HEALTH & HEALING

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Liberating Limbs

3D-printed prosthetics give veteran amputees more independence, increased comfort

By Matt Alderton

U.S. MARINE CORPS VETERAN Dan Lasko had been in Afghanistan for less than 30 days when two roadside bombs struck the convoy in which he was riding. He still remembers the blast — and the sight of his mangled leg afterwards.

"That's how I became an amputee," said Lasko, 36, who lost his left leg below the knee in April 2004 and received his first prosthetic limb later that year.

Today, Lasko is an athlete of the highest order, competing in marathons and triathlons all over the world. He's the kind of person who can do anything. And yet, some things remained a struggle. Like swimming with his boys, 9-year-old Luke and 5-year-old Ben. Because his prosthesis was not designed for swimming, Lasko for years had to remove it before joining. Then he had to either scoot into the water while seated, which was cumbersome, or hop to it on wet pavement, which was dangerous. In the water, he had to continue hopping on one leg or lean against the side of the pool for balance. During triathlons, his prosthesis was an anchor. His habit, therefore, was leaving it with his wife while he swam.

In 2017, swimming became easier for Lasko thanks to an amphibious device developed by Dr. Todd Goldstein, director of 3D design and innovation at New York-based health care system Northwell Health. Called The Fin, it's a V-shaped component with conical holes in it that attaches to a waterproof prosthesis. When worn by amputees, they can go seamlessly from land to sea, and can swim in a manner that physically propels them through the water.

"I have two feet on the ground now," Lasko said. "I can get in and out of the

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water safely. I can throw my kids up in the air and catch them. I just have a lot more options now."

It's not just what it does that makes The Fin special, it's also how it was made: with 3D printing.

CUSTOM CREATIONS

3D printing is a machine-based process for turning digital models into physical objects. Machines "print" items by depositing filaments — thermoplastic materials that melt when they're heated and solidify when they're cooled — in layers according to the digital blueprints they receive. The process has been used to manufacture a wide range of items — smartphone cases, shoes, musical instruments and houses.

Its cost, speed and flexibility make 3D printing especially attractive for prosthetics, orthotics and assistive devices.

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– JEN OWEN, co-founder, e-NABLE

"The problem with this field is that one size doesn't fit all, and so prosthetists hand-carve custom prosthetics and orthotics designs, which is a highly time-consuming and manual process," explained U.S. Air Force veteran David Cullen, director of applications engineering at 3D Systems, a maker of 3D printers. "3D printing has a unique digital differentiator from traditional manufacturing, especially when it comes to freedom of design," said Cullen. "Digital patient-specific designs allow for custom orthotics and prosthetics to rapidly fit each patient with better fit and functionality at a much lower cost."

Rapid customization is what attracts practitioners like Brent Wright. The prosthetist at EastPoint Prosthetics & Orthotics in Raleigh, N.C., uses a 3D Systems printer to manufacture prostheses that help limbless patients participate in activities they could not otherwise. One veteran patient, for example, is an equestrian who's missing an arm.

"He's a super technical horseback rider, and he was having trouble finding something lightweight to attach to his arm so he could hold the reins and give his horses the commands he needed to give. So we came up with something fairly wild and printed it," Wright said. "Even two years ago we wouldn't have been able to do that, and that's what excites me about 3D printing. ... We can dream up new tools to get veterans back to their pre-amputative function, and then we can actually draw them up and print them."

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Veteran Dan Lasko dives using The Fin, a V-shaped component that attaches to a waterproof prosthesis and allows him to swim.

3D printing has democratized prosthetic manufacturing, according to Jen Owen, co-founder of e-NABLE, a global volunteer network whose members create and share open-source designs for 3D-printed assistive devices. The community, whose focus is upper-limb devices, has generated designs for body-powered arms and hands, as well as task-specific tools like hand grips for carrying grocery bags and tweezers for grasping credit cards.

"With 3D printing, you can crowdsource ideas from people from all walks of life," Owen noted. "In the ecosystem of the maker community, someone can put out a request for help in designing something that is specific to them but may also help someone else with the same struggle. Within hours, they may have a potential solution created in a 3D printable file that they can then download and print out right at home. Or they can find their nearest library, school or makerspace where they can get it printed out in a matter of hours for a few dollars worth of plastic."

RANEE STOLLENWERK

Shea Stollenwerk's "Cyborg Beast" hand was created using a 3D printer in 2014.

Along with visionary prosthetists and makers, the 3D printing revolution belongs to the U.S. Departments of Defense (DOD) and Veterans Affairs (VA). Since 2013, for example, Walter Reed National Medical Center in Bethesda, Md., has been pioneering 3D-printed prostheses from its 3D Medical Applications Center (3DMAC), which every year receives more than 300 requests for various 3D-printed items, including prosthetic attachments for wounded veterans.

"We're dealing with patients in their 20s and 30s who don't just need care now, but for the next 30 to 40 years," said 3DMAC Director of Services Peter Liacouras, who has designed and printed devices for holding fishing rods, hockey sticks, toothbrushes, deodorant and smartphones, as well as devices to help wounded veterans rock climb, drive, weld, snowboard and lift weights. "It's the goal of the DOD and the VA to provide the best possible care for those who sacrifice for their

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Two hand orthoses printed on a 3D printer at the Albuquerque VA.

Stratasys J750 3D printer

Staff at the San Antonio VA are actively exploring opportunities for 3D printing to contribute to the creation of prostheses.

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country, so they can participate in any activity they did prior to being injured, or any activity they would like to try in the future."

VA: 3D-PRINTING PIONEER

Attachments and accessories are low-hanging fruit. The next frontier in 3D-printed prosthetics is sockets — the component of a prosthesis that interfaces directly with an amputee's residual limb.

For example, Wright recently designed and manufactured a 3D-printed socket for 34-year-old Marine Corps veteran Brad Lang, who lost both legs above the knee to a roadside blast in Afghanistan in 2011. Although he has conventional prostheses, he rarely uses them.

"It takes an incredible amount of energy to operate two above-the-knee prosthetics," said Lang, who was so easily fatigued and pained by his prostheses that he elected to live fulltime in a wheelchair. He decided to give prostheses another try, however, when he met Wright, who designed a 3D-printed socket tailored to Lang's situation.

"My goal of having prostheses is to be able to use them as a tool when I want to use them, but to not have to be in them all the time," said Lang, who explained that residual limbs constantly expand and contract, such that custom-fitted sockets will no longer fit him if he doesn't wear them consistently.

Wright solved that problem by designing a socket that is made of rigid carbon fiber in the front and soft, adjustable nylon in the back. "Traditional ways of manufacturing use resins and carbon fiber that are stiff all around. With 3D printing, you can make a socket that's both stiff and flexible," Wright explained. "There's ways to do that in traditional fabrication, but the sockets often end up bulkier and heavier. And the reason 3D-printed prostheses are attractive (to someone like Lang) is that they tend to be lighter and more comfortable."

Initially, just three VA medical centers were equipped with 3D printers; now 25 have them. Currently, only one printer produces sockets for amputees.

Comfort also is a principal objective at the VA, where the Veterans Health Administration (VHA) has been building and scaling its 3D-printing operation since 2017. Initially, just three VA medical centers were equipped with 3D printers; now, at least 25 have them. Currently, only one printer produces sockets for amputees: Audie L. Murphy Memorial Veterans' Hospital in San Antonio, where Chief Prosthetist/Orthotist Gordon Bosker is developing best practices that eventually will allow 3D-printed prosthetics to scale across the entire VHA system.

"If you walk hundreds and thousands and tens of thousands of steps on something that doesn't fit quite right, it can be uncomfortable," explained Dr. Beth Ripley, chair of the VHA 3D Printing Advisory Committee, who likens having an ill-fitting socket to having a pebble in one's shoe.

The only way to fix a flawed socket is to make a new one, she said, which could take days or weeks with a conventional prosthesis compared with mere hours with 3D printing. "If you find a pebble-equivalent in a socket, you can just digitally fix that on the computer and reprint it," Ripley added.

And to amputees who rely on prostheses to execute the tasks of daily living, speed is everything. "We can ... give the veteran what he needs at a much faster rate," Bosker said.

That the VA moves so quickly does as much to advance the technology as it does to help individual patients, argued Rich Garrity, president of the Americas at Stratasys, a maker of 3D printers whose machines are currently deployed inside 12 VA hospitals. "The VA from our standpoint is really pioneering 3D printing," he said. "Because they're federally funded and don't have the same constraints as a private institution, they can be really quick and nimble."

The VA promises that everything it learns about 3D printing it ultimately will share with the health care community at large.

"This is not just for the VA," Bosker said. "This is for the country."

If there's one positive thing to come out of Iraq and Afghanistan, that might be it, Lang said. "Until recently, there weren't a lot of veterans who survived with injuries like mine," he said. "Now we've got a lot of 18-, 19- and 20-year-old kids with traumatic amputations who have their whole lives ahead of them still, and that's really pushed the envelope with technology. Prosthetics have come a long way."