The Emerging Role of 3-Dimensional Printing in Rhinology

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KEYWORDS

• Nasal septal perforation • Prosthetic closure • 3D printing • Computed tomography • Septal prostheses

KEY POINTS

- The most common symptoms of nasal septal perforation are crusting, bleeding, difficulty breathing, pain, and rhinorrhea.
- Septal perforations larger than 2 cm can be difficult to surgically close and have a higher rate of reperforation than smaller defects.
- Three-dimensional (3D) printing technology offers a new technique for sizing custom septal buttons with a better fit than previously described methods.
- Patient retention rates are 90% when the 3D sizing method is used; symptom improvement rates are comparable with other techniques for septal perforation closure.

INTRODUCTION

The increasing availability of 3-dimensional (3D) printing has led to multiple applications in rhinology. These applications include the creation of accurate patient-specific preoperative models for procedure planning, rehearsal, and patient consultation. It allows for the production of patient-specific customized prostheses for multiple applications, including nasal septal perforations.

The anatomically accurate 3D printed models can be used before complex surgical cases to provide the surgeon with additional information on the location and orientation of a lesion. Modern 3D printers can print models of patients' unique anatomy and in multiple color components. This ability allows different structures within the model to be represented by different colors, demonstrating the difference between bone, soft tissue, tumor, or major vascular structures. Simulated surgery can be conducted on these models to plan osteotomies, better understand anatomic variants, practice

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drilling near vital structures, or to develop templates for prostheses or reconstructive plates. These models provide the surgeon with conceptualization beyond what 3D image analysis offers. Models can also be printed with the removed to assist with reconstruction planning or to design a template for the future skull base defect.

Although most of the applications described earlier are used for complex skull base cases in tertiary care settings, 3D printing has a role in the general otolaryngologist's practice as well. Three-dimensional models can be used to create templates for maxillofacial trauma surgery or to design prosthetic implants. Prostheses can be designed for large and irregular septal perforations or defects caused by trauma or tumor ablation. This article discusses and provides examples of how 3D printing is improving the treatment of large or irregular nasal septal perforations by using both simulated surgery and prosthetic design.

Nasal septal perforations result from various causes, including previous nasal surgery, external nasal trauma, intranasal trauma, cocaine use, history of nasal cautery, and vasculitis.[1] Septal perforations can cause symptoms that range from minimal to severe, and they can significantly impact patients' quality of life. The most common symptoms are crusting, epistaxis, difficulty breathing, pain, rhinorrhea, postnasal drainage, hyposmia, malodor, and whistling.[1] Treatment options are tailored to the individual based on the severity of symptoms and size of the perforation. Nasal moisturizing agents are typically used as a first-line therapy and may be adequate therapy for the minimally symptomatic. Various surgical and nonsurgical closures have been used for more than 60 years in patients who do not respond to conservative topical agents.[2]

Surgical closure is a good option for small- to medium-sized defects, but successful closure can be difficult to attain for large and/or irregular perforations. A review of surgical methods for closure of septal perforation from 1960 to 2011 found that larger perforations (>2.0 cm) have a lower rate (73.8%) of successful surgical closure than smaller perforations.[3] Another review found a reperforation rate of 48% and attributed the failures to larger-sized perforations with unilateral mucosal closure.[4] The amount of available, nonscared mucosa relative to the size of the perforation is an important consideration. Since 1972, symptomatic patients with large nasal septal perforations, who were not candidates for surgery, have had the option of custom prosthetic closure at the Mayo Clinic.[5–7] Although septal prostheses have helped many patients, 27% of patients before 1982 chose not to keep the prosthesis in place because of discomfort.[8]

Before the 1980s, a custom prosthesis carved by a medical artist proved to be more comfortable than commercially available prostheses for large and irregular perforations. As accurate sizing remained a challenge, the carving technique was improved with the use of 2-dimensional (2D) computed tomography (CT) sizing[1,8]; more patients choose to keep their prosthesis. The introduction of 3D printing to the sizing process in 2007 offered the potential for further improvement by allowing the prosthesis to fit each patient's nasal anatomy exactly. The resulting product would provide more patient comfort and, thus, a higher retention rate. This article reviews how 3D printing technology is improving the fabrication of nasal septal prostheses for sizing nasal septal perforations.

EXPLANATION OF THE TECHNOLOGY

Image Data Acquisition and Printing

After patients are evaluated by an otolaryngologist, are not surgical candidates, and are found to be candidates for a septal prosthesis, a high-resolution CT of the face and paranasal sinuses is obtained (**Fig. 1**). The target resolution of the CT imaging