Rebuilt Body Parts: Technology Puts a New Face On Disease and Disability

Soldiers returning from the conflict in Iraq, accident victims, cancer patients, or those with muscle-wasting diseases often end up with grossly misshapen bodies for which there is no off-the-shelf prosthetic. For these individuals, obtaining reconstructed, rebuilt body parts is as essential to treatment as addressing core activities of daily living. Yet even today, there's no such thing as a spare cranium or jawbone.

Recent advances in digital medical modeling are delivering customized human body parts with amazing new speed and efficiency, and putting a new face on disease and disfigurement – literally. Doctors today are ordering up just about any patient-specific body part, designed with digital perfection, in far less time and with improved fit and patient ease. These custom body parts are facilitating faster surgeries and more complete patient recovery, as well as restoring patients both aesthetically and emotionally.

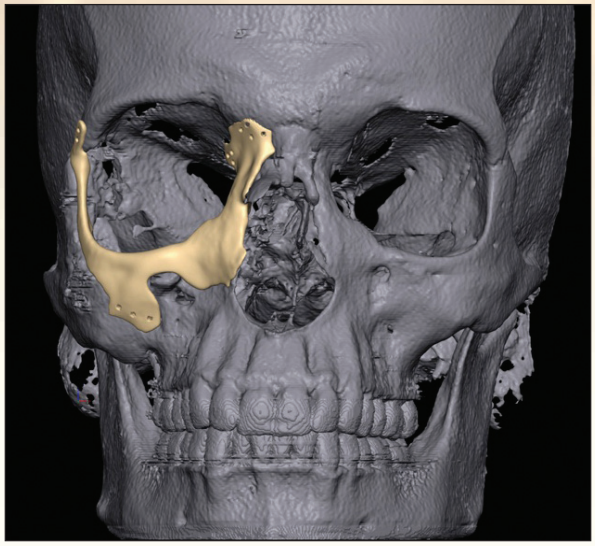

Figure 1. Orbital implant designed using sculptural CAD. (Photo courtesy of Walter Reed Army Medical Center)

Materials and Digital Data Advances

What's behind the advances? First, is the digital transition. "The technology to create a digital 3D model has existed for some time, but it's really taking off now because the process is vastly easier – from data acquisition to modeling and manufacturing," said Dr. David G. Genecov, a craniomaxillofacial surgeon and director of the International Craniofacial Institute, who has provided numerous custom-made reconstructive implants to adults and children.

"We frequently have to reconstruct just one side of the face, and computers can create a mirror image based on the normal side that's far more accurate than hand-drawings. The technology improvement has made custom implants more adaptable for clinical use. Once I identify what I need from an implant, it's almost a one-stop shop from data acquisition to surgical modeling to implant creation and delivery."

The second advance is the fact that younger, tech-savvy physicians and technicians are comfortable with digital technologies and, in fact, often see them as superior ways to reduce surgical time when the patient is open and exposed to infection.

Third is 3D modeling software that better accommodates organic shapes. Traditional 3D CAD modeling packages were created for designing cars and aircraft, where geometric shapes could be readily extruded mathematically. However, with complex, organic shapes – like the bones of the human body – the time required to create such models skyrockets. Medical modelers increasingly reach for so-called sculptural CAD solutions, such as the FreeForm® modeling system from SensAble Technologies because they are designed to quickly and easily handle the intricate organic shapes of patient-specific implants.

The next advance is the rapid revolution from better scanners, 3D printers, RP, and RM techniques, as well as biocompatible materials that knit into the patient's own bone for faster regrowth. "The next frontier is seeding these custom scaffolds with cells and/or growth so that the implant ultimately transitions into bone; therefore, relieving any stress of implant incompatibility, movement, or extrusion. We're already doing similar procedures in the skull," Dr. Genecov said.

The final advance is the "Extreme Makeover" effect. Celebrity make-overs have heightened expectations among consumers, according to Allen Andrews, president of AART, a full-service implant provider in Reno, NV that does one-third of their business in patient-specific implants. The firm has seen its custom implant business grow ten-fold in the past ten years.

Extensive Military Applications

With soldiers' frequent exposure to blunt trauma, military medical centers are a logical

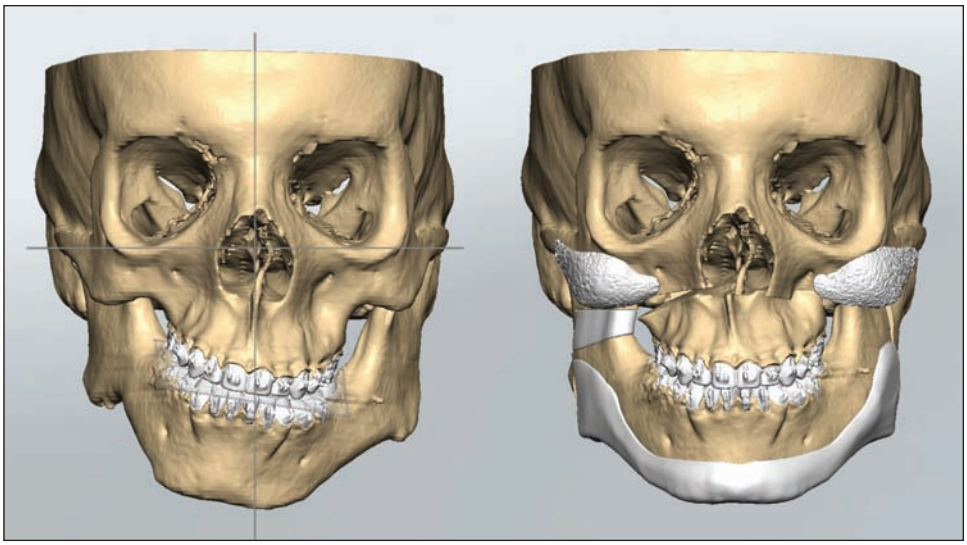

Figure 2. Facial asymmetry before and after surgery in a 16-year old female. White areas on the right are mandible implants designed in the FreeForm sculptural CAD system. (Photo courtesy of MedCAD, Inc.)

choice for digital medical modeling. Walter Reed Army Medical Center has operated a 3-D Medical Applications Center since 2004, and handled over 200 cases in 2008 alone. For example, 3D lab technicians created an orbital (eye socket) implant for a soldier who sustained severe blunt trauma from a gunshot wound to the head (see Figure 1).

Beginning with a CT scan of the soldier's intact left orbital bone structure, the Center's technician sculpted in "virtual clay" to match the unique surface features and complicated geometries of the patient's damaged orbital area. Because the eye socket has different concavities, it is tricky to design — stretching out side-to-side with unique geometry based on the patient's eye shape and size, while also extending back into the head. Special care was required to design the implant so that it could allow sturdy attachment sites located on available facial bones to allow the small screws that hold it in place. Using digital modeling allowed the Walter Reed center to complete a formerly three- to four-week process in days, or, in emergencies, to design the model in 24 hours and complete the finished sterile implant in a week.

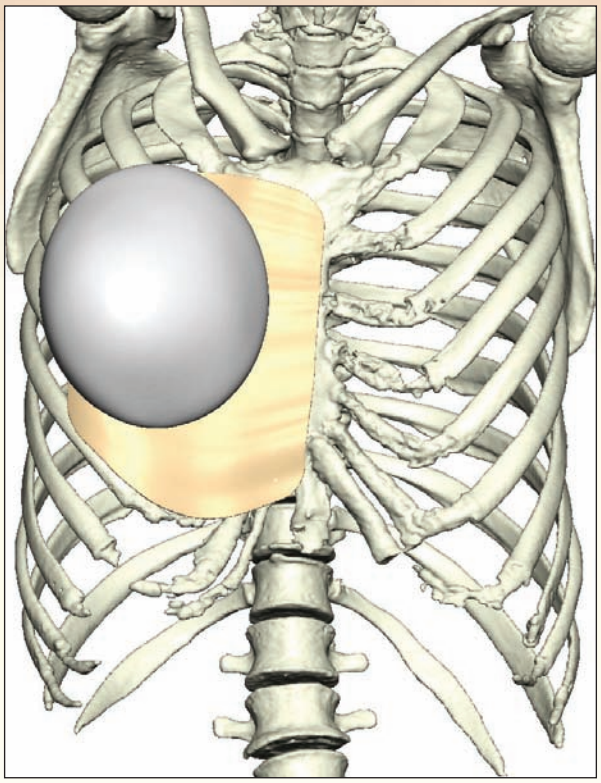

Figure 3. Pectoral muscle/breast implant. A custom pectoral muscle implant provides better support to an off-the-shelf breast implant for a woman with Poland's syndrome. (Photo courtesy MedCAD, Inc.)

Facial Asymmetry – Mandible Implant

Many times, disease causes facial asymmetry that warrants the creation of replacement bones. MedCAD, a Dallas-based medical modeling service bureau, assisted Dr. Ron Caloss, now at the University of Mississippi, to plan for surgery on a 16-year-old female with Langer-Giedion Syndrome. The disease left her with an asymmetrical face (see Figure 2, "before" view) and pain while chewing. After importing her CT scan data files, MedCAD made 3D models of her face showing the precise degrees of movement required to realign her maxilla and mandible, and e-mailed them to Dr. Caloss as 3D PDFs. Once he saw the digital 3D models, Dr. Caloss realized through the surgical planning that the bones would collide, and therefore virtually planned a better surgical approach by applying a custom mandibular implant that was perfectly shaped to the new facial design. The result was a new, symmetrical face for the young woman that required less surgery time and less risk overall (see Figure 2, "after" view).

Prosthetic Nose

The University of Wales Institute — Cardiff's National Centre for Product Design & Development Research (PDR) — and the Maxillofacial Lab at Morriston Hospital, Swansea, digitally created a nasal prosthesis for a male in his early sixties with cancer. The prosthesis is held on the face by small magnets on its underside. Working with sculptural CAD, PDR's staff moved from design to completion in approximately one-third less time than using traditional wax models, and spared the patient lengthy chair-side appointments for fittings. A panel of 13 experts rated the digitally created prosthesis as the same or better than a conventionally created prosthesis in terms of positional accuracy and shape.

Pectoral Muscle/ Breast Implant

Lopsidedness in other body parts can also be addressed with custom reconstructive muscle implants. A fit, healthy woman in her mid-fifties was born with Poland's Syndrome, a condition in which underdeveloped chest muscles leave female patients with the appearance of having, at best, only one breast, and at worst, a sunken depression next to the normal breast. The patient previously received off-the-shelf breast implants with unsatisfactory results.

Using sculptural CAD to achieve the perfect fit, MedCAD designed a custom pectus excavatum implant to address the chest wall deformity. The surgeon attached the implant to her intact muscle wall and used it as a solid foundation for addressing the missing, undeveloped pectoral musculature (see Figure 3). Using CAD technology, MedCAD also was able to estimate and specify the best-fitting, off-the-shelf breast implant to match the opposite side. The patient was thrilled to be symmetrical for the first time in her life.

Custom-Made Dignity

CAD technology isn't just for making car parts better, faster, and cheaper. Digital medical modeling techniques are restoring physical normalcy to those with trauma-based deformities, life-threatening injury, or diseases. It is delivering custom replacement body parts with improved fit faster, and hastening their return to the dignity and confidence that comes from a restored appearance.

This article was written by Dr. David Chen, Chief Technology Officer of SensAble Technologies, Inc. in Woburn, MA, and Nancy Hairston, President of MedCAD in Dallas, TX. For more information on SensAble Technologies, visit ***http://info.hotims.com/ 22916-175****; for more on MedCAD, visit* ***http://info.hotims.com/22916-146****.*

Reprinted from Medical Design Briefs, May 2009. On the web at www.techbriefs.com.