Bone Fracture Repair: Testing Porous Properties of Calcium Phosphate Bioactive Cement and How it Compares to Pig Bone

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Abstract

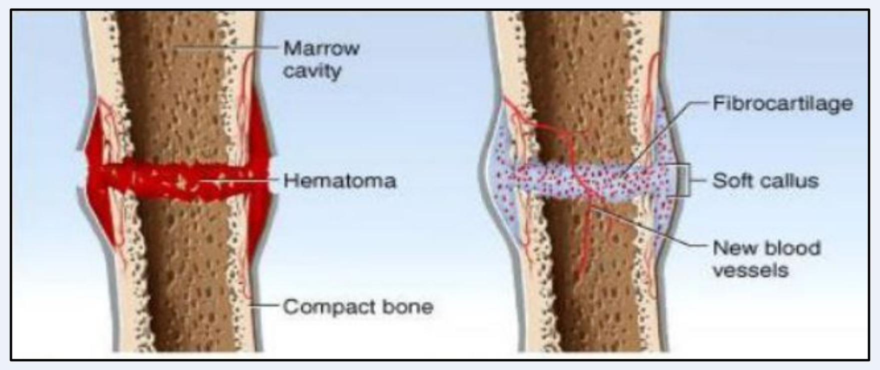
Autografting is the most effective method used for supplementing and replacing bone. Autografting is a risky procedure because of its invasive nature. When performing the procedure of autografting, one needs to remove small sections of bone to use as a stimulant at the fracture site. This study is made to design an alternative method to replace autografting. In our study, we used pig fibula as a model to compare the properties of our novel cement which is Calcium Phosphate based. Calcium Phosphate Cement (CPC) is ideal because it is a biocompatible bone substitute composed of hydroxyapatite (HA), which constitutes a major component of human bone. The hydroxyapatite will serve as the base ingredient for the cement. The cement allows for the successful osseointegration and the initiation of bone growth. We focus our efforts into understanding and finding a consistent porosity size between the bone and the cement. This will be done by using different concentrations of chitosan and sodium bicarbonate. Results of the experiment show that the sample most similar to the bone sample was the chitosan.

Objectives

Fractures can only heal under certain conditions such as, a proper cellular environment, a porous matrix and mechanical strength[1]. This study introduces a chemically modified Calcium Phosphate Cement (CPC) which is a bone substitute that replace the need of an autograft[2]. Hydroxyapatite based cement will be used in this project as a bone substitute because of its ability to form a moldable cement, along with it being naturally found in human bone[1].

The goal of this study is to attempt to create a system that satisfies all of the conditions needed for proper union with the use of a cement polymer/resin system. Chitosan, sodium bicarbonate, and hydroxyapatite are materials that have qualities that may increase the rate of the healing process. Chitosan has qualities that interlock and form pores in the cement that show porosity similar to pig bone[3].

Pores in calcium phosphate materials are necessary for bone tissue formation because they allow migration and proliferation of osteoblasts and are expected to enhance osteogenesis. Different concentrations of chitosan and sodium bicarbonate sample cements will be examined to take a closer look at how porosity and pore size works to increase the rate of the healing process during bone formation.



Materials & Methods

I. Preparation of the Pig Fibula

Pig fibula was obtained, being most similar to bone, and boiled to remove bacteria and set to dry. Bone samples were made by sawing and sanding to 11mm in length and 0.5 mm in height.

Figure 1: Pig fibula bone at 11mm.

II. Synthesis of Sodium Bicarbonate-Hydroxyapatite Cement

Three cement samples were made at 20% sodium bicarbonate mixed with hydroxyapatite, distilled water and dental solvent. These samples were then dried overnight and modified to fit on SEM mounting.

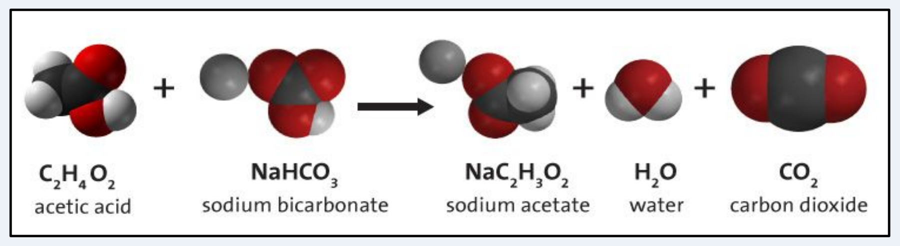


Figure 1: Equation of sodium bicarbonate combined with acetic acid

III. Synthesis of Chitosan-Hydroxyapatite Cement

Five cement samples of 5%, 10%, 15% 20% chitosan cement samples mixing hydroxyapatite, distilled water and 1% (w/w) citric acid. Similarly to the previous procedure, the samples were dried overnight and modified to be mounted for SEM

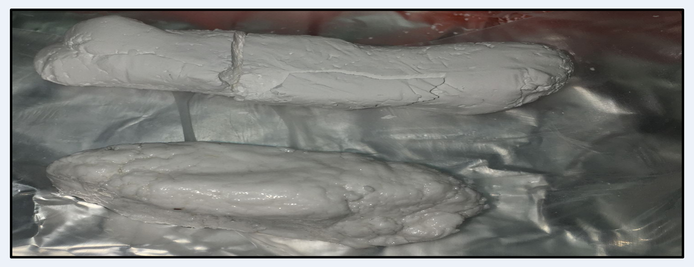


Figure 2: (Top) Chitosan cement sample completely dried, (Bottom) Chitosan cement sample still drying

IV. SEM Images of Cement Samples

The cross-section of the cements, Sodium bicarbonate and Chitosan, were mounted. The scanning electron microscope was able to capture images of the cement and pore sizes were able to be analyzed.

Results

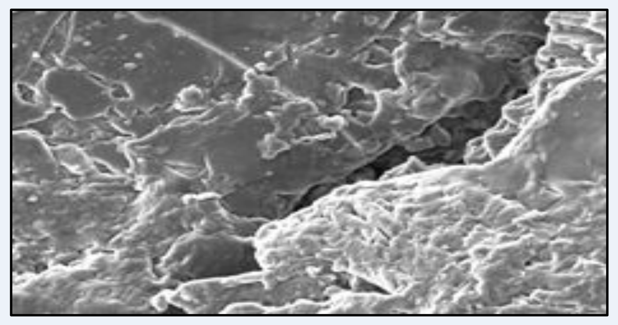


Figure 4a: Chitin

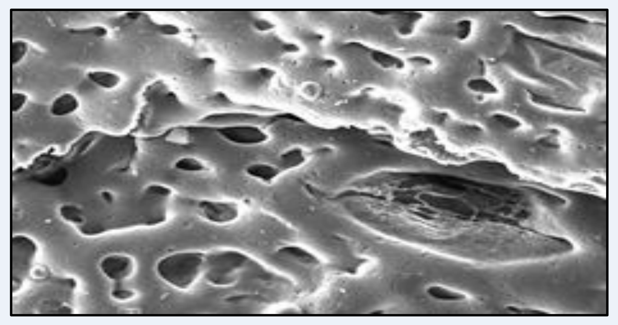


Figure 4b: Chitosan, a chitin derivative

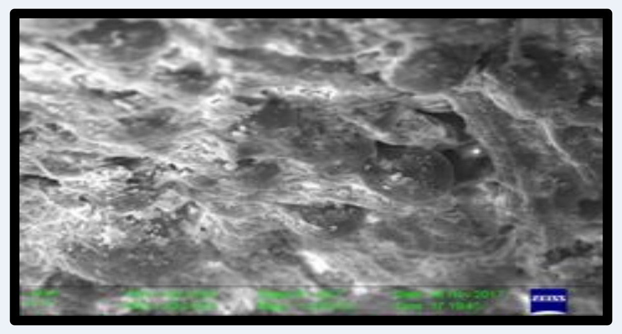


Figure 5a: Sodium Bicarbonate (3.05kx magnification)

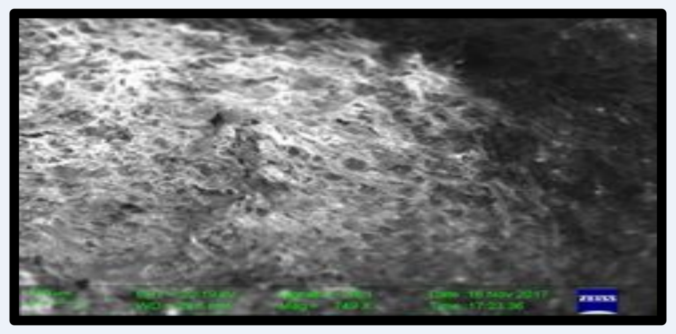


Figure 5b: Sodium Bicarbonate (749x magnification)

Conclusion

Samples of chitosan and sodium bicarbonate cements were used in experiments to test for a porosity similar to bone. From the sodium bicarbonate samples, (Figure 5a) using the bone sample as the standard comparison for all pore sizes, it was determined that the most similar pore size at magnification of 200x was hydroxyapatite. The standard pore size of the bone at 200x was 10 m and with hydroxyapatite was 6 m. The significance of this finding shows that using more hydroxyapatite in the cement sample can increase the size of the pores and produce a more adequate sample that allows for a more integrative environment in which bone-inducing cells can move across these pores to speed up the normal bone healing process.

SEM results showed a coarse surface structure that resulted from the experimental chemical being cross-linked to hydroxyapatite during the growth process. This may provide a conducive condition for adhesion and growth of biological tissues.

Porous hydroxyapatite is safe, reliable, and biocompatible for use in the host. Previous studies report that porosity, combined with a bioactive material, such as HA, can have a synergic effect and may contribute to improvements in material colonization by cells.

Future Directions

An important feature of the bioactive cement is its viscosity. Viscosity of the cement in its liquid form will determine its injectability through a syringe and possible delivery methods. Future directions can include looking into biodegradable oils as they can reduce the viscosity of the cement and make it more fluid. Higher injectability can lead to less invasive procedures and completely eliminate the surgery aspect when dealing with serious bone fractures. Different biodegradable oils and amounts can be studied in the fabrication process of the cement leading to many opportunities to further enhance the effectiveness of the bioactive cement.[7]

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