 3 layers that would be inset with a microvascular anastomosis. The possibility of a complex lab-grown cartilage framework was initially developed in the infamous Vacanti mouse model, though to this day human trials of this technology have not come to fruition.[42]

Patient Counseling

Perhaps the most critical component of reconstructive planning for major nasal defects is patient counseling. These situations are far from straightforward and pose a challenge to even the most experienced reconstructive surgeon. Patients very likely have little to no frame of reference for what such a complex reconstruction will look like or what their functional outcome could be. Elucidating their goals is critical; some patients' main goal may be to avoid multiple procedures and they may be willing to accept a suboptimal aesthetic or functional outcome. Others may want their nose to appear as close to normal as possible. In these conversations, they must be counseled about the likelihood for several surgeries over the course of months to years as well as the reality that even the best outcome will likely not be identical to their native nose. When considering a multistage approach, an intermediate stage for free cartilage graft placement or soft tissue thinning could be considered to optimize aesthetic outcome but prolongs a patient's time

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with an unsightly and sometimes distressing pedicle in the case of the paramedian forehead flap. Appropriate oncologic treatment should always be the primary goal. A patient's overall health needs to be taken into account, as does their ability to travel for multiple procedures and their network of friends and family for wound care and psychosocial support. Patients should be adequately prepared for their abnormal appearance and potentially compromised nasal airway in the interim repair stages which may affect their willingness or ability to perform their normal daily tasks. Finally, the idea of prosthetic rehabilitation to many seems like an inferior option to autologous tissue reconstruction. However, very nice aesthetic results may be obtained when a skilled anaplastologist is available.

Putting It All Together

In cases of multi-subunit or total nasal defects, a multi-staged approach to autologous tissue reconstruction may provide optimal results. Careful patient counseling is critical in these cases as reconstruction may span many months with more than 3 stages. In these cases, a combination of VSP, model surgery, prelaminated free tissue transfer, and delayed structural reconstruction may be necessary such as in the case demonstrated by Ahcan and colleagues (**Fig. 10**).[43]

SUMMARY

Reconstruction of large nasal defect with multi-facial subunit involvement, aggressive malignancies, need for radiation or wound bed monitoring, and cases of prior reconstruction are challenging for any reconstruction surgeon. A large number of factors may be considered when counseling patients, electing procedures to perform, and deciding when to perform them. Technological advances may assist in providing an optimal functional and aesthetic result and should be considered in complex cases.

CLINICS CARE POINTS

- Thoughtful planning, including discussion with patients regarding their desires and willingness to undergo multiple procedures, is essential in the reconstruction of complex nasal defects.
- The pros and cons of reconstructing before or after radiation should be considered, particularly in patients with recurrent or aggressive disease.
- Smaller procedures before a larger reconstruction including tissue expansion and prelamination of flaps can optimize outcomes.
- Developing technology like 3D printing and VSPcan be used creatively for planning and implementation of otherwise difficult to reconstruct defects.

DISCLOSURE

The authors have nothing to disclose.

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