



Titanium Nanotubes Improve Bone Implant Contact in a Dog Model

Authors:

David Detwiler, PhD
Sabrina Huang, PhD
Alan Kraft, BSNE
Kreigh Williams, BS



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Background

Orthopedic devices made from titanium are implanted to restore structural function to the body. In order to maintain structural stability, the implant needs to integrate with the bone at the site of implantation^{1,4}. The more contact a device has with bone, the better the stability of the implant³. Better stability allows for less pain, faster healing, and fewer complications^{2,3}. To drive osseointegration, the surface of titanium can be modified with coatings or nanotextures to influence the biology of healing bone to increase and accelerate the healing process⁴⁻⁷.

There are many surface alterations available. Roughened acid etching creates a microscale surface texture, while anodized nanotubes create a nanoscale texture that have demonstrated improvements for osseointegration²⁻³. The increase in surface area increases protein adsorption, accelerates vascular on growth, improves stem cell differentiation, and increases bone-implant contact⁴⁻⁹. In this white paper, Ding et al. compared micron-roughened sandblasted and acid-etched (SLA) surfaces with SLA surfaces further modified by anodized nanotubes of varying diameters. The authors evaluated these surfaces through an in vivo animal model placing the implants into the tibia of dogs.

Methods

Implant pins with a void chamber for bone ingrowth were shot peened with aluminum oxide to create a micron roughened surface. The roughened surface was then etched with hydrochloric and sulfuric acid to create a micron-roughened acid-etched surface (SLA). The acid-etched surface was further modified through anodization in an aqueous solution of hydrofluoric acid to have nanotubes with a diameter of 30, 50 or 80 nm. Male beagle dogs were implanted with devices in both tibias. Groups of animals were sacrificed at two and four weeks to recover the devices in bone. Hard tissue sections of the bone and implant were made and stained with toluidine blue for imaging. The authors quantified bone implant contact (BIC) and bone area (BA) in the volume between the threads.

Results

All pins showed integration into the bone at both the 2- and 4-week timepoints, as shown in Figure 1. Compared with the baseline SLA surface, nanotube surfaces of all diameters showed statistically significant increases in both BIC and BA measurements at both time points, as shown in Figure 2. The SLA surface with 80 nm nanotube diameter outperformed all other surface variants.

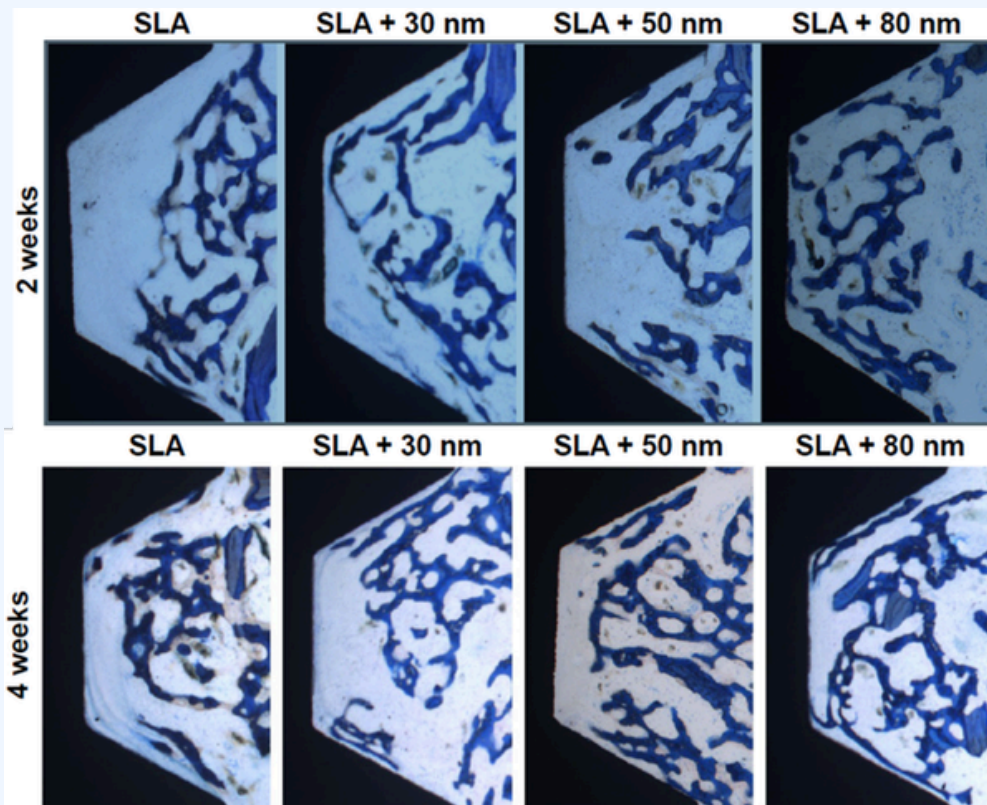


Figure 1: Hard tissue with implant histology after 2- and 4-week implantations. Toluidine blue staining of bone ingrowth into the chamber between threads. This image is modified from the work of Ding et al⁴.

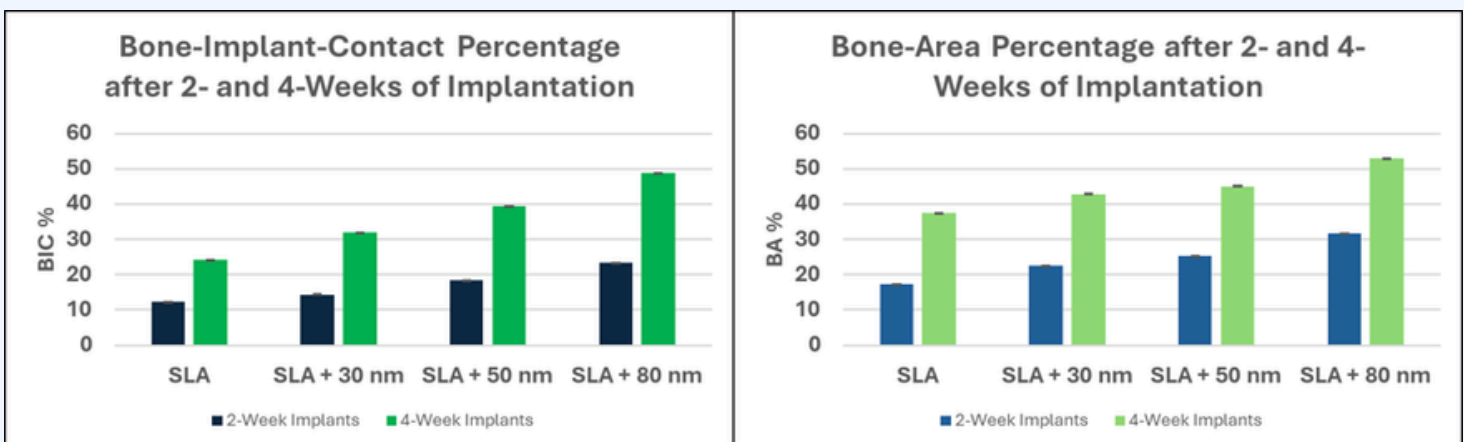


Figure 2: Bone implant contact and bone area after 2- and 4-weeks of implantation in dog tibias. This image is modified from the work of Ding et al⁴.

Discussion

The anodization of titanium implants to form nanotube structures is a very well understood way to dramatically increase the surface area of an implant, significantly outperforming the SLA surface demonstrated in this paper^{4,7-9}. The tunability of the nanotube size allows for controlled biologic response by bone to the nanotube surface, giving nanotubes a distinct advantage over basic micron-roughened surfaces with acid etching^{4,6,8-10}. Other researchers have found similar results to nanotube structures, showing increase protein binding, decrease immune profiles, along with increased vascular on growth to support osteoblast function in building more bone rapidly^{5, 8-10}. The improvements in interactions with the host tissues are attributed to the size and uniformity of the nanostructures created through nanotube anodization^{4,5,7-9}.

Conclusion

Integrating implants into bone quickly and efficiently is the primary aim of implant surface modification. This study demonstrated that sandblasted and acid-etched (SLA) surfaces modified with titanium nanotubes of various diameters provided a significant improvement over baseline SLA surfaces, exhibiting statistically higher bone implant contact and bone area measurements. Among all nanotube diameters evaluated, the 80 nm nanotubes produced the greatest improvement in this dog model study.

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