EVALUATING NASAL TIP SUPPORT USING A MULTI-COMPONENT NASAL MODEL

Eric Gray, BS1,2; Jason Chen, BS2; Marlon Madudoc, MD, MBA1,3; Brian J.F. Wong, MD, PhD1,3
1University of California, Irvine School of Medicine, 2Beckman Laser Institute, 3Department of Otolaryngology-Head and Neck Surgery, 1002 Health Sciences Rd, Irvine, CA 92612

Abstract

Objective: Stability of the nasal tip is essential for maintaining proper form and function of the nasal airway, particularly following rhinoplasty. Palpation is the standard method for accessing nasal tip support. A new method to quantitatively measure tip support was sought as current measurement techniques have had limited utility.

Study Design: Nasal tip support mechanisms were evaluated by performing mechanical analysis on a CT derived 3D-printed multi-component model to gauge how tip palpation alters tip displacement and reaction force.

Methods: A digital nasal model was created using a CT scan and CAD software. The facial skeleton was 3D-printed in ABS plastic. 3D-printing was used to create molds to cast the nasal cartilages in polyurethane of appropriate stiffness (septum: 13.3 MPa; upper and lower lateral cartilages: 10.4 MPa). The five individual nasal cartilages were embedded within the negative mold of the nasal skin envelope. Then polyurethane representing the skin envelope was poured into the mold (0.167 MPa). Mechanical analysis was performed on the model and the integrated response to tip depression was recorded.

Results: The multi-component model had a reaction force of 0.261 N and 0.783 N at 0.5 mm and 1 mm tip displacement, respectively.

Conclusion: This study demonstrates a novel way to create a customizable multi-component nasal model. 3D printing ensures a constant form factor, while the casting process allows for manipulation of the mechanical parameters of the individual cartilage structures and skin envelope. This process demonstrates a novel way for surgeons to create an advanced model to improve their surgical planning.

Introduction

The nasal tip is an important structure for both the aesthetics and function of the nose. Most descriptions of nasal tip support focus on the intrinsic ability of the nasal tip to counteract the forces of gravity, and in the case of the post-operative nose, the forces of contracture. Tip support is commonly evaluated by depressing the lobule and gauging the integrated reaction force, which resists this deformation. Numerous attempts have been made to quantify the biomechanical properties of the nasal tip. Beaty, Dobratz, and Wilson developed tools to measure the reaction force of the nasal tip to displacement. These attempts, while novel, were performed on live subjects or cadavers and thus the investigator could not alter the mechanical parameters. We sought a new method to quantitatively measure tip support as current measurement techniques have had limited utility. In this study, we demonstrate the use of 3D printing and polyurethane casting to create a multi-component nasal model, in which the mechanical parameters can be altered for biomechanical testing.

Methods & Materials

Using a high-resolution computer tomographic (CT) scan of single patient as a template, an open source computer-aided design program (3DSlicer, Boston, MA) was utilized to create a nose model with appropriate projection, rotation, and shape (Figure 1).

Figure 1. Digital model is created from individual CT scan in 3DSlicer.

Segmentation of CT Scan

Rendering of Composite Digital Model

The upper lateral, lower lateral, and septal nasal cartilages were then integrated into the digital model using a computer-aided design program (Blender, Amsterdam, Netherlands) (Figure 2).

Figure 2. Integration of nasal cartilages. (A) The five individual nasal cartilages were attached to the nasal skeleton. (B-C) The soft-tissue component was placed over the nasal skeleton and cartilage components to create the final model.

Using the digital model, a physical nose model was created. The bone, cartilage, and soft-tissue components were 3D printed (MakerBot Replicator, Brooklyn, NY) separately in ABS plastic (Figure 3).

figure 3. 3D printing process.

3D-printing was used to create molds to cast the nasal cartilages in polyurethane of appropriate stiffness (septum: 13.3 MPa; upper and lower lateral cartilages: 10.4 MPa). The upper lateral, lower lateral, and septal cartilages were embedded within the negative mold of the nasal skin/soft-tissue envelope. Then polyurethane representing the skin/soft-tissue envelope was poured into the mold (0.167 MPa). The complete polyurethane casting process is shown in Figure 4.

Figure 4. Polyurethane casting process. (A) Polyurethane is poured over printed nasal tissue. (B) After the polyurethane has set, the printed nasal tissue is removed from the negative mold. (C) The assembled nasal cartilages are placed in their anatomic location inside the negative mold. (D) Polyurethane of the desired stiffness is poured into the negative mold, and then the casted polyurethane with the embedded cartilages are removed and placed on the printed nasal skeleton.

Mechanical analysis (EnduraTEC ELF 3200; Bose, Eden Prairie, MN) was performed on the final multi-component model and the integrated response to tip depression was recorded (Figure 5).

Discussion

• Beaty12 found that 35.5 g were required to displace the nasal tip 1 mm along the vector of the columella.
• Dobratz11 found that it took 25 g to depress the nasal tip 1 mm.
• Wilson12 found that it took an average of 1.0 - 1.4 N to compress the nasal tip of a fresh-thawed cadaver from 0.5 mm to 1 mm.
• Our data fits within the range of Beaty, Dobratz, and Wilson demonstrating the ability to create a customizable multi-component nasal model that can be used for mechanical testing.
• Previously, this 3D printing and polyurethane casting approach has been applied to only simple structures in the past, and this study represents the progression from rectangular slab, to cranial model, to intact nasal model.

This approach also provides a link between experimental measurements/modeling and the rhinoplasty surgeon’s evaluation of nasal tip support. This type of model could be further used to validate finite element and computational fluid dynamics models used for surgical planning and simulation.

Conclusions

• This study demonstrates a novel way to create a customizable multi-component nasal model.
• 3D printing ensures a constant form factor, while the casting process allows for manipulation of the mechanical parameters of the individual cartilage structures and skin envelope.
• This allows analysis of mechanical response independent of object shape.
• This approach also provides a link between experimental measurements/modeling and the rhinoplasty surgeon’s evaluation of nasal tip support.

This process demonstrates a novel way for surgeons to create an advanced model to improve their surgical planning.

References


Contact
Brian J.F. Wong MD, PhD Email: bwong@uci.edu Website: http://www.ent.uci.edu

DEPARTMENT OF OTOLARYNGOLOGY
HEAD AND NECK SURGERY
UNIVERSITY OF CALIFORNIA, IRVINE • SCHOOL OF MEDICINE