Applications of Color 3D Printed Anatomical Models for Complex Maxillofacial Diagnosis and Surgery

PC Liacouras, CA Villamizar, SL Rouse, MP Brazaitis
Walter Reed Army Medical Center
3D Medical Applications Center
Departments of Radiology and Surgery
Orthopaedics and Rehabilitation
Washington, D.C.

3D Medical Applications Center

INTRODUCTION

Currently, physicians depend on diagnostic radiology to interpret the extent of a patient's injury. CT scans alone, however, are not always able to provide adequate representation of the injured area. Three-dimensional models of an anatomical region can help providers visualize the full extent of an injury and therefore aid in providing a diagnosis. (1)

Maxillofacial trauma sustained during the conflicts in Afghanistan and Iraq by Improvised Explosive Devices (IEDs) have created complex and unique surgical cases not widely discussed in the literature (2). These patients require extensive surgeries with prolonged operating room time and in many cases numerous surgeries. Complex fractures of the mid-face and mandible must be identified, as do any surrounding metal, shrapnel, and bony fragments retained in the soft tissue. The surgical team must decide which boney fragments are salvageable and if bone grafting is necessary. Generating an accurate anatomical model prior to surgery, allows the physician to create a surgical plan for patient treatment. This plan-of-action allows the surgical team to become familiar with the patient's injured anatomy and anticipate potential complications that may be encountered prior to surgery. In essence, the full extent of a problematic region is sometimes only truly identified and visualized with virtual and physical three-dimensional (3D) anatomical models.

Three-dimensional models generated post-operatively can provide beneficial information regarding the surgical outcome and help determine if a need for revision surgery exists. In some cases, the models can even persuade the doctors against surgical intervention. Along with the complex craniofacial fractures, custom implants may be required for facial reconstruction. The same rapid-prototyping techniques used in three-dimensional reconstruction of facial injuries can be adapted and used to create complex custom implants. Custom implants will fit the exact patient's anatomy and do not require modification in the operating room.

METHODS

Three-dimensional Reconstruction

- Computed Tomography (CT) sets spanning the area of interest are imported into MIMICS (Materialise, Ann Arbor MI) to create a 3D Stereolithography (STL) file.
- Any artifact is manually removed from the computational file
- Supporting cylinders are added to maintain the geographic locations of the larger loose bony fragments.
- Separate STL files of the patient skull/face and the supporting cylinders are exported.
- Final proccessing, assignment of color, and saving as a ZPR file is done in Magics (Materialise, Ann Arbor MI).

Anatomical Modeling

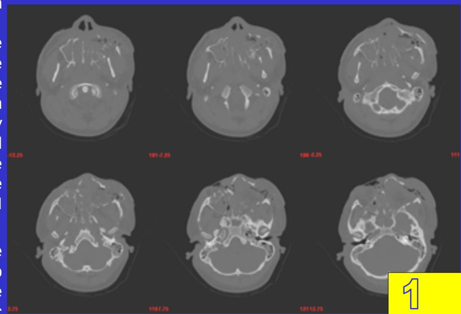
- File is rapid prototyped using an Zprinter 450 (Z corporation, Burlington, MA). A plaster powder spread across a build chamber and a binder is used to solidify each layer in 0.004 inch increments.
- Models are excavated from the powder-filled chamber and allowed to thoroughly dry; if necessary, models are placed in an oven at 60 degrees Celsius.
- Models are then infiltrated with cyanoacrylate and allowed to dry.

Treatment/Surgical Planning

- Physicians are then provided with a model to plan the appropriate treatment or surgical plan. Most models are delivered 24-48 hours after the request is made.

Figure 1: Standard CT Scan (Right)
On this CT scan, the radiologist notes and describe this patient as having multiple comminuted fractures through the maxilla and across many sections of the orbital and nasal regions. The extensive facial and orbital fractures are consistent with Le Fort Type III fractures.

Without 3D modeling the surgeon would have to envision the extent of the injury through diagnostic radiology alone.



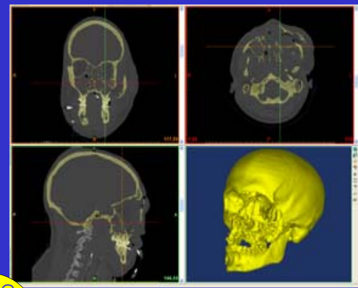


Figure 2: MIMICS (Left)
MIMICS imports standard CT scans, calculates the sagittal and coronal views, and using Hounsfield Units allows the user to threshold the scans and make virtual 3D reconstructions. These virtual models can be seen and rotated to display the injury. Sometimes the injury is so complex, even the virtual model is hard to comprehend.

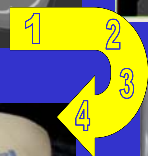


Figure 3: Zprinter 450 (Left)
This 3D printer can make models of multiple colors in hours instead of days

Figure 4: Frontal and Isometric Views of Pre and Post Operative Models (Right) Surgeons use the Pre-operative model to generate a diagnosis and surgical plan. The relative location of large bone fragments were maintained by incorporating black cylinders into the model. The color of the cylinders allow the surgical team to clearly identify bone. The post-operative model (left) shows the patient with all fixations represented in light blue.

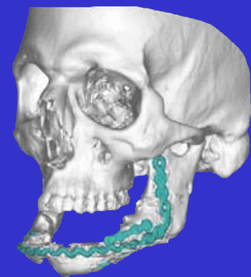


Figure 5: Digital 3D File (Right)
The digital file is made and then transferred to the Zprinter. This particular patient has had his mandible reconstructed using a fibula graft. Separating the fixation from the bone can provide the surgical team with more information. In a case like this, one can see if any of the grafted bone has been reabsorbed by the body.

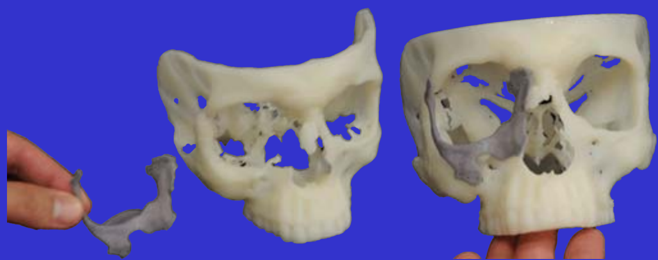


Figure 6: Custom Orbital Implant (Above)
Orbital implants similar to the one above can be rapid prototyped in just a couple of hours. This allows the design team to check the fit of the implant, general aesthetics, and fixation locations; it also enables immediate feedback from the surgical team. Once the implant is approved, it can be fabricated in the appropriate material. This particular implant was manufactured out of titanium alloy.

RESULTS / DISCUSSION

The virtual and physical models provide information not easily obtained from standard radiographic scans. Physicians can evaluate the full extent of the injury and decide on an appropriate plan of action for each patient. Once the first operation is performed, the surgeon can request a post-operative model to evaluate the outcome and determine if any revisions are needed.

To date more than 15 maxillofacial, mandibular, and orbital implant cases have been rapid prototyped using the Zprinter 450.

REFERENCES

[1] Gajewski et al. J AAOS. 2006.
[2] Powers et al. Oral and Maxillofac Surg Clin North Am. 2005