World’s first patient-specific jaw implant

News this month of the first titanium jaw made specific to a patient’s bone structure made a big impression on both the nontechnical and technical press. But how important is this development, and what does it mean for the future of additive manufacturing? Liz Nickels investigates...

LayerWise, headquartered in Leuven, Belgium, is a specialist in additive manufacturing (AM) in many industrial applications (complex metal articles for various industries, like semicon, food processing, chemical industry), as well as dental prostheses. The company recently revealed that it had manufactured a titanium implant that replaced an entire lower jaw. While AM has made implants for medical applications before, this is the first time the technology has made an entirely custom-built implant that fits exactly to a patient’s existing bone structure.

“Previously, patients were implanted with plates to replace bones lost to cancer or other diseases,” says Dr. Chris Turk from the additive manufacturing research group at Loughborough University in the UK. “But plates sometimes have to be replaced regularly, especially in the case of children. An implant made by AM has the advantage of porosity, meaning that it can adjust to bone ingrowth, as well as allow blood flow.”

Additive manufacturing is defined by the American Society for Testing and Materials (ASTM) as the “process of joining materials to make objects from 3D model data, usually layer upon layer,” as opposed to subtractive manufacturing methodologies, such as traditional machining. One common form of AM is laser sintering, which is accomplished by directing a high power laser at a substrate to create a melt pool. Material is then added, which enlarges the melt pool and adds to the part. To create the desired geometry, the laser is rastered across the substrate while material is continuously added.

After gaining recognition across industrial sectors, AM is increasingly being adopted in different medical fields such as dentistry, orthopaedics, maxillofacial and spinal surgery, according to Dr. ir. Peter Mercelis, managing director of LayerWise. “AM’s freedom of shape allows the most complex freeform geometries to be produced as a single part prior to surgery,” he says. “As illustrated by the lower jaw reconstruction, patient-specific implants can potentially be applied on a much wider scale than transplantation of human bone structures and soft tissues. The use of such implants yields excellent form and function, speeds up surgery and patient recovery, and reduces the risk for medical complications.”

Selective laser melting

LayerWise uses a high-precision laser to selectively heat the titanium powder particles, which then attach themselves to the previous layer without glue or binder liquid. As layers are built successively, the complex lower jaw implant structure is produced. AM can be used to print functional implant shapes that otherwise require multiple metalworking steps or even cannot be produced any other way.

“The technology used in this case is called selective laser melting,” Dr. Mercelis tells Metal Powder Report. “In this case, we built the implant starting from Ti6Al4V ELI powder material to build up the piece.”

Figure 1: Surgeons implant the titanium part.
The AM technology specialists at LayerWise printed the complex implant design incorporating the articulated joints and dedicated features, and the reconstruction was postprocessed with dental suprastructure provisions, polished joint surfaces and a bioceramic coating. The implant structure was then coated with a hydroxylapatite bioceramic coating by Cam Bioceramics BV, based in the Netherlands. Hydroxylapatite, also called hydroxyapatite (HA), is a naturally occurring mineral form of calcium apatite with the formula Ca₅(PO₄)₃(OH).

The patient in this case suffered from progressive osteomyelitis of almost the entire lower jawbone. The implant featured dimples to increase the surface area, cavities promoting muscle attachment, and sleeves to lead mandible nerves. The mandible implant is equipped to directly insert dental bar and/or bridge implant suprastructures at a later stage. The surgery took less than four hours at the Orbis Medisch Centrum in Sittard-Geleen. Shortly after waking up from the anesthetics, the patient spoke a few words, and the day after the patient was able to speak and swallow normally again. The implant also restored the patient’s facial aesthetics.

“AM is not cheap,” adds Dr. Turk, “but it can add value by reducing waste streams and the weight of the part, which is particularly important for the aerospace industry. Companies such as Boeing, Rolls-Royce and GE have all shown interest in using AM for their complicated structural parts.”

**What this means for metal powder**

The impact on metal powder production is, however, still in doubt. “Typical AM parts, in general terms, consume only little metal powder due to their limited material volume,” admits Dr. Mercelis. “However, AM technology has been used in the past to replace local bone defects or to repair fracture bones, so it is not so that AM has never been used before to make a medical implant.”

Mercelis adds that other implants with large potential for AM are orthopedic implants (hips, knees, shoulders, etc.), skull plates, spinal implants, and various types of dental prostheses. Besides the type of implants, functionality is important. “AM will facilitate designing and developing more complex implants with increased functionality,” he says. “One of the hot topics in this sense is the combination of AM technology with tissue engineering.”

Dr. Turk agrees. “Over the next ten years, I foresee a big growth in AM for medical on a case by case basis, depending on the trauma. In 10 years, it will be the norm for patients requiring a customised implant to receive one made by AM.”

As for applications beyond the medical, both Dr. Mercelis and Dr. Turk recognize growth in areas already benefiting from AM technology, such as aerospace and tooling. “Medical implants have a large potential for AM technology, but general industrial applications may be even larger,” Dr. Mercelis says. “We are talking about complex shaped metal components for a large variety of applications – low weight components for aerospace industry, complex machine components, complex tools, etc. Industries with potential are complex machinery – ICT, food and beverage, textile, pharmaceutical, etc. – aerospace and industrial tooling.”
advance is the use of bio-absorbable polymers, which are slowly absorbed into the patient’s body after implantation, allowing organic matter to re-grow and reducing the need to remove implants.”

The titanium total lower jaw implant reconstruction was developed in collaboration with project partners from medical industries and academia, including the Biomed research group of the University Hasselt, Belgium, in collaboration with engineers from the Xios Hogeschool, also in Belgium, Xilloc Medical BV in the Netherlands and University Leuven and maxillofacial surgeons from the Orbis Medisch Centrum Sittard-Geleen. The implant has won the 2012 AM-Award by the Additive Manufacturing Network in Belgium with support from Sirris and research and policy specialist Vito.

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Figure 4: Adding the hydroxylapatite bioceramic coating.

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