Biological Implications of Hydroxyapatite Coatings on Manufactured Titanium Implants

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Introduction

Titanium is a common metal for orthopedic applications due to its biocompatibility and capability to withstand the pressure and weight that exist within the skeletal system. Through the ability to 3D print titanium, medical providers can manufacture customizable implants. Biocompatibility may be increased through different surface manipulations.

Hydroxyapatite (HA) is an inorganic compound that is naturally occurring in the body. It is one of the main surfaces that osteoblasts interact with in the body. Tests have shown that a coating of HA on other types of surfaces gives a more favorable environment for osteoblast growth (Tazi, Zhang, Messaddeq, 2012).

This test was designed to determine how osteoblast cells interact with and grow on 3D printed titanium disks that have been coated with HA and compare the results to osteoblast cell interaction and growth on uncoated titanium disks. The study employed the use of 3D printed titanium disks (Tangible Solutions, LLC) which had a printed surface roughness. Half of the disks were coated with HA through electrochemical deposition. These disks were then used in a 4-day cell growth trial.

Objectives

This study looked at two metrics with regard to osteoblast interactions with coated and uncoated titanium disks.

1. Cell count after a 4-day cell growth trial
2. Cell viability after a 4-day cell growth trial

Experimental Method

Electrochemical deposition was used to coat the 3D printed titanium disks which had a surface roughness that was selected based on data from a previous experiment which showed this roughness to be best for cell growth (Seman, S., Trautman, G., Southwell, J., Rotello, R., & Norman, T., 2021).

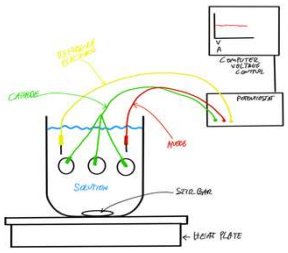

Figure 1. Electrodeposition Experiment Set-Up

Electrochemical deposition drives the chemical reaction of ammonium hydrogen phosphate dibasic and calcium nitrate tetrahydrate to form hydroxyapatite. An open glass cell and a three lead potentiostat were used. An anode was placed into the solution. This caused the HA to adhere to the cathode, thereby coating the titanium disk (Isa, Mohd, & Yury, 2012).

Two four-day osteoblast growth trials were performed which used five control and five HA-coated titanium disks each, making an n of 10 for the total experiment. The disks were placed into a 12 well culture plate, and each disk was seeded with 15,000 cells.

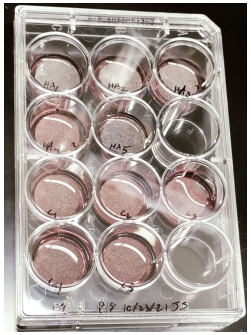

Figure 2. First 4-Day Cell Culture Trial

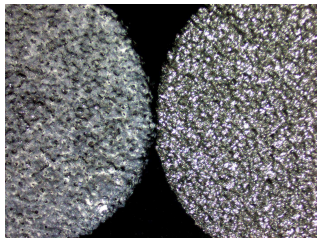

Figure 2. HA Coated Titanium Disk Left, Uncoated Titanium Disk Right

The culture plates were placed into the incubator for four days. The cells were observed daily over the duration of the experiment, and the media was changed as needed. After 4 days, the cells were removed from the implants and counted using the CytoSmart Automated Hemocytometer. The cell count from each disk as well as the viability of the cells from each disk were recorded. Data was analyzed using the Tukey-Kramer method of analysis.

Experimental Results

Results from the cell count portion of the experiment showed that the mean of the hydroxyapatite group was not significantly greater than the control group ($p=0.83$). In addition, cell viability of the hydroxyapatite group was also not significantly different than the control group ($p=0.31$).

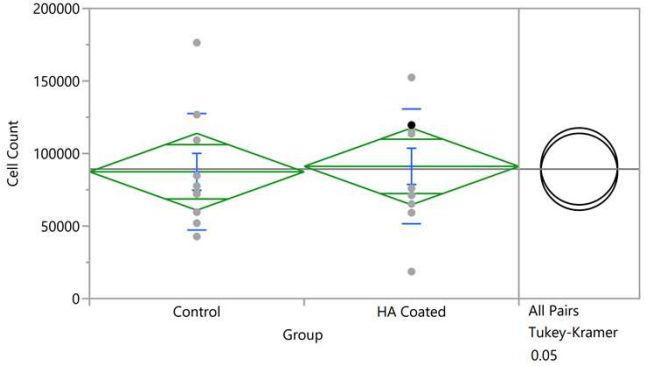

Figure 3. Analysis of Cell Count by Group

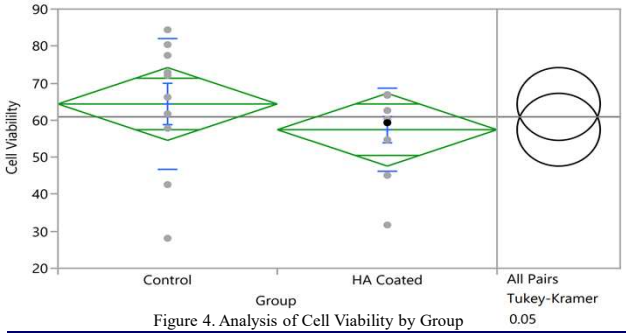

Figure 4. Analysis of Cell Viability by Group

Discussion

This data was unexpected but may be due to a change in the surface roughness between the two groups caused by the hydroxyapatite coating decreasing the surface roughness. The surface roughness selected for the experiment was specimen I, chosen due to it being the most ideal for osteoblast growth (highest mean on graph.) Any slightly less rough surfaces were shown to be less ideal for osteoblast cell growth (Cedarville University Senior Design Report, April, 2021).

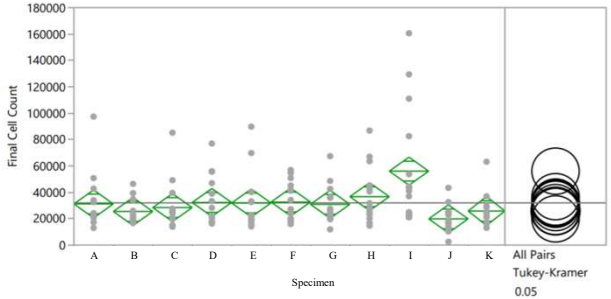

Figure 5. Analysis of Cell Count by Surface Roughness (Cedarville University Seinor Design Report, April, 2021)

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