Summary of ß-TCP Manufacturing and Experimentation as a Bone Graft Material

The necessity of bone grafts for traumatic injuries presents a challenging problem of where to source the bone for the operation. Currently autologous bone grafts are the medical standard, in which a section of healthy bone is removed from another area of the body and transplanted into the damaged area. While this is a satisfactory solution, it requires multiple surgeries, and only limited material can be obtained. Currently being researched and utilized are ß- Tricalcium Phosphates (ß-TCP). This is a bioactive ceramic material which is ideal for bone grafts thanks to its ability for bone to regeneration around the ß-TCP structure.

Manufacturing parts with ß-TCP can prove to be tricky as the parts for bone grafts require intricate micro scaffolds. Designing these parts requiring precision to the micrometer level. The journal follows the manufacturing and testing of multiple scaffolds using a lithography-based ceramic manufacturing (LCM) process. LCM is a form of digital light processing (DLP). Commonly these scaffolds are manufactured with a powdered 3D printing process. This process is relatively simple but lacks the necessary microlevel precision LCM can produce.

Three sets cylindrical lattice structures were designed. These being cubic, octahedron, and hexagonal as shown in figure 1. The cylinders had a diameter of 4.5 millimeters and had varying pore sizes. The pore sizes tested were 200, 400, 600, and 800 micrometers. The cylinders were denoted with their shape and pore size C400/O600/H800. The first letter denotes the lattice shape, and the number is the pore size. The scaffolds were produced using a Lithoz Cerafab7500, and a slurry called LithaBone TCP 300. This slurry has a base of ß-TCP with a purity greater than 95%. This material is currently used to make bone graft implants as it will be absorbed into the body as bone grows around it.

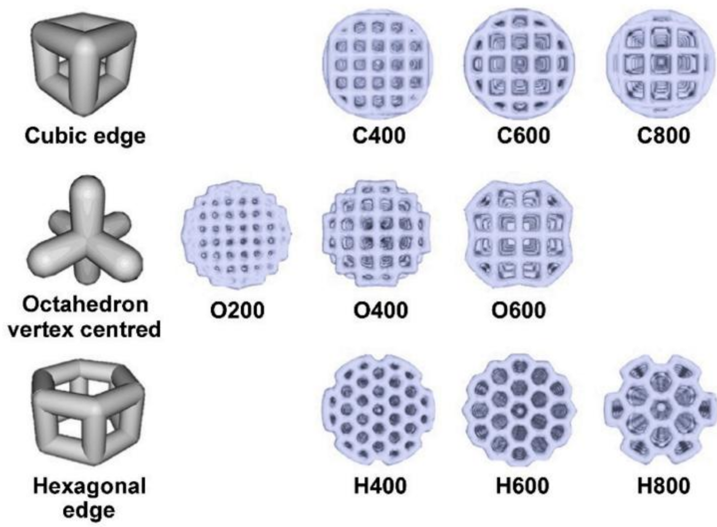

Fig 1. Design of lattice structures.

After the parts were produced, they were then put through a drying, debinding, and sintering process. This heat treatment cycle lasts around 90 hours. This process required the specimens to reach a hold temperature of 1200°C. Reaching this temperature causes the ß-TCP to become a pure sample of ß-TCP. The heating process causes mechanical issues such as shrinkage and cracks formed within the part. On average the cylinders shrunk 17%. During this shrinkage fractures occur within the material, and nanometer micro porosities also become present.

Mechanical testing consisted of a Zwick/Roell Z005 performing a compression test. Inserted into the machine was a 2.5 kilonewton load cell which detected 3 newton changes in force. Software aligned the loadcell and a preload step was performed to have the specimen contact the load cell. A preload of 2 newtons was held for 10 seconds before more compression, then specimens were subjected to additional compressive forces until failure.

During the compressive tests a relation between porosity and compressive strength was analyzed as shown in figure 2. Observed was an increase in compressive strength as porosity decreased. Furthermore, these relationships in porosity to compressive strength when compared to separate types of bone found that porosities greater than 30% performed similar to cancellous bone, and in some cases had greater compressive strength.

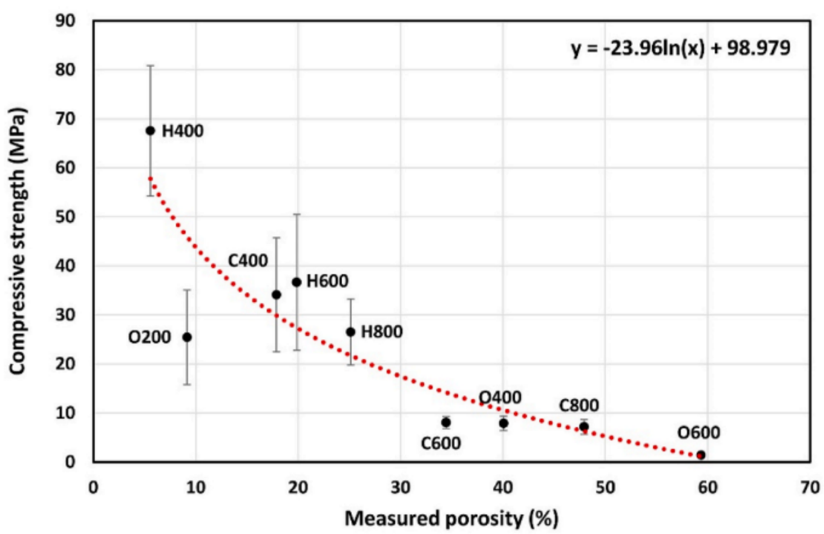

Fig 2. Specimens graphed with a logarithmic trendline of Compressive strengths versus porosity.

In conclusion the ß-TCP structures were deemed to be ideal for smaller bone grafts, and that there is a large potential for the technology to progress and make much more precise specimens that can be adequate for medical use.

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