

3D Printed Ceramics Serve As Both Bone Graft and Support

By Stephanie Hendrixson



3D-printed ceramics can supply a replacement for bone graft and support structures. This proof-of-concept example from Lithoz actually combines both, with a bioresorbable bone scaffold inside and a stiff outer cage for stability.

bone. Bioceramics such as tricalcium phosphate (TCP) are gaining ground, and developments in the 3D printing of these materials are pointing the way toward future implants that can be customized to each individual's anatomy, while eliminating secondary surgeries, reducing the time spent in the operating room and leading to a better patient experience.

One company currently exploring the realm of 3D-printed artificial bone is Lithoz, a developer of 3D printers and materials based in Austria. The company's Lithography-based Ceramic Manufacturing (LCM) technology and CeraFab 3D printer have been applied to ceramics such as TCP, magnesia, porcelain and zirconia. The LCM process is a digital light processing (DLP) printing technique that uses light to selectively cure a slurry of polymer resin filled with a secondary, powdered material into a green part.

"The green body is a composite consisting of the polymerized photoresin with interspersed ceramic particles," explains Daniel Bomze, head of the medical business unit at Lithoz. After the green part is cleaned of excess slurry, it is placed into a furnace to burn away the photoresin binder and achieve its final ceramic part properties. "The sintering process ensures that we will end up with the classic ceramic properties — for example, high hardness, high strength and wear, and smooth surfaces," Bomze says.

But for bone graft replacement, a material like TCP serves a somewhat different purpose; rather than strength and hardness, the material's advantage is biocompatibility and resorbability. TCP resembles the inorganic content of natural bone and can be used as a temporary solution to facilitate the regeneration of the

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Bioceramics for Bone Replacement: The Cool Parts Show S3E2

Co-host Peter Zelinski and I discuss this proof-of-concept, dual-material jaw implant on The Cool Parts Show, as part of the show's third season. Watch the episode at gbm.media/bioceramic



The jaw implant example is a dual-material implant that combines a zirconia cage for stability plus tricalcium phosphate bone graft inserts. The different materials are printed separately and then assembled together. Photo: Lithoz

patient's own bone tissue. As this regeneration happens, the TCP implant will eventually dissolve away to complete the healing process.

Powdered TCP is used in conventional surgeries, where it is mixed into a paste with the patient's own blood and applied to the injured area by hand. But the ability to 3D print the material into a solid form provides new benefits. The implant can be made to exactly the right size and shape needed based on 3D data from a CT scan or MRI; this means less handwork for the surgeon and reduced time in the operating room. 3D printing also enables the incorporation of design features to facilitate and encourage bone in-growth, such as lattices and surface roughness that provide anchors for the native bone. Although TCP lattice structures are not meant to be durable over the long term, they can provide enough stability to allow delicate regions of the body such as cheek bones or eye sockets to heal on their own.

But 3D printing a bone graft replacement solves only part of the problem for many surgeries. Human bone is composed of both cortical tissue that forms a hard exterior and the sponge-like cancellous bone in the interior. TCP is a replacement for the cancellous bone only; for areas such as a jaw, it is also necessary to replace or augment the cortical bone.

Historically, this has meant the use of implants made from materials such as titanium and PEEK that provide stiffness and strength. But 3D printed ceramics now offer another solution, one that can be used in conjunction with artificial printed bone replacement.

Lithoz researchers have developed a proof-of-concept solution for jawbone reconstruction, a mandibular cage implant that combines the resorbable TCP bone graft replacement and a rigid outer cage made from a different bioceramic: zirconia. The hybrid solution is made in three parts, the zirconia cage and two TCP inserts that can be inserted into the cage's geometry. The resulting implant would provide both the stability and bone in-growth needed to help a patient's jaw heal. The zirconia cage can remain in place permanently while the TCP interior dissolves over time.

"By combining a very high strength, very rigid material to give proper stability during the healing phase, in this case the zirconia cage, and a bioresorbable material that helps the body to form new healthy bone, in this case, tricalcium phosphate, we combine solutions from the best of two worlds," Bomze says.

(Why not print the assembly complete? The sintering process is different for both feedstocks, and it would be more difficult to guarantee quality if they were to be sintered together, Bomze says. The shrinkage of the green ceramic part in sintering can be between 25 and 30%, and is dependent on each material. For now, the best results can be achieved by building the two portions individually and combining them.)

No patients have yet been treated with Lithoz's dual-material implant. However, both TCP and zirconia are already safely used for other kinds of implants, and there is at least one ongoing study using 3D-printed TCP implants alone in nonload-bearing scenarios that has so far been successful. But the real promise of LCM and dual-material implants is the ability to customize them to the patient's own anatomy. Down the road, Lithoz hopes to equip medical manufacturers and the surgeons they work with to be able to build exactly the zirconia cage needed and precisely the TCP lattice that will fit inside, using CT scan or MRI data. Even if this literal jaw configuration is never used in a patient, Bomze and his fellow researchers believe in it as an effective case study.

"We want to make people think about the possibilities that come with LCM technology, and about solutions for their problems which are now possible with Lithography-based Ceramic Manufacturing," he says. **AM**