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Volume 8 V2

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Introduction

For sterile packed implants, the surfaces will typically sit for months to years before being implanted into a patient. Although sterile packed implants remain structurally and mechanically stable, their surface energy is unstable and deteriorates over time because of surface aging. Emerging research underscores the importance of considering the biological age of an implant (i.e., how the implant interacts with surrounding tissue after aging) rather than relying solely on its sterilization age (i.e., the prevalidated shelf-life limit of the sterile packaging)[1-3]. Many manufacturers are developing specialized high-surface-energy surfaces and nanostructured surfaces with engineered biological properties to encourage osseointegration, reduce inflammation, and enhance other biological responses. Whether the surface acts the same way after sitting on the shelf for several months is an important consideration for patient outcomes. In this paper, Minamikawa et al. examined how new and aged titanium surfaces perform by evaluating osteoblast responses and changes in surface hydrophilicity (i.e., contact angle) over a 6-month period[1].

Methods

Commercially pure titanium disks were acid etched to produce a surface with micron roughness and some nanofeatures. Surfaces were examined as new or aged to 1-, 3- and 6-months[1]. The contact angles of the surfaces were measured, followed by looking at how osteoblast cells attached, proliferated and differentiated on the surfaces.

Results

Hydrophilicity of the surface dramatically changed from the new surface to the aged surface for only 1-month, going from a super-hydrophilic contact angle of near zero to about 90°, Figure 1. The 3- and 6-month samples showed little difference in contact angle compared with the 1-month sample.

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, whereas 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, as shown in Figure 2[1].

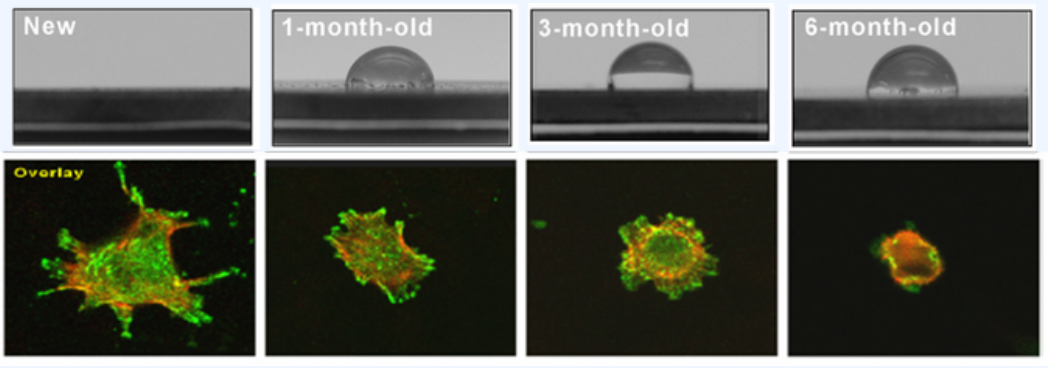

Figure 1: Hydrophilicity of new and aged titanium nanosurfaces. Attachment and spreading behavior of osteoblasts on new and aged titanium surfaces. Confocal microscopic images of osteoblast with immunochemical stain for cytoskeletal actin and adhesion protein vinculin are shown at New, 1-month, 3-month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

Discussion

Minamikawa et al. have effectively shown that the biological performance of common micron rough (acid-etched) titanium implant surfaces degraded over time, even though the surface hydrophilicity plateaued after the first month. They attributed the lack of correlation between surface hydrophilicity and biological responses to the accumulation of hydrocarbons from the atmosphere and packaging materials, starting at 20% carbon and going up to 60%[2]. This led to a decrease in cell attachment, spreading and differentiation of osteoblasts, as shown in Figure 1. Reduction in osteoblast function can be seen with aging implants for only 1 month[1,2]. Very few implants are placed into patients 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[2]. The importance of protecting highly energized surfaces from hydrocarbon contamination needs to be considered.

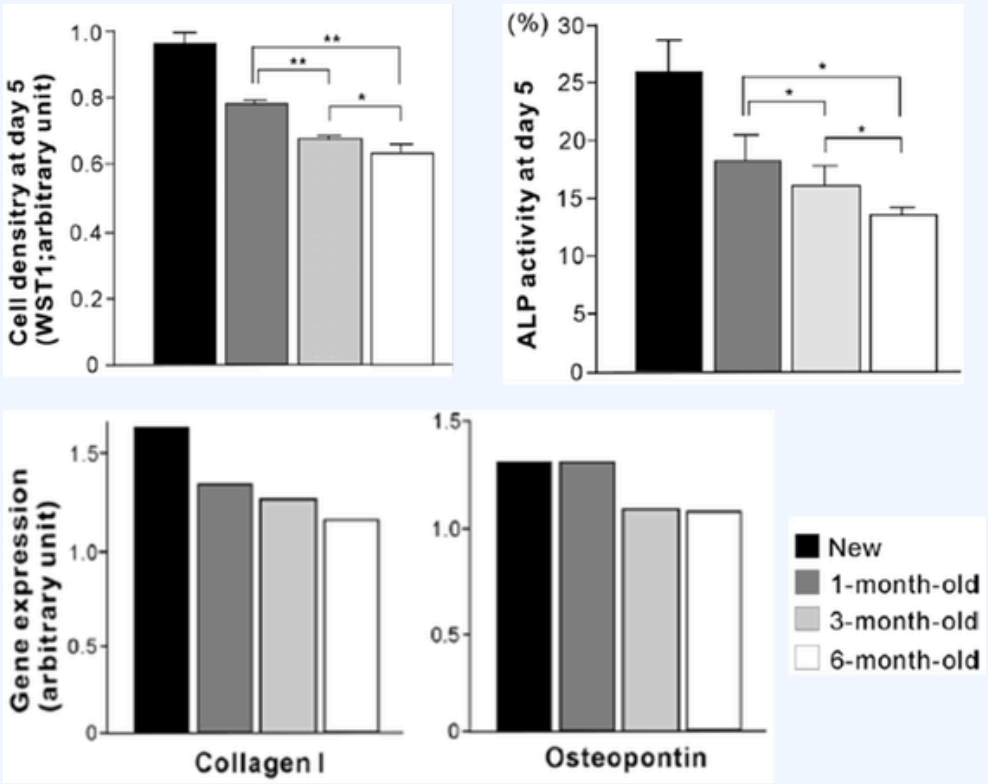

Figure 2: Cell proliferation (top left), ALP activity (top right), collagen-1 expression (bottom left) and osteopontin expression (bottom right) show age related decreases for osteoblasts on aged titanium surfaces. (Modified from Minamikawa et al. Figures 5, 6 and 7)

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 or acid etched implants in this paper demonstrated that these surfaces are particularly susceptible to this kind of aging deterioration of their surface properties due to their very high surface energy and hydrophilic properties when freshly manufactured[1-3]. Although the biological responses evaluated in this study decreased significantly on aged surfaces, no direct correlation was found between surface hydrophilicity and the biological responses, suggesting that other factors like hydrocarbon accumulation may be responsible for the observed biological effects.

References

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