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Loss of Biological Function with the Aging of Titanium Implant Surfaces

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Volume 8

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Introduction

For sterile packed implants, the surfaces will typically sit for months to years before being implanted into a patient. Structurally and mechanically, that implant is stable. But what about the surface? Emerging research underscores the importance of also considering the biological age of the implant as opposed to just the sterilization age[1-3]. Many manufacturers are creating specialized high energy surfaces and nanosurfaces that have engineered biological properties to encourage osseointegration, reduce inflammation, reduce bacterial contamination and more. The question of whether that surface acts the same way after sitting on the shelf for a few months is important for patient outcomes. Protecting the high energy surfaces produced by nanosurfacing methods is important for the effective implementation of nanosurface technology on implants.

Methods

Minamikawa et al. have looked at how new vs. aged titanium surfaces perform by looking at the surface contamination (i.e., hydrocarbon percentage) and hydrophilicity (i.e., contact angle) are altered[1]. This was followed by looking at how osteoblast cells attach, proliferate and differentiate on the surfaces. They used an acid etched titanium surface with micron roughness and some nanofeatures, common in dental and orthopedic devices. Surfaces were examined as new or aged to 1-, 3- and 6-months[1].

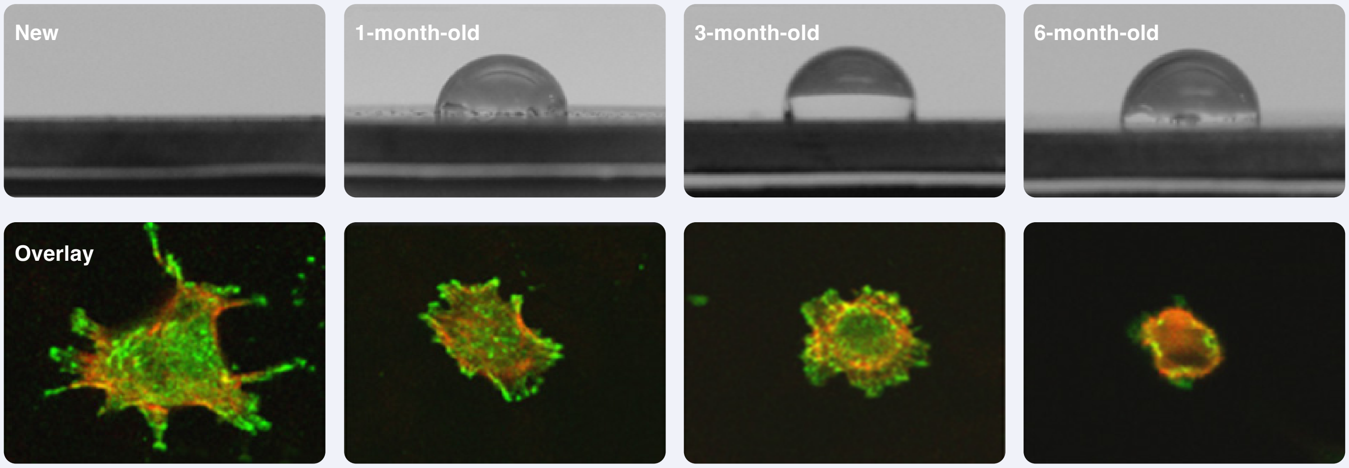

Figure 1: Hydrophilicity of new and aged titanium nanosurfaces. Attachment and spreading behavior of osteoblasts on new and aged titanium surfaces. Confocal microscopic images of osteoblast with immunochemical stain for cytoskeletal actin and adhesion protein, vinculin is shown at New, 1-month, 3-month and 6-month-old. (Modified from Minamikawa et al. Figure 2 and 4)

Results

Hydrophobicity of the surface dramatically changed from new surface to one aged for only 1-month, going from a superhydrophilic contact angle of near zero to greater than 90°. Figure 1. 3- and 6-month samples showed little difference from the 1-month sample. Minamikawa et al. have attributed this to the accumulation of hydrocarbons from the atmosphere and packaging materials, starting at 20% carbon and going up to 60%[1]. This led to a decrease in cell attachment, spreading and differentiation of osteoblasts, Figure 1.

Minamikawa et al. visualized osteoblasts attached to new and aged surfaces looking at cell structure (actin staining), cell attachment (vinculin staining), and cell spreading (surface area covered by a cell), Figure 1. Cell attachment was significantly reduced with one 1-month aging and even further at 3- and 6 months aging. The new surfaces show dramatic cell spreading and attachment where the aged samples have a decreasing attachment and spreading profile. Aged samples also showed reduced proliferation, alkaline phosphatase, collagen-1 and osteopontin expression, all correlated with aging of the surface, Figure 2[1].

Discussion

Minamikawa et al. have effectively shown that biological performance of common micron and nanostructured titanium implant surfaces degrades over time. Reduction in osteoblast function can be seen with aging implants for only 1-month[1,2]. Very few implants make it into a patient within 1-month of their manufacture date. Though these results are based off in vitro testing, other authors have shown that aged surfaces result in reduced bone-to-implant contact for the same implant in the same animal. The importance of protecting highly energized surfaces from hydrocarbon contamination needs to be considered.

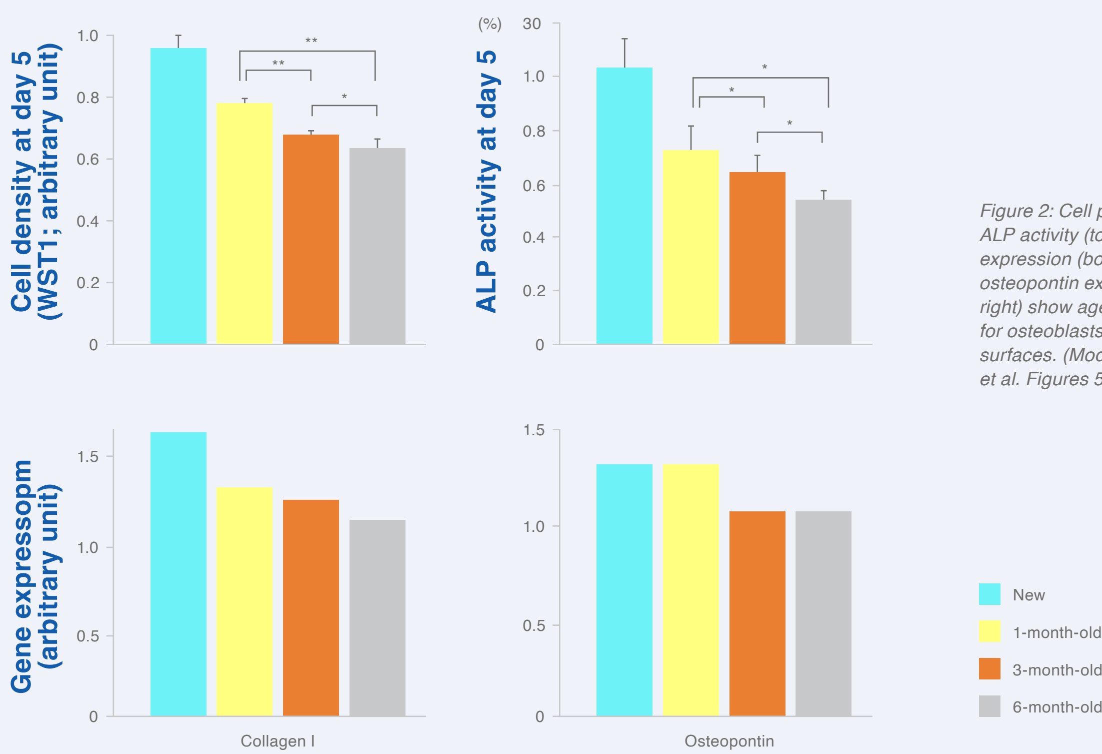

Figure 2: Cell proliferation (top left), ALP activity (top right), collagen-1 expression (bottom left) and osteopontin expression (bottom right) show age related decreases for osteoblasts on aged titanium surfaces. (Modified from Minamikawa et al. Figures 5, 6 and 7)

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Conclusions

Testing for surface aging takes time and costs money. Because of this, little data exists for comparison, but surface aging is an important aspect of how implants will perform in patients. Micron rough and nanosurfaced implants are particularly susceptible to this kind of aging deterioration of the surface properties due to their very high surface energy and hydrophilic properties when freshly manufactured[1-3].

Nanovis' nanoVIS Ti™ Surface Technology has been created with nanosurface aging complications in mind. A nano-thin layer of calcium phosphate stabilizes the high energy nanotube surface at the time of manufacturing and acts as a barrier to hydrocarbon accumulation on the surface. When the implant comes into contact with blood, the nano-thin calcium phosphate dissolves away quickly, removing the hydrocarbon contamination and revealing the pristine high energy nanosurface, as if it was newly manufactured.

References

1. Minamikawa, H., Att, W., Ikeda, T., Hirota, M. & Ogawa, T. Long-Term Progressive Degradation of the Biological Capability of Titanium. Materials (Basel) 9, doi:10.3390/ma9020102 (2016).

2. Att, W. et al. Time-dependent degradation of titanium osteoconductivity: an implication of biological aging of implant materials. Biomaterials 30, 5352-5363, doi:10.1016/j.biomaterials.2009.06.040 (2009).

3. Lee, J. H. & Ogawa, T. The biological aging of titanium implants. Implant Dent 21, 415-421, doi:10.1097/ID.0b013e31826a51f4 (2012).