Hyperelastic Bone

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Hyperelastic bone is the term created to describe a form of 3D-printed, fast-drying, synthetic bone graft produced at Northwestern University. The Hyperelastic Bone can be 3D-printed at room temperature using a mixture of solvents. Once implanted into the body, it integrates with the body's natural systems to naturally regenerate the bone.

I. Introduction

When patients have genetic or experiential bone damage beyond normal repair, bone grafts are often used to help during the regenerative process. However, bone grafting is a highly invasive way to fix complex fractures and usually requires bone to be taken from other areas of the patient's body, mainly in the iliac crest region. Another way to fix complex fractures or genetic bone disorders are with osteoregenerative biomaterials. However, until recently these are often expensive, and the repair is slow. In addition, there is limited manufacturing capacity, because these are grown and have to made made to fit a specific person. Recently, a new 3D-printed synthetic bone replacement has been created called hyperelastic bone that minimizes all the limitations of previous osteoregenerative biomaterials.

II. Methods

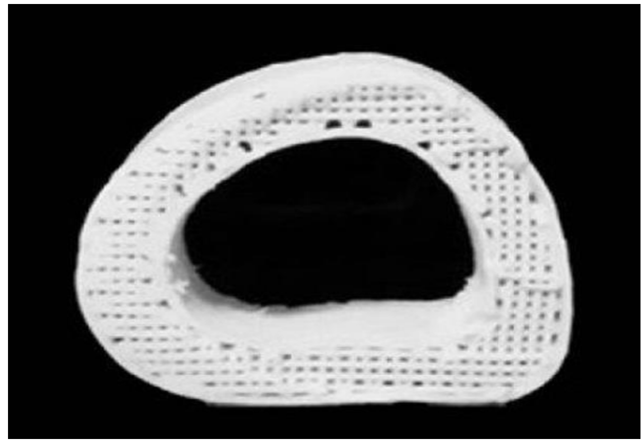
The hyperelastic bone is 3D-printed from a liquid "ink" that consists of 90% hydroxyapatite and 10% polycaprolactone. The hydroxyapatite is a common bone regenerative material used in similar grafting and bone replacing practices. The polycaprolactone is a polymer that is used in order to make the new compound able to 3D-print. The 3D-bioplotter by EnvisionTEC is the 3D-printer used in the process because it uses a solvent based printing technique that can be used at room temperature with quick-drying results. However, each layer does not dry immediately so each layer that is printed is able to adhere to the layer that came before it, making the overall structure more stable. The hyperelastic bones are printed in a weave pattern that allow open space within and add to its ductility.

III. Results

Once the hyperelastic bone is made it is strong and flexible. It has a 32-67% strain to failure, a 4-11% MPa elastic modulus, and a 50% material porosity. The strain to failure measured during testing means that based on the different bone shapes and designs that have been used thus far, the hyperelastic bones will warp an additional 32-67% from its original size. The hyperelastic bones have a relatively low elastic modulus meaning that it takes a large amount of force to warp the shape a little amount. In addition, 50% porosity means that the bones are half empty space.

IV. Discussion

Overall the design seems to show great promise. It is light, strong, flexible, and most importantly it is not brittle. This is



important because during implantation, surgeons can easily cut off pieces of the hyperelastic bone without breaking it in order to make the bone more custom fit to the individual who will host it. Besides the synthetic bone's resilience, it also integrates well into the host's body. Once implanted, it is quickly vascularized, integrated with surrounding tissue, and ossified to help restore natural bone growth. Also, during testing, the hyperelastic bone was not once reject by the immune system of any animal. The porosity of the design is important. The weave pattern that the bone is printed in allows for natural materials in the body to enter and treat the bone as it is a real one. They will grow bone around and within the artificial one until the printed version natural biodegrades within the body over time. One major advantage of hyperelastic bones is the low cost. The 3D-printer used is a relatively cheap, commercially available one that can be used in a normal, room temperature environment. The only additional cost is for the materials and solvents. Also, the bone shape and size can be redesigned for individuals of different shape and size. The hyperelastic bones are printed relatively quickly and can be implanted almost immediately after finishing printing. There are seemingly very few disadvantages of this practice, as it has been used in animal test studies successfully. However, the product is very early in development and needs additional testing before it can be used in human studies.

References

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