Cell interaction with nanomaterials for medical device applications

SCHOOL OF BIOMEDICAL ENGINEERING
COLORADO STATE UNIVERSITY

WALTER SCOTT, JR. COLLEGE OF ENGINEERING
COLORADO STATE UNIVERSITY

Richard Morales-Villalva, Prof. Popat, Roberta Maia Sabino

Department of Department of Mechanical Engineering/School of Biomedical Engineering.

Colorado State University, Fort Collins, CO, USA

Background/Introduction/Motivation

In this project, over many years many researchers in the medical industry have tried to find materials for implants that not only are safer but also better than the ones already in the market, the aim is to make biomaterials that are safer and more effective for implants and in this research project a surface modification strategy using natural biopolymers on titanium is proposed to improve bone healing and promote rapid and successful osseointegration of orthopedic implants.

This research is being done to improve bone healing and promote rapid and successful osseointegration of orthopedic implants and another part of the research we do is testing hemocompatibility of blood-contacting medical devices to be able to prevent device failures.

The problems that our research aims to fix are, titanium implant failures due to non successful osseointegration to then reduce revision surgeries. One of the other problems we are working to solve is blood compatibility and blood clotting by developing hemocompatible surfaces.

Methods/Experimental Setup

In this project, TA-based PEMs on NT were fabricated by first changing the surface topography of titanium to make titania nanotubes. We then scanned these and (fig 2) is how the nanotubes look like under SEM. We also must test hydrophobicity and whether they are hydrophilic or hydrophobic surfaces, and we do this by measuring contact angles.

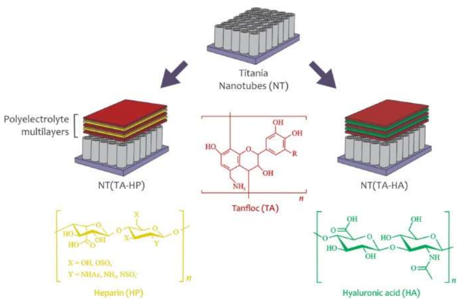

Figure 1. Schematic of PEM fabrication on titania NT and the polyelectrolyte structures

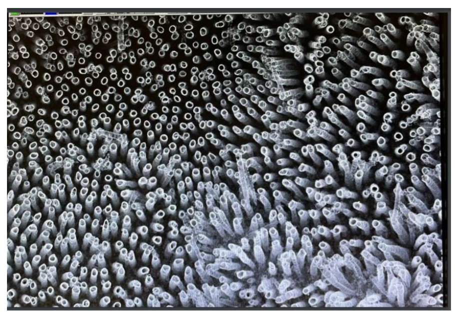

Figure 2. Representative SEM images of NT surfaces before and after modification with PEMs. The images were taken at 10,000× magnification.

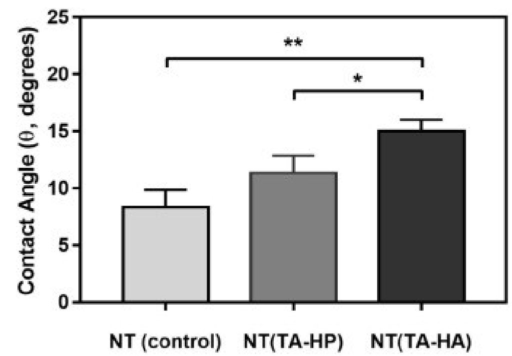

Figure 3. Water contact angles for different surfaces

Results

Our results showed us that the TA/HP PEMs on NT significantly improve osteogenic differentiation of ADSCs and bone mineral deposition compared to unmodified NT, indicating potential for enhanced osseointegration.

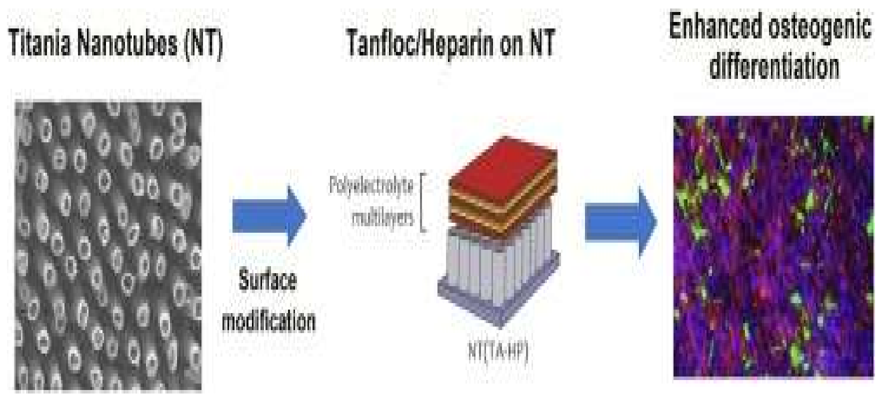

Figure 4. This is a simpler model of what the titanium goes through

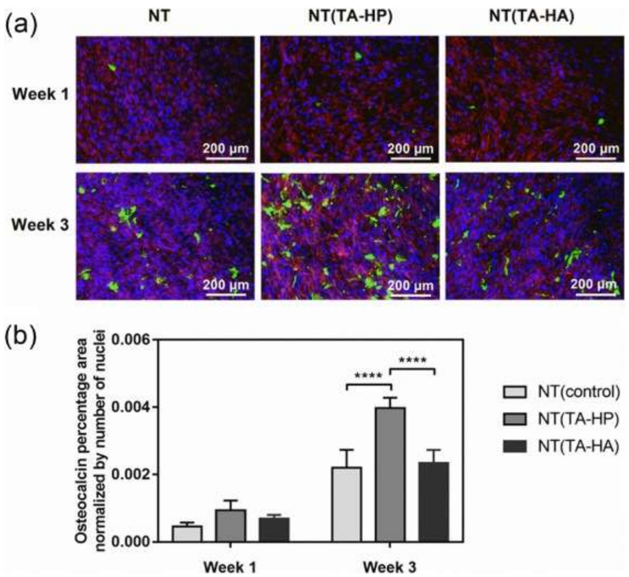

Figure 5. In part (a) these are ImageJ pictures, and the green represents osteocalcin In part (b) we can see that the percentage area of osteocalcin increased and got significantly higher than week 1.

Discussion/Next Steps

Since this research isn't over and we need to keep testing the titanium-based biomaterials and since the surfaces are still in the early stages and they may improve osseointegration of implants we still need to do more tests in order to be able to then start trails to test these new titanium implants and then one day, be able integrate these into implants that people get all the time for orthopedic surgeries.

Conclusions

From the work done during the research, TA/polysaccharide PEMs were prepared on titania NT to improve cell behaviors associated with osseointegration on titanium implants. The NT surfaces were successfully modified and were able to be stable in phosphate exposure. The other NT surfaces modified with the TA/HP PEMs showed enhanced osteoinductivity toward human ADSCs. By modifying these two titania NT we show that with the TA/HP can promote stem cell differentiation and they can improve osseointegration of implants and reduce the risk of implants failing.

What benefits did you get from you SURE experience?

The SURE experience gave me the opportunity to do research my first year which is something not many first-year college students get to do. I was able to be in a lab for the first time ever which was an experience I will never forget and the moment that I put that white coat on I feel as though I had made it. Being in the lab and doing research work in a field that I am currently majoring in was a great opportunity to see if I really wanted to major in biomedical engineering and I can proudly say I do want to major in this. I have learned many skills that I can transfer to other research projects and can say that I have experience working in a lab. Being apart of SURE I now have been able to make connections with faculty to be able to continue the research I am doing and find other research opportunities here at CSU. Financially the SURE program did support me, and it let me worry less about my financials during the semester. This program opened the doors of research for me and now I have the tools and knowledge to continue doing research.

References & Acknowledgements

“Polyelectrolyte Multilayers Containing a Tannin Derivative Polyphenol Improve Blood Compatibility through Interactions with Platelets and Serum Proteins.” Materials Science and Engineering: C, vol. 112, July 2020, p. 110919,

“Tanfloc/Heparin Polyelectrolyte Multilayers Improve Osteogenic Differentiation of Adipose-Derived Stem Cells on Titania Nanotube Surfaces.” Carbohydrate Polymers, vol. 251, 1 Jan. 2021, p. 117079,

Thank you to the Suzanne and Walter Scott Foundation, Tointon Family Foundation, The Filsinger Family, Caterpillar Inc., and Contributors to the Dean’s Innovation fund for making the SURE program possible.

Thank you

Colorado State University