Using CAD to create Patient Specific 3D Printed Bone Scaffolds

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Introduction

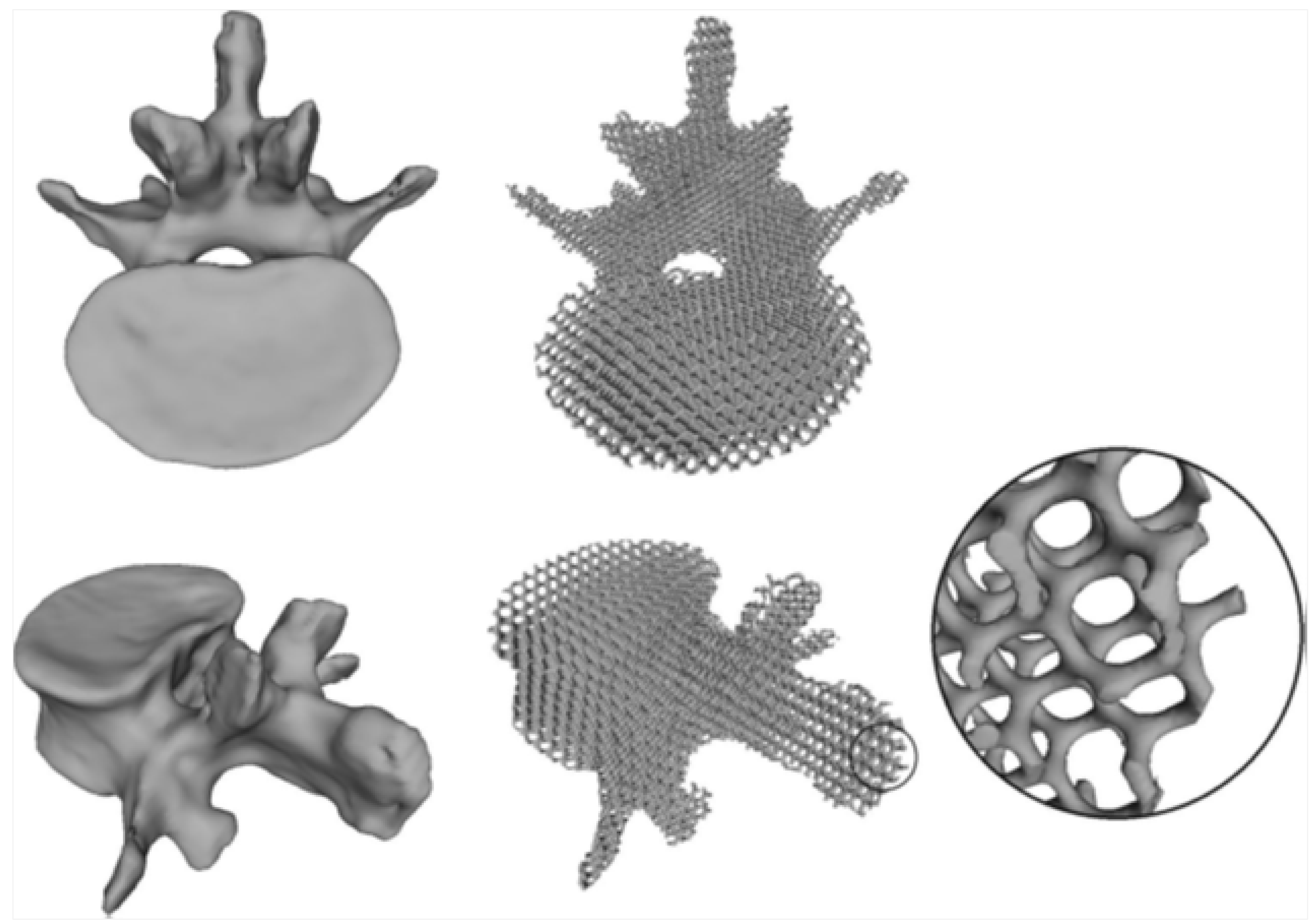
There are several reasons to design the geometry of porous spaces in tissue engineered scaffolds that will be 3D printed in resorbable polymer. First, the pore geometry facilitates cell seeding on the surface. Second, the pore geometry guides the infusion of new (regenerative) tissue into the scaffold. Third, the design of the pores and the material between them will control the timing and nature of the scaffold's resorption. Our laboratory has implemented a gyroid structure (Schoen's gyroid) MATLAB (MathWorks, Natick, MA). The program fails at high resolution for high levels of porosity (i.e., porosity is the percent of the scaffold filled with air [pore] space). By converting this algorithm from MATLAB IML (Interactive Matrix Language) to a Visual Studio (Microsoft, Redmond, WA) C# class I will be able to make the program more reliable and run it in a more powerful visualization environment, Amira (Thermo Fisher Scientific, Waltham, MA). I expect that we will then be able to create a scaffold of any shape with the gyroid porosity of any desirable level by specifying strut diameter, pore size, and surface area instead. Surface area is a critical parameter because the lab hypothesizes it controls resorption of the scaffold.
The first step of the conversion process was to take the high level MATLAB code that had been used and translate it to C#, which is what AMIRA uses. At that point the code could be made to be more easily updated, such as improving the memory handling and the surface topology of the shapes that it outputs. Next, the goal is to use Amira to visually overlay the selected porosity and tissue engineered implant shapes.

Aim

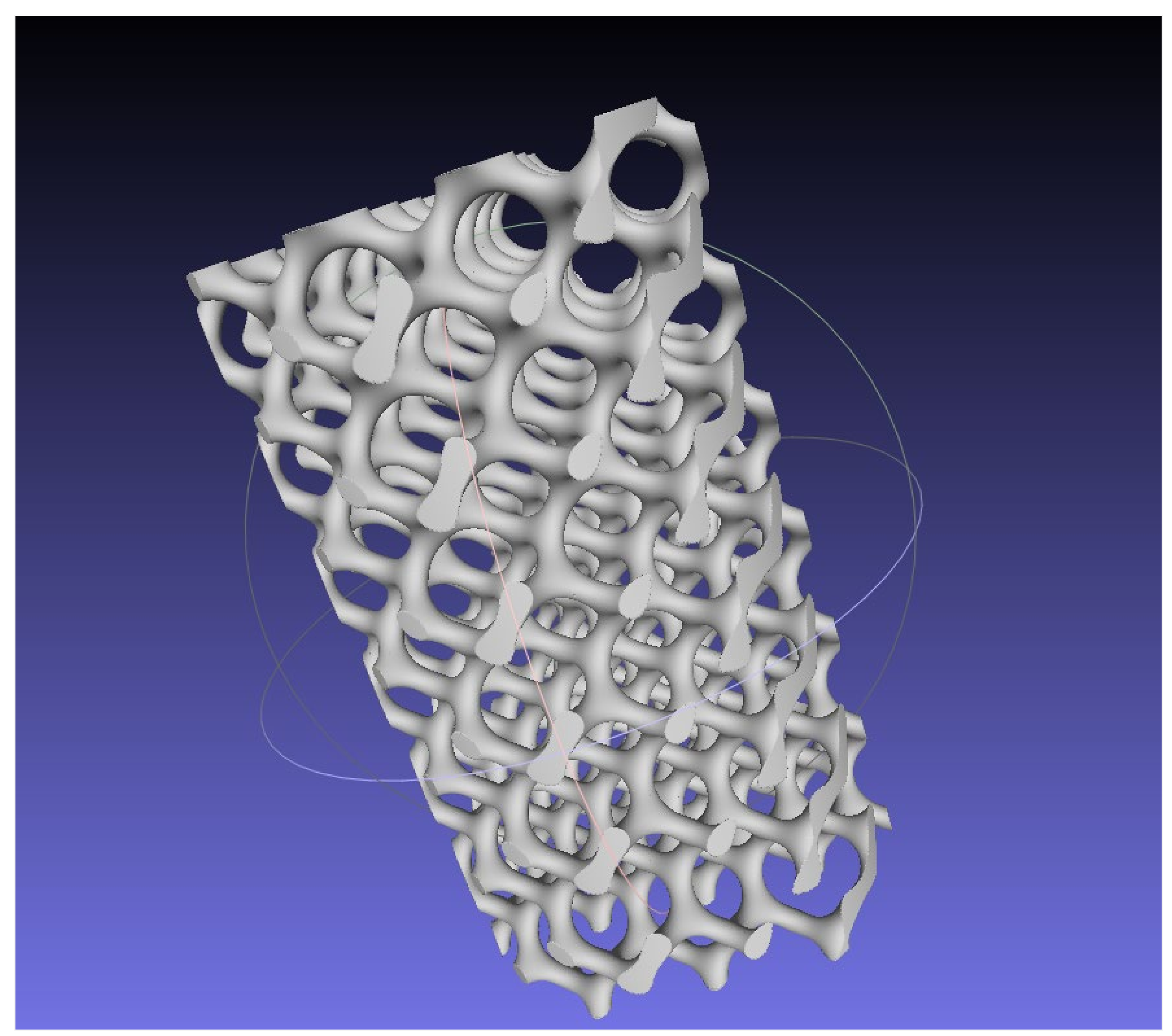
The aim of this project is to create a program that will be able to take CT scans from patients and create a stereolithography file of the gyroid pore geometry bone scaffold with patient specific porosity, which can then be 3D printed.

Methods

The first step was to solve the problem with the MATLAB code, where the program would start to crash after getting to scaffolds of a certain size. The next step was to translate the program into C#, so that the program could be used with AMIRA. After translation, work needed to be done to apply the pore geometry to the patient scans.



End Goal: Being able to apply the pore geometry to specific bone defects in order to help patients recover.



This is an example of the scaffolds we have created in the lab, that are used for testing purposes in other research, like resorption.

Results

The process to create a final program that could accomplish all the tasks ran into a few problems. Although the MATLAB code was fixed so that scaffolds could be made in much larger sizes, the remaining steps proved to be difficult. After translating the code from MATLAB into C#, the program would not create the same structure in Visual studio as it did in MATLAB. After some further digging, it was found that there was more complicated code that was missing that needed to be translated as well. It was then decided to first try and overlay two stereolithography files, one with the shape of the bone defect and one with the pore geometry, to create a single stereolithography file of the bone defect with the gyroid geometry. After using multiple different kinds of software, a way to overlay the images could still not be found. AMIRA was then used to see if a custom module could be created to accomplish this task. Unfortunately, this did not work either.

Conclusion

The process to create a final program that could accomplish all the tasks ran into a few problems. Although the MATLAB code was fixed so that scaffolds could be made in much larger sizes, the remaining steps proved to be difficult. After translating the code from MATLAB into C#, the program would not create the same structure in Visual studio as it did in MATLAB. After some further digging, it was found that there was more complicated code that was missing that needed to be translated as well. It was then decided to first try and overlay two stereolithography files, one with the shape of the bone defect and one with the pore geometry, to create a single stereolithography file of the bone defect with the gyroid geometry. After using multiple different kinds of software, a way to overlay the images could still not be found. AMIRA was then used to see if a custom module could be created to accomplish this task. Unfortunately, this did not work either.