Rise of 3-D printing stretches the limits of plastic surgery’s potential

BY KEITH LORIA

Plastic surgeons do not like surprises. They are known for meticulously planning surgical procedures, and a growing number are embracing 3-D printing as a viable tool to further eliminate variables in the O.R. Though the technology has existed since the 1980s, 3-D printing’s embrace by the medical community has accelerated in recent years – and ASPS members are using it to extend the limits of treatment possibilities.

Also known as “additive manufacturing” or “rapid prototyping” (or “one layer at a time”), the process works by creating objects through sequential layering of plastic, resin, metal, paper or other material – including biomaterial – based on a three-dimensional digital scan or model. The $2 billion 3-D printing industry – which is projected to expand into a $6 billion industry by 2017 – represents a rapidly evolving technology that is currently being used by surgeons to create physical objects from digital renderings to plan complex surgical procedures. Future application hold even greater promise, from “printing” patient-specific surgical tools to implants imbeded with living cells to regenerate human tissue.

3-D printed organs and body parts, and computer-aided tissue engineering, all may one day result from this relatively nascent technology.

“We use 3-D printing as an educational and planning tool, where we can ‘cut out’ a patient’s anatomy and learn what it is before going into surgery,” says ASPS member Samuel Lin, MD, Boston, associate professor of surgery at Beth Israel Deaconess Medical Center. “The precise and cost-effective pre-fabricated model ascertained from computed tomographic data have the ability to yield pre-contoured plates that can help surgeons plan for potential bone-graft harvest geometry before the procedure.”

The 3-D printing process begins with entering geometric data into a computer, which forms it into graphics in a process that has been likened to digital sculpting. The


**Assistance to the max**

**Early adopters**

Many medical and surgical procedures today require the use of computer-aided design (CAD) and computer-aided manufacturing (CAM) technologies, which are used to create digital models of organs, tissues, and other medical structures. These models can be used to plan surgeries, create surgical instruments, and even train surgeons.

One key area where these technologies are being used is in the field of 3-D printing, which involves using a 3-D printing machine to create physical models of organs and tissues. These models can then be used to plan surgeries, create surgical instruments, and even train surgeons.

**3-D printing**

3-D printing technology is still in its infancy, and there are many challenges that need to be overcome before it can be used widely in medical and surgical procedures. However, there is a growing number of early adopters who are using this technology to develop new medical and surgical procedures.

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models of the infant’s jaw and used them as a guide intraoperatively to successfully lengthen her lower jaw and open her airway. The child’s breathing reportedly has vastly improved and her jaw is developing normally, thanks to the surgery.

Earlier this year, ASPS member Elliott Dubois, MD, associate professor of neurosurgery at Stony Brook University School of Medicine, and Michael Egnor, MD, director of pediatric neurosurgery at Stony Brook Children’s Hospital, collaborated with Colorado-based Medical Modeling Inc., to plan the virtual surgery of a 6-month-old infant who had unilateral coronal synostosis. Using 3-D printing technology, the modeling company created before-and-after models of the young boy’s skull, simulating the symmetry and dimensions it should have, so the surgeons could accurately predict how the results of the operation would look.

Dubois says they had accurate cutting templates to follow — so they simply traveled where the cuts should be on the skull like a stencil.

Going soft

While 3-D printing for bone is gaining popularity, Dr. Tepper believes that it won’t be too long until the technology proves useful in soft-tissue reconstructive procedures.

“I think we will see 3-D printing in the O.R. for soft tissue in the next couple of years. This is the next big area of reconstruction surgery,” he says. “It’s a lot easier when planning on bone to see where cuts are made, how you can print a guide to help and print a solid structure.”

“There are plans for the future to have actual printed models that would allow us to peel off the soft-tissues and look at the vessels in relationship to the soft tissues as well as to the bone,” adds Dr. Pomahac. “That’s where the future is in terms of medical modeling and 3-D printing applications in plastic surgery.”

Dr. Tepper, who specializes in ear reconstruction, says he looks forward to the day when he can use the 3-D technology for otologic procedures.

“I’m actually collaborating with some 3-D colleagues who work in automation and aerospace, and incorporating some of that technology,” he says. “We’re starting to come up with ways we can print 3-D constructs that we can use as a reference — guides we can use in the O.R. A lot of what happens with ear reconstruction is postoperative, with the dressing and getting things to heal in the way you want them to.”

The ability to create patient-specific orthoses and splints custom-designed to fit the patient in the position needed for optimal postoperative results — without the need for an occupational therapist to redesign or fine-tune the device postoperatively — is also a real possibility, says Drs. Tepper and Pomahac.

“You could even print, perhaps, instruments that you could use in the O.R. rather than selecting from hundreds of instruments in a kit,” says Dr. Pomahac. “The ability to immediately substitute things that you need — or to make patient-specific products — would result in greater efficiency in the O.R.”

‘Customizable’ implants

Dr. Lin co-authored a February 2014 PRS article on 3-D printing. “A Plastic Surgery Application in Evolution: Three-Dimensional Printing,” which notes how hand surgery could benefit from this technology, as it one day might form prosthetic portions of the upper extremity adapted specifically to individual patients’ functional needs and anatomy; in addition to customized implants for both large and small joints.

He also tells PSN that 3-D printing could have revolutionary aesthetic applications, as well. Breast implants, for instance, theoretically could be designed in an office setting by the plastic surgeon, who would input a patient’s measurements and desires to generate a 3-D model — with the result being a customized implant that would originate in a printer, he says.

“This technique has the potential to produce improved aesthetic outcomes as a result of individual fitting, and to complement individual anatomical needs,” says Dr. Lin.

“In the future, there might be a way to print-out customized implants for a patient. I think over time the material will get better and the speed at which implants can be made and implantable will increase.”

Dr. Salyer agrees: “This technology may one day be used in breast repair or enhancement, to provide a customized breast for each patient.”

The 3-D printing principle also could be applied to facial aesthetics as well, Dr. Lin adds.

Using mandible reconstruction as an example, Dima Elissa, CEO of Proof3D, a Chicago-based prototype and short-run fabrication company, says that 3-D printing can reach a plastic surgeon’s objective of obtaining a true rendering of the lower jaw that’s accurately sized and contoured. This rendering can allow the surgeon to properly form the titanium reinforcement, for example, to be screwed into the patient’s jaw, to act as a lifetime support structure as a whole and for the bone graft that would be concurrently performed.

“The advantage to this process is that it reduces the amount of time the patient has to be in the O.R. by 15-20 minutes and allows the surgeon to do the physically hard labor of bending the titanium in advance — rather than immediately just before complex microsurgery is about to start,” Elissa says.

“One ancillary benefit is the reduction of hand fatigue for the surgeon at a critical time in the procedure,” she adds. “In addition, it can reduce overall operative time and improve outcomes, both through a better fit of the titanium reinforcement and the lessened risks associated with shorter surgical times, and reduce the number of stitches.”

If adopted as a standard, Elissa says it will eliminate the need to purchase the tin plate type of used in mandible reconstruction to create a template of the lower jaw after it’s exposed.

A journey begins

An anatomical part begins its 3-D journey when the geometric data is uploaded through a computer design model or scanned in.

Max Cormack explains that all 3-D printing starts with a 3-D data file, with stereolithography (STL) being the universal industry standard file format for 3-D product designs. Also widely utilized are “object files (obj)” and “virtual reality modeling language (.vrm).”

“All mainstream 3-D computer-aided design (CAD) software products, including free programs such as SketchUp, produce STL files, and STL files are the most widely used and most appropriate for professional output. Most STL files are the result of complex scanning techniques designed to produce a standard file that can be read by 3-D printers.”

“Tinkertoy” STL files are typically generated by STL scanners, and the STL file is used to print the part. Each slice of the STL file is converted into a plane, and the 3-D printer then protagonist builds layer by layer until the part is complete. The process can take anywhere from 90 minutes to several hours, depending on the size and complexity of the part.

“Once the STL file is complete, the software is able to identify the individual layers of the part, and the software produces files that can be used to print the part.”

“The STL file can also be printed directly, which is a more efficient process. The STL file is sliced into layers, and the 3-D printer then builds the part layer by layer until the part is complete. The process can take anywhere from 90 minutes to several hours, depending on the size and complexity of the part.”

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