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Volume 15

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Background

Orthopedic, dental, and trauma 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 implant[3]. 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 process[4-7].

There are many surface alterations available. Two surfaces discussed in this whitepaper, roughened acid etching and anodized nanotubes, both create a nanotexture on the surface of the implant that have demonstrated improvements for osseointegration. The increase in surface area increases protein adsorption, accelerates vascular on growth, improves stem cell differentiation, and increases bone-implant contact[4-9]. The authors of this study compared micron roughened surfaces that have an additional acid etched surface or anodized nanotubes of varying diameters. The authors looked at in vitro cell studies and an 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 nanoroughened 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

Il the pins showed integration into the bone at 2- and 4-week timepoints. The nanotube surfaces outperformed the base SLA surface at all timepoints and for all nanotube sizes for both BIC and BA measurements, Figure 1. The 80 nm nanotube size outperformed all other surface variants.

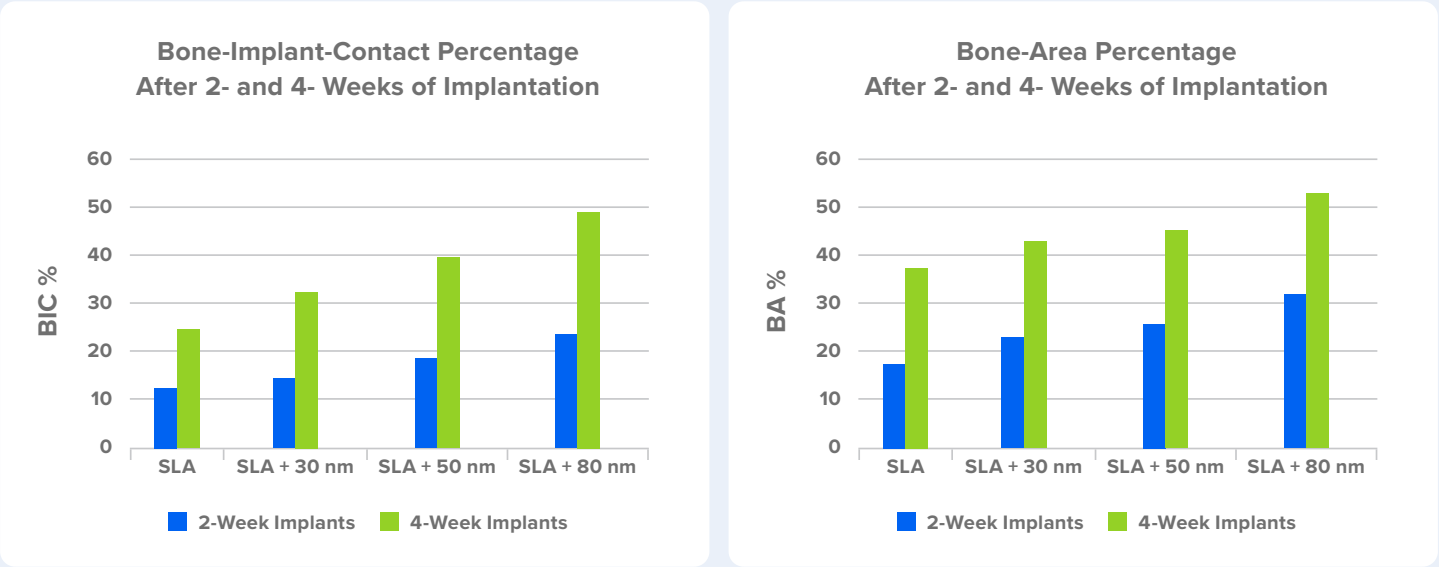

Figure 1 - Bone implant contact and bone area after 2- and 4-weeks of implantation in dog tibias

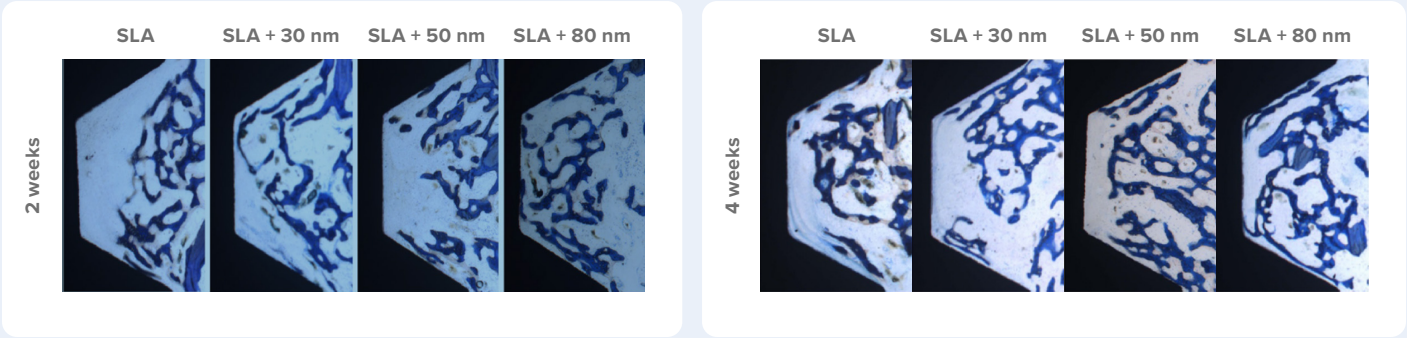

Figure 2 - Hard tissue with implant histology after 2- and 4-week implantations.
Toluidine blue staining of bone ingrowth into the chamber between threads.

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 here[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 rough 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. Micron roughened and acid etched surfaces (SLA surface) have improved outcomes, but this study demonstrates that the titanium nanotubes, at 80 nm diameter, are a significant improvement over micron roughened and acid etched surfaces. Nanovis offers the only commercially available nanotube surface, nanoVIS Ti™ Surface Technology to upgrade implants with a more bioactive surface to improve BIC.

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