Designing and Manufacturing Rhinoplasty Templates Using Digital Technology and Rapid Prototyping

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INTRODUCTION

Soft tissue models of the face can aid providers in the visualization and diagnosis of injuries. Three-dimensional photography, along with rapid prototyping techniques, can provide surgeons with a clinically accurate representation of the injury site for upcoming procedures. In addition to the 3D models of the injured area, models can be digitally adapted to create an ideal situation/state. Templates can then be constructed based on the digitally created ideal model.

Techniques, such as using a templates for a rhinoplasty, are not new. The previous methods used to achieve these templates, however, are quite complex. Utilization of foil that has been folded and crimped has long been the gold standard. Another method involving therma plastics has also been used to make a three-dimensional representation of the defect, which is then transferred into two-dimensions by making releasing cuts. The two-dimensional plastic is then used as a outline for forehead flaps [1]. Another institution used facial moulages to create models of patients' faces and then subsequently sculpted an anatomically correct nose using wax. This new face was then scanned and rapid prototyped. Templates were then constructed and molded [2]. No published studies, however, show a transition from three-dimensional photography to digital manipulation, template design, and manufacturing.

Using digital technology and rapid prototyping, surgeons can visualize the desired outcome before each procedure. After a "digital rhinoplasty" is performed, templates are easily designed and manufactured to serve as a surgical guide for an upcoming operation.

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METHODS

Three-dimensional Acquisition

- Soft tissue contours of the patient captured using 3dMDcranial system (3dMD, Atlanta, Georgia), a non invasive imaging system with an accuracy of <0.2mm in a two-millisecond window. (Figure 1)
- Data exported from the 3dMD system as a .vrml, .stl, or obj file
- Thickness was added to the tissue surface using Magics Software (Materialise, Ann Arbor, Michigan).

Computational Rhinoplasty and Template Design

- Defective part/section of the nose was digitally removed and replaced with and "ideal nose" from another individual. Ideal nose was scaled and transitions were smoothed using Magics (Materialise, Ann Arbor, Michigan) and FreeForm Modeling Plus (SensAble Technologies, Woburn, MA) Software. (Figure 2)
- If pre-injury pictures are available, it's beneficial to scaling and contouring
- Templates created digitally by using an offset algorithm on the ideal face
- Original face, ideal face, and templates were saved as a STL files

Template Manufacturing

- STL Files are processed on a build platform using Light Year (3D Systems, Rock Hill SC).
- Files are rapid prototyped using a Stereolithography Apparatus, by local curing resin using an ultraviolet laser layer by layer in the Z-direction at 0.125 mm increments
- Models are drained, washed in Tripropylene Glycol Monomethyl Ether (TPM), rinsed in water, and dried.
- Supports (lattice structure) are stripped from the model, followed by the models being post-cured (Post Curing Apparatus, 3d Systems, Rock Hill SC)
- Templates are molded and made from polymethyl methacrylate (PMMA), then sterilized for the surgery.

Surgical Planning and Techniques in the Operating Room

- Physicians can evaluate the models or examine pictures before the templates are molded, manufactured, and sterilized
- Models and templates can be designed in 24-48 hours after the initial request is submitted
- The ideal facial model is used to create two-dimensional templates from foil that has been formed over the three-dimensional model. These templates are then flattened and used as patterns for incising the donor tissue.
- The PMMA templates are used as intra-operative guides; these templates aid the surgeon in sculpting the cartilage and soft tissue constructs to mimic the ideal facial model.
- The templates can then be used in later re-constructive stages to further refine and achieve an ideal result.

Figure 1: Acquisition of 3dMD Photograph
The system consists of five synchronized cameras/projectors, which mathematically constructs a digital representation of the patient's facial shape. Patient is seated in the center of the frame.

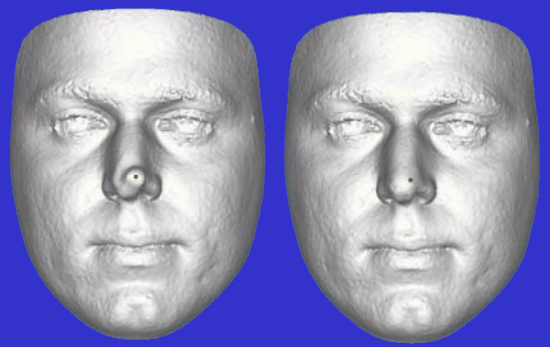

Figure 2: (Above) **Digital Rhinoplay**
On the left is the patient's face before the surgery and on the right is the patient's face after a digital rhinoplasty. An ideal nose is selected from another individual, positioned, then scaled to fit the patient's face. The nose is then adapted further to achieve smooth transitions to surrounding facial tissue. Pre-injury pictures can provide addition information, such as width and depth, to the surgeon/engineer; thus making it easier to create the desired "ideal" nose.

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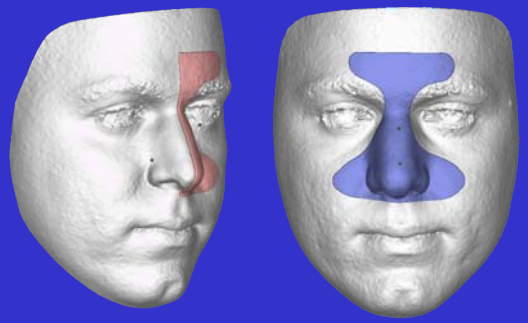

Figurt 3: Template Design (Above)
Nose Templates are digitally offset from the face and digitally cut to the desired shape. After verification and minor modifications, these guides are rapid prototyped and molded. Molds are then used to manufacture guides in PMMA. It has proved beneficial in the operating room to have both the entire nose and half-nose guides of the patient's "ideal" nose.

Figure 4: In Operating Room (Right)
Example of the stereolithography face with an "ideal nose." The ideal nose has been covered in foil to achieve a grafting template. The "half nose" rhinoplasty guide, laying next to the face, is made from PMMA. The transparency of the PMMA is an added benefit to the surgical procedure. Cheek and forehead indexing tabs are located on the guide to verify proper translation/rotation with respect to the patient's face.

RESULTS / DISCUSSION

The virtual and physical models can provide information not easily obtained by standard photography/examination. Digital manipulation and models prove helpful to physicians when evaluating the full extent of the of the injury, and when creating a surgical plan. Digital rhinoplasties can be performed before taking the patient into the operating room. In addition to the examples shown, surgeons/engineers can show the patient a digital 3D representation with texture (color). Templates have helped surgeons achieve 'ideal' geometry of the nose in complex rhinoplasty procedures.

To date, this procedure has been applied to two rhinoplasty procedures. Templates are saved and can be placed on the patient at follow-up appointments to examine the surgical results. Future studies will include calculations of how close the digital rhinoplasy compares to the surgical rhinoplasty.

REFERENCES

[1] Murrell et al. Plast Reconstr Surg. 2003.
[2] Byrne et al. Plast Reconstr Surg. 2008