Autogenous Nasal Tip Reconstruction of Complex Defects

A Structural Approach Employing Rapid Prototyping

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We have sought strategies to enhance our ability to successfully reconstruct the human nose. We present one of our efforts to use current technology to improve our ability to accurately create the subsurface framework on which the success of such an endeavor rests. Our novel approach involves the creation of an intraoperative surgical guide, aided by 3-dimensional laser surface scanning and rapid prototyping. This translucent template is developed through cooperative effort by the patient, anaplastologist, and surgeon working together. It is then custom made, sterilized, and available for use during the procedure. It is placed on the patient's face at critical points during the procedure. The subsurface framework is then painstakingly built in a stable fashion to reflect the dimensions and contour of this guide. It is created in such a manner as to anticipate the effect of the thickness of the forehead flap on the final external dimensions.

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The re-creation of the human nose is perhaps the most difficult challenge in reconstructive surgery. Burget and Menick[1] have elegantly described the essential concepts of the nasal subunit anatomy and 3-layer reconstruction (vascularized inner lining flaps, rigid subsurface framework of autogenous materials, and skin lining with like tissue). In cases of total or subtotal nasal reconstruction, the obstacles to the creation of a functional and natural-appearing nose are considerable. The 3-dimensional (3D) structure, suspended in space, requires lifelike dimensions and surface contour. It must be vascular enough to heal predictably, stable enough to withstand the scar contracture and maintain symmetry, and functional enough to be acceptable to the patient's lifestyle. The success of such an endeavor requires accurate insight into the nature of the defect and the development of a thoughtful surgical plan. Only then does the possibility exist of a successful outcome, if the plan is executed with precision. The margin of error is small. We have sought strategies to enhance our ability to successfully reconstruct the human nose. We present herein one of our efforts to use current technology to improve our ability to accurately create the subsurface framework on which the success of such an endeavor rests. Our novel approach involves the creation of an intraoperative surgical guide, aided by 3D laser surface scanning and rapid prototyping (RP). This translucent template is developed through cooperative effort by the patient, anaplastologist, and surgeon working together. It is then custom made, sterilized, and available for use during the procedure. It is placed on the patient's face at critical points during the procedure. The subsurface framework is then painstakingly built in a stable fashion to reflect the dimensions and contour of this guide. It is created in such a manner so as to anticipate the effect of the thickness of the forehead flap on the final external dimensions. Case examples are provided.

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Figure 1. Initial rendering of model nose for patient 1.

Figure 2. A 3-dimensional laser surface scanning of the plaster model nose.

METHODS

PATIENT SELECTION AND CREATION OF THE TRANSLUCENT 3D INTRAOPERATIVE GUIDE

The technique is used in patients with complex, subtotal, or total nasal defects. Because the primary use of this technique is for the creation of the subsurface cartilaginous framework, it is used in patients with full-thickness, complex defects of the nasal tip. The causes of these defects vary and include those caused by surgical resection of a neoplasm and by trauma. The creation of a custom template based on the patient's unique anatomy does introduce a delay from the time of presentation until the initiation of the surgical reconstruction. This delay is not acceptable to some patients. The patient is referred early in the treatment process to the anaplastologist in the Johns Hopkins Department of Art as Applied to Medicine, who is one of the authors (J.R.G.). An impression is taken, and a presurgical model is made. The anaplastologist is a highly trained artist with a sophisticated understanding of the subtle contours that constitute the human nose. This skill has been honed through years of creating prosthetic noses used by patients in their daily lives. The reconstructed model is sculpted using wax, with the aid of presurgical photographs (**Figure 1**). This reconstructed model is approved by the patient and the surgeon. A duplicate reconstructed model is made.

The subunits of the nose are defined and etched into a duplicated reconstructed model by the senior author (P.J.B.). A dashed line is used to indicate subunits, and a solid line is used to indicate the outer perimeter. The model is then sent to Direct Dimensions Inc (Owings Mills, Maryland) for surface scanning, digital manipulations of the resulting 3D file, and final output. The etched, reconstructed model is scanned using a surface laser scanner (Perceptron Laser Scanning Systems, Plymouth, Michigan), which produces 3D point cloud data (**Figure 2**). PolyWorks software (Inovmetric Software Inc, Quebec City, Quebec, Canada) is used to create a 3D polygonal model from the laser scan point cloud. The scribed boundary and subunit lines are defined on a 3D polygonal model using polylines, which are made up of a series of connected straight line segments on the 3D model; these define the shapes that make up the subunits (**Figure 3**).

CREATION OF RP 3D TEMPLATE

The template is divided into upper, middle, and lower thirds and digitally offset down from the external surface contour (**Figure 4**). This is performed to account for the eventual placement of the paramedian forehead flap over the subsurface framework. The top is often left as is. The middle third is generally gradually offset to 1 mm below the surface of the skin. The bottom third is offset 1.5 to 2.0 mm below the surface. These alterations are individualized as dictated by the senior author or surgeon, depending on the location and extent of the defect and the skin type of the patient. The model is approved by the anaplastologist and the surgeon. The RP output of the 3D guide is made of a semitransparent resin material.

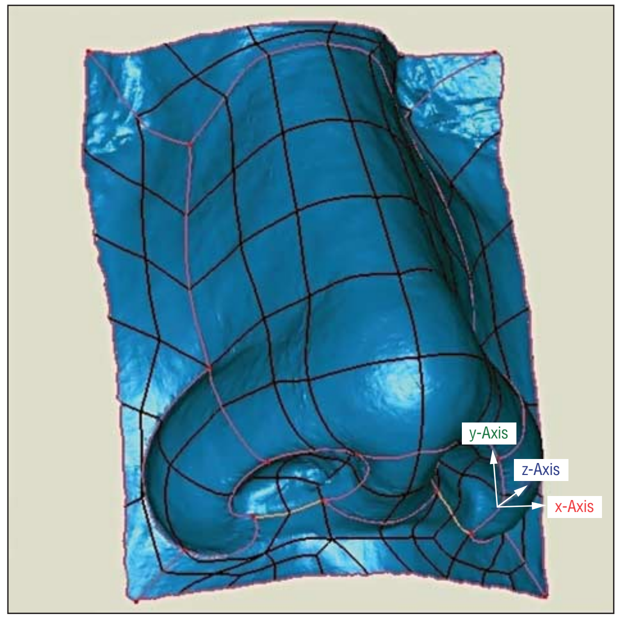

Figure 3. The digital 3-dimensional image of the nose created by laser surface scanning, subdivided using polylines to define boundaries and subunits.

The RP output is verified by the anaplastologist, who then duplicates the template into a clear plastic material. This is done by casting silicone putty material as a negative into the RP output. A 1.5-mm-thick theromoforming clear baseplate or tray material is then vacuformed over the negative model. Vacuforming material is loaded onto a carrier plate and heated to soften it. The plate is then brought down over the model and vacuum is applied from a platform underneath so as to adapt the material intimately over the surface of the model. The baseplate material is trimmed, and holes are made for nostrils. Templates are delivered to the surgeon along with instructions for cold sterilization (using iodine solution, STERRAD Sterilization Systems [Advanced Sterilization Products, Miami, Florida], or methylene oxide gas) (**Figure 5**).

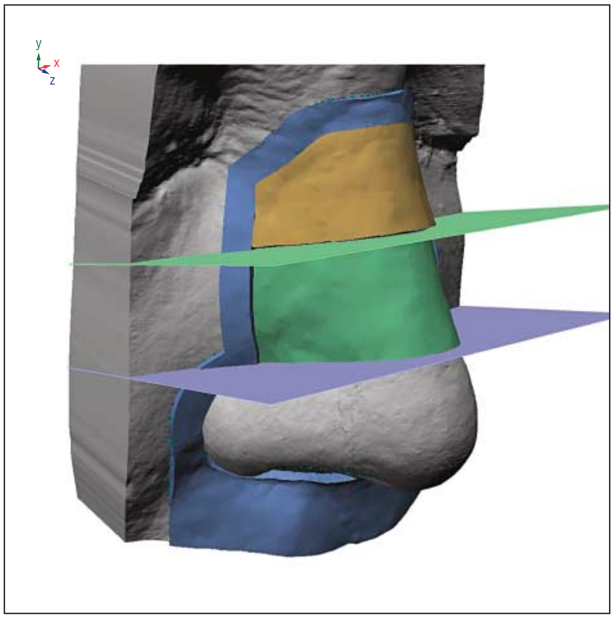

Figure 4. The digital 3-dimensional image of the model nose is reduced in size to anticipate the thickness of the overlying nasal skin. This is done in vertical thirds, and corresponds to the thickness of the forehead skin.

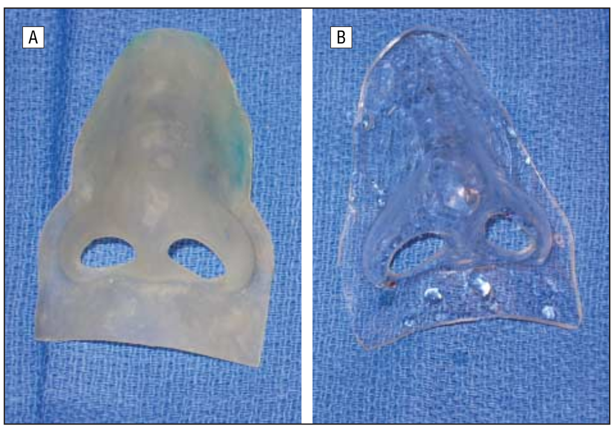

Figure 5. Custom-made surgical guides. A, Opaque version. B, Translucent version, found to be most helpful during the surgical procedure.

SURGICAL RECONSTRUCTION

The provision of well-vascularized, thin lining tissue is achieved by a variety of methods depending on the individual patient's needs. We use septal mucosa flaps, tunneled galeal flaps, nasal turn-in flaps, or free tissue transfer. The paramedian forehead flap dimensions are determined by using the wax model created at the beginning of the process (described in the subsection "Patient Selection and the Creation of Translucent 3D Intraoperative Guide"). A foil wrap is often used for this, prior to the start of the procedure (**Figure 6**). The clear intraoperative guide is used exclusively for the creation of the rigid framework of the nose. Typically, rib and ear cartilage is used. The reconstruction essentially begins with the assurance of a stable L-shaped strut. This may involve the use of a caudal septal extension graft or the creation of an open framework L-shaped strut, depending on the available tissue. Once achieved, the tip is created by building from the nasal base. A stable nasal base and dorsum are essential. The surgical template is initially placed to visually determine the degree of projection required. This important step (which can

Figure 6. Foil is used to create the template for the forehead flap. This is done by molding the foil over the model nose, then flattening the template into 2 dimensions onto the forehead.

Figure 7. Intraoperative view of patient with the custom-made surgical guide in place. This translucent guide provides a very clear 3-dimensional reference for the reconstruction.

Figure 8. Nasal tip reconstruction for total and near-total defects require a very stable reconstruction of autogenous cartilage.

be done preoperatively in the clinic as well) ensures that the surgeon has a clear understanding of the magnitude of the patient's particular needs for projection and dimension (**Figure 7**). Suture fixation of the rigid rib graft is performed to the nasal spine, when present. The creation of the nasal tip then proceeds from the base of the columella to the tip defining points, to the production of a continuous arch of stable cartilage to define the contour of the ala (**Figure 8**). Note that by this point a layer of vascularized inner lining tissue

Figure 9. The custom-made surgical guide is placed on the rebuilt framework multiple times to ensure accuracy and completeness of the reconstruction. Micrografts of cartilage are used to complete the framework to the desired end point.

has already been created to assure subsequent viability of the cartilage grafts. The tip construct must be stable enough to resist deformation by dependent edema initially and eventually by scar contracture. The stability is checked repeatedly with palpation. This requires suture fixation to adjacent stable structures. Once the initial M-arch tip structure is created, additional layers of cartilage micrografts are then meticulously suture fixated in another layer where needed. The template is placed on the patient's face as a guide multiple times throughout this process to check the projection of the reconstructed cartilaginous framework (**Figure 9**). The goal is to perfectly fill in the spaces on the undersurface of the clear template. Once the framework is structurally sound, and the template rests comfortably over the framework like a glove, this portion of the procedure is complete. The paramedian forehead flap procedure then follows.

CASE EXAMPLES

Case 1

A 32-year-old woman presented with a squamous cell carcinoma of the nasal septum. This required her to undergo a rhinectomy, including total septectomy with resection of the upper lateral cartilages and midline nasal bones. The skin cover was maintained. A full course of radiotherapy followed. Owing to the aggressive nature of her cancer, the decision was made to withhold definitive reconstruction until after radiotherapy and a year of surveillance. Initial management of her defect was achieved with the placement of a resorbable plating material, which allowed excellent cosmesis and function during this time period and has been previously described.[2] A year and a half later, she was left with a severe nasal deformity (**Figure 10**). A multistage surgical plan was developed. Internal lining was provided with a combination of a tunneled gale frontalis flap for the upper two-thirds of the nose, and nasal turn-in flaps for the lower third. Using rib grafts, a stable L-shaped strut of cartilage was created during these preparatory stages.

A model nose was created by the anaplastologist and deemed acceptable by the patient and the surgeon (Figure 10). This led to the creation of the translucent intraoperative guide as already described. The template was used intraoperatively to accurately re-create the dimensions of the nasal tip and dorsum with rib and ear cartilage in a stable fashion. The model was used to determine the dimensions of the forehead flap (**Figure 11**). The patient remains disease free 2 years later and has satisfactory nasal breathing (**Figure 12** and **Figure 13**).

Figure 10. Patient 1. A, After total septectomy with resection of all of the nasal cartilages and midline nasal bones. A stable foundation has been created from rib cartilage nourished by a tunneled pericraniofrontalis flap. B, With the model nose in place. This precedes the process of 3-dimensional laser surface scanning and reverse-engineered production of the intraoperative surgical guide.

Figure 11. Intraoperative view of patient 1. The model nose was used to create the forehead flap template.

Case 2

A 54-year-old woman with a distant history of a squamous cell carcinoma of the left nasal ala presented with a adenosquamous carcinoma of the vestibule of the nose. This ultimately required 2 resections, which was followed by a full course of radiotherapy (**Figure 14**).

A multistage surgical plan was developed. Delayed nasal turn-in flaps and a septal mucosal flap were used to provide vascularized inner lining. A nasal model was created by the anaplastologist with feedback from the patient and the surgeon. The translucent template was created as described. This template was used intraoperatively. Meticulous re-creation of the nasal tip form followed, using the guide extensively to assure accuracy. The forehead flap followed, using the model nose as the template (**Figures 15**, **16**, and **17**). One year later the patient remains disease free and is breathing well (**Figure 18**).

COMMENT

There is no greater challenge in reconstructive surgery than the re-creation of the human nose. While smaller

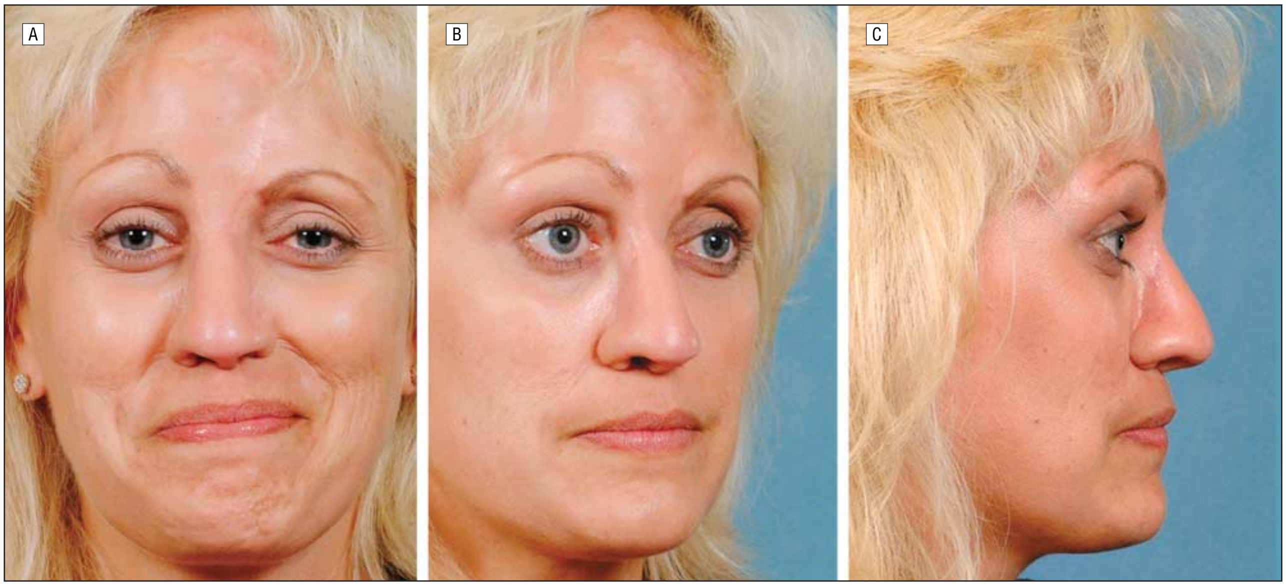

Figure 12. Patient 1. Postoperative view 1 year after nasal reconstruction. A, Anterior view; B, three-quarter view; C, lateral view. She subsequently has undergone a conservative tip narrowing and dorsal hump reduction.

Figure 13. Patient 1, postoperative base view.

Figure 14. Patient 2 after resection of a recurrent adenosquamous cell carcinoma of the nasal vestibule. A full course of radiation therapy followed.

(skin only) defects present their own challenges, larger complex defects are extremely difficult to reliably reconstruct. Patients with such defects typically have full-thickness defects through multiple subunits, often have had their septum completely removed, and, at least in our patient population, have undergone radiation treatments. The essential work done by pioneers in nasal reconstruction has established that it is possible—even in the case of extensive rhinectomy—to produce a reasonable facsimile of the human nose in many patients. However, this process is fraught with challenges.

The principles of complex nasal reconstruction, including the provision of thin, highly vascular lining tissue, a rigid cartilaginous framework, and an external cover of adequate skin match such as the paramedian forehead flap, are well established. Many reports exist of attempts by surgeons to produce templates to assist in the accuracy of nasal reconstruction. These include templates of foil wrap, Aquaplast (WFR/Aquaplast Corp, Wyckoff, New Jersey),[3] and other materials for accurate skin replacement. There have also been multiple reports[4,5] of the use of silicon and bone wax as templates created intraoperatively for the representation of nasal dorsal and tip grafts. In addition, 3D models have been used for surgical planning for a variety of procedures.[6] To our knowledge, this is the first report of the use of custom-made 3D translucent intraoperative surgical guides for nasal reconstruction. We have found value in improving the predictable accuracy of performing one component of nasal reconstruction: the creation of a subsurface framework of an appropriate size, shape, and contour. The clear template is created by a multidisciplinary team, which includes the patient as well. A lifelike model is created by the anaplastologist and deemed acceptable by the patient by trying the nose on his or her face. The surgeon reviews this model and scribes the important subunit anatomy. The artist and surgeon thus work as a team to create an acceptable construct.

Further elaboration is appropriate in understanding the reasons why an anaplastologist was chosen as a team member in this clinical endeavor. The anaplastologist is a nonphysician clinician involved in the care of patients requiring facial (and sometimes somatic) prostheses. They

Figure 15. Patient 2 with the model nose. A, Lateral view; B, anterior view; C, base view.

Figure 16. Intraoperative view of patient 2 during the creation of the subsurface framework of the tip. Internal lining was provided by nasal turn-in flaps, which were delayed with the incision created 3 weeks previously.

Figure 17. Patient 2 after completion of the nasal cartilage framework. A combination of rib and ear cartilage was used. The internal lining of the nasal turn-in flaps lies underneath. The framework is made very stable with suture fixation employing rigid cartilage.

Figure 18. Patient 2, 1 year after surgery. A, Postoperative lateral view; B, anterior view; and C, base view.

routinely create custom-designed silicone prostheses for patients by taking a moulage impression, sculpting the missing anatomy (usually in wax), creating molds, and finally casting the form using medical-grade silicone intrinsically colored to match skin tones. The ability to make a lifelike nasal prosthesis requires years of training to become certified and many more years of practice to master. The anaplastologist is key in working with the physician and patient to arrive at a physical representation of the reconstructive goal. The reconstructive model is then reverse engineered in the form of a surgical guide. Furthermore, the anaplastologist directs the clinical application of the advanced digital technologies of surface laser scanning, 3D file manipulation, and RP used in producing the surgical guide.

The advantages of this process relate to the accuracy of both the gross size, width, and projection of the nose, as well as the fine detail manifest in the subtle contours and shadows of the various nasal subunits. In complex nasal reconstruction, each are equally important. Conscious perception of gross irregularities precedes the recognition of more subtle contour shortcomings.

The final guide is translucent, can be sterilized, and is custom fitted to the patient's facial contour. We have found it extremely useful to have an intraoperative visual and tactile reference that can be placed directly on the patient's face. It compels the surgeon to sculpt the tip in all its detail and assists with the achievement of stability and completeness of the nasal reconstruction.

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