Rebuilding Faces with 3D Printing: How Technology is Reconstructing Surgery

A Tennessee-based oral and maxillofacial surgeon and his team of residents are using 3D printing to create better treatment plans, implants and other life-changing devices for patients with birth defects, or recovering from disease or trauma.

Most of the time, a car accident victim with trauma to the face will undergo hours of surgery in the operating room, as doctors work to rebuild the damaged area based on their best analysis of how the face might have looked before — usually using a CT scan.

This usually involves bending, cutting and drilling stock titanium bars, plates and mesh under small flaps of skin in an active wound.

But 3D printing is transforming all of that, leading to shorter surgeries, better reconstructions and improved results for patients.

In Tennessee, Dr. Jeffrey Brooks, who has more than 20 years of experience and multiple roles at the University of Tennessee Health Science Center (UTHSC), has been leading the way with this progressive approach.

Today, he explained, a trauma patient will still have their injury scanned after a comprehensive exam. But now, Brooks and his team will plan the reconstruction digitally and 3D print a life-sized biomodel on an EnvisionTEC Vector 3SP. The machine creates a replica of the patient's bony structure with accuracy to 100 microns.

The surgeons can then build reconstructive devices right on the 3D printed biomodel at their desk, crafting it exactly as they want before they ever set foot in the operating room. Once they do enter surgery, they have all the fabricated parts they need to do the reconstruction quickly.

"It has truthfully been a game-changer for us," said Dr. Brooks, who also serves as US Director of Clinical Affairs of ACTEON North America and has appointments at four Memphis-area hospitals. "This method is substantially better than conventional methods."

Charlie Felts, an oral surgery resident at UTHSC, said the new approach saves precious time and money, in addition to delivering a better outcome for patients. "When you're in the operating room, there's all kinds of tissue, blood, irrigation, the lighting is not always great, it's hard to see," he explained. "When you just have the boney model on your desk, you see every little piece, every nook and cranny … We can perfect it before we go in there and make sure it fits. We can get very close to perfect."

The EnvisionTEC Vector 3SP also plays a critical role that other printers cannot. Dr. Brooks explained that the fast turnaround time needed in emergency cases wouldn't be possible with the kind of FDM filament 3D printers he started with years ago.

"What would take the Vector several hours to print would sometimes take a filament-type printer 36 hours with significantly less accuracy," Brooks explained. "We needed something that could print fast, with easy clean up and would be ready to go within a 24-hour period of time because a lot of the trauma cases come in the night before."

A Wide Variety of Clinical Applications

But trauma is far from the only use for 3D printing in reconstructive medical cases. Oral and maxillofacial surgeons specialize in treating a wide variety of complicated diseases, injuries and defects in the hard and soft tissues of the head, neck, face, jaws and mouth.

An early adopter of 3D printing technology, Dr. Brooks and his team have been using the technology to assist in a wide variety of plastic and reconstructive surgery as well — perfecting different approaches to printing both hard and soft tissue.

For most non-emergency reconstructive cases, the process typically starts in Dr. Brooks' clinic, where he takes a 12-second cone beam CT (CBCT) scan of the patient's area of interest. He then uses software to render the scan at the bone level and converts that data to an STL file, from which he can print a three-dimensional model of the bone.

The Vector 3SP his team uses is large enough — 300 x 200 x 275 mm (11.8 x 7.9 x 10.8 in.) — to print the patient's mandible, maxilla, orbits, frontal sinus bones, cheek bone (zygoma), or even the entire head if needed.

The 3SP technology uses a laser beam to cure photopolymer in a vat, but in a faster and more accurate fashion than traditional SLA systems. Unlike most SLA printers, where the laser beam is stationary, and the beam is directed within the vat, the 3SP system allows the laser beam to move or scan across a large vat, much like a 2D printer, delivering highly fast and accurate objects.

Once printed, Dr. Brooks then uses the model as a mold on which he bends and constructs titanium bars, plates and mesh cribs to reconstruct the post-resection defect.

Plus, he can strategize the plate selection and contour all components in detail, taking as long as he needs to. He can then review the changes with a patient and get their feedback on the model before ever setting foot in the operating room.

"The biomodels are durable enough to withstand the flexing and manipulation as the surgeon is bending the rigid titanium plates around it," Brooks said. "It doesn't scratch very easily."

This same method can also be used for cases involving distraction osteogenesis of the mandible. A process used to repair skeletal deformities, usually in children, the procedure involves cutting and slowly separating the bone, allowing healing to take place in the gap, and consequently elongating the bone. The method is used to treat a variety of conditions from unequal leg length to certain cases of airway obstruction in babies. Having a working 3D model to plan the surgery and prepare the devices that are frequently used to help lengthen the bone can help save time and deliver better results.

"One of the most gratifying parts of being an oral maxillofacial surgeon is to have a good outcome, and we want to embrace any technology or any advances in medicine that will allow us to have the most optimal or best outcome for our patients," Brooks said. "As we evolved from lower end to higher end printers, we continue to appreciate the advantages of printing biomodels in medicine. We continue to find new usages."

Improving Reconstructive Surgery

Dr. Brooks is also using a similar but slightly different method of 3D printing biomodels for patients who must have reconstructive surgery done after the removal of a tumor, either benign or cancerous.

"Frequently I'm asked to print a maxillofacial biomodel for other services like the ENT head and neck cancer surgeons to aid in their reconstructive efforts," said Brooks. "In-office 3D printing is growing rapidly in my specialty as well as other surgical specialties that can greatly benefit from this exciting technology. I recently printed a full thoracic and spine biomodel for an orthopedic colleague of mine for a pediatric patient."

In these cases, fabrication of extensive soft tissue is required for, say, the replacement of an ear, nose or area of the face. This process also starts with a CBCT or CT scan.

But instead of using his software to render the scan at the bone level, Dr. Brooks renders the scan at the skin level and prints a solid skin-level model as well as a "twin" for the defective side. UTHSC's anaplastologist then creates the necessary prosthesis.

Traditionally, the anaplastologist would have been required to take impressions of the patient's face with a thick impression material, which is a time-consuming and uncomfortable procedure for the patient — especially when it involves children — before creating a plaster cast on which to create a prosthetic.

Easier than it sounds

While Dr. Brooks might be using his EnvisionTEC for new and quickly evolving applications, he stressed that using the machine itself is easy.

"When selecting a printer, it was critical for us to make sure we didn't have to calibrate or otherwise maintain the machine with any frequency," he said. "We're not a lab, and we don't have a full-time technician to perform such duties. The Vector is a really stable and reliable unit."

He added that he uses two different software packages with his 3D printer:

· Anatomage and its Medical Studio module to manipulate, mirror, and extract segments from a scan, produce a 3D rendering, and then export to an STL file.

· AutoDesk MeshMixer for edits to the STL required for certain orthopedic procedures.

A software product that bundled these together would make it easier for hospitals to embrace the technology, he said, but the printer is pretty much plug and play.

Dr. Brooks takes pride in saying that every resident at UTHSC now learns how to "go from A to Z" with digital planning — taking a scan, manipulating the data, and 3D printing whatever guides or models he needs to perform the necessary procedure.

"They may not realize they're at the cutting edge of best practices, but they are," Dr. Brooks said. "And they may not do all this in their practice, but they leave here knowing how it can be done."