3D Printing: Exploring the New Possibilities

This revolutionary technology has the potential to change how we practice medicine in the future.

BY ALEC HOCHSTEIN, DPM

Three dimensional printing technology is quietly disrupting a number of industries as its potential uses expand—but no sector has been affected more dramatically than the field of medicine. The revolution in medical care catalyzed by 3D printing brings fresh news from the front lines nearly every week, and patients across the globe are suddenly discovering hope where previously none existed. Here's a snapshot of the status of 3D medical printing, as of Summer 2015.

Origins and Process

For people who haven't watched a 3D printer at work, the concept can be confusing at first. It's actually similar to printing on paper, except as if one sheet of paper were being printed over and over, with layers and layers of material deposited by the print heads in a specific pattern. Because of this layering, the process is sometimes referred to as "additive manufacturing."

First developed in the 1980's, 3D printing initially used an acrylic liquid "ink" that would harden when exposed to Ultraviolet light from a laser beam. In those early days, the printed results were only prototypes, fragile representations of potential objects which then had to be manufactured in a conventional factory. Current 3D printing technology is a $2 billion industry that directly produces usable objects.

New possibilities for materials to use in 3D printing are being constantly explored; currently, it's possible to print objects from plastics, ceramics, metals, wax, food, and even a growing selection of complex biological substances. Collagen lends itself readily to the printing process, while new "self-healing" print materials are being developed with microchannels built into them. It's even possible to print tissue, with interior vessels lined with epithelial cells.

Applications for Healthcare

Three-dimensional scanning has been available to medical science for some time; now those CT scans of a body part can be translated into a highly detailed digital map or "cloud of point in 3D space," readable by the printer. This 3D reproductive process makes it possible to produce prosthetics and orthotics that precisely match the body's contours down to a micron level. Exact replicas of body parts have other uses in medical science as well: Surgeons can practice on a model ahead of time, for example, manipulating an exact duplicate of the patient's mitral valve or optic nerve before embarking on the actual surgery.

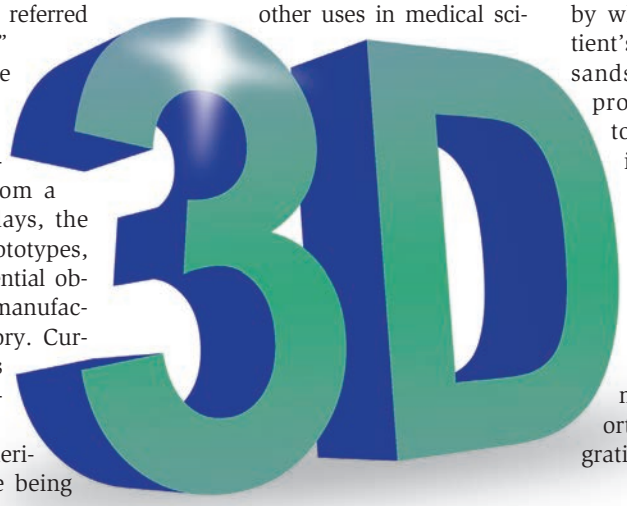

Illustration by Christopher Donoghue

Orthotics

Custom foot supports are widely used for alleviating biomechanical foot and leg inadequacies, and the precise mapping technology of 3D printing has made orthotics one of its early successes.

Researchers at England's University of Bath have not only devised a machine to print customized polypropylene orthotic insoles, but they have also taken the manufacturing cycle one step further by making their printer nearly self-replicating; a few hardware store items combined with printed parts enables users to assemble their own orthotic printer for about $500.

SOLS® has developed a process by which just three images of a patient's foot are used to generate thousands of data points, enabling the production of a completely customized orthotic. The 3D printing process takes into account the patient's weight, activity level and shoe type, as well as the provider's input on specific misalignments. In early 2015, SOLS® received $11.1 million in Series B funding on the strength of its custom mass manufacturing model, and other orthotic producers are quickly migrating to similar technology.

Continued on page 104

3D Printing *(from page 103)*

Prosthetics and Assistive Devices

Customized "exoskeleton" mobility devices can be slipped on like snug sleeves, using motors and hand controls to allow some wheelchair users the opportunity to walk again. While mobility aids have existed for some time, the personally sculpted customization prevents pressure points and abrasions from developing.

The cost savings of electronic customization can be spectacular: A "robo-hand" custom-printed for an artist who had lost her fingers due to sepsis ended up costing only 1/200th of the cost of a traditional prosthetic with similar functionality. The story of a robotic arm produced in pink plastic for a teenage girl at Washington University at St. Louis again shows the power of the technology. The arm, printed out in minutes while the patient and her family watched, costs about $200. The previous cost for producing this level of custom prosthetics? Between $50,000 and $70,000. Some companies are even printing prosthetic "hand kits" that patients can assemble at home.

The hearing aid industry was one of the earliest adopters of this technology, and over ten million 3D-printed hearing aids were in circulation by late 2013. To make these individually customized devices, an audiologist scans a patient's ear with a 3D laser scanner, producing a digital map which enables the printing of a perfectly-fitted resin shell.

Orthodontics and Dentistry

"Invisalign" clear plastic teeth aligners, used by over 2.5 million people worldwide, are printed to meet each patient's needs. These orthodontic devices are successively reprinted at intervals to adjust to the mouth's changes until the problem is resolved. Interestingly, Align Technology Incorporated, which makes Invisalign braces, is now engaged in a global legal dispute over the copyright laws covering 3D digital data sets. Trade laws have not entirely caught up with the new twists and turns of ownership created by this revolutionary production method.

While dentists have been using digital technology to produce crowns and dentures for a couple of decades now, the process has been one of computer-aided sculpting or "milling." 3D printing is far more capable of reproducing intricate details, and these "stereolithography" methods are now challenging the classic chairside milling technology. Dental-specific printer sales are expected to reach $180 million per year in the U.S. alone, as each machine costs $20,000 and has an anticipated lifespan of 10 years.

Therapy

A form-fitting spinal brace that slips easily underneath clothing provides a scoliosis remedy that self-conscious teens are actually willing to wear. This flexible brace, printed from breathable nylon powder, was the product of a collaboration between 3D Systems and Oakland's Children's Hospital.

Meanwhile, 3D materials are also valuable as templates: By 3D-printing a jaw "stencil" and carefully attaching it to the outside of a child's face, a craniofacial surgeon slowly put pressure on the growing jaw to bring it into alignment with the stencil and avoid risky bone-grafts.

New Developments

Recent news articles have featured the story of infants born with weakened tracheas. This condition is normally resistant to treatment because of the fragility of tissue, and cardiac or pulmonary arrest was the all-too-common outcome. With the use of a 3D printer, flexible tracheal splints can now be created from a biodegradable polymer; once inserted into the trachea, the stretchable splints expand with the growing child and eventually dissolve, requiring no surgical removal.

Public-Private Collaborations

The humanitarian benefits stemming from 3D printing are leading to innovative collaboration between the nonprofit and health technology sectors.A foundation named e-NABLE was recently awarded a $600,000 grant from the Google Impact Challenge, for its network of volunteers that donate their time to printing low-cost prosthetics for needy patients. Addressing wider needs, the National Institutes of Health 3D Print Exchange provides "an open, comprehensive, and interactive website for searching, browsing, downloading, and sharing biomedical 3D print files, modeling tutorials, and educational material."

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Future Possibilities

The eventual possibilities offered by 3D printing are being conceived of somewhere out at the point where bio-technologists' imagination meets science fiction wizardry. Researchers are exploring printing "ink" made of living cells, and the possibility of growing replacement organs on polymer scaffolds. The future holds the prospect of printing whole organs, bypassing the need for human donors.Wake Forest Institute for Regenerative Medicine has already created "miniature livers that live in petri dishes." The pharmaceutical industry looks forward to testing experimental drugs on bio-printed tissue, saving millions of dollars each year on drug development.

The world of medical science is clearly poised on the brink of changes so vast that their overall shape is still hard to see. 3D printing has the potential to change how we practice medicine in the future. Every healthcare provider should explore this new and limitless technology, to witness and integrate unimaginable changes into the everyday care we offer our patients. **PM**

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