Overcoming the biological aging of titanium by using electrolyzed deoxidized and ionized water

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Background: The biological aging of titanium (Ti) surface is a time-dependent degradation of the osteoconductivity, lead to a decrease in the biomechanical strength of the bone–Ti integration. To overcome the aging, ultraviolet light (UV) has been shown to changing the physicochemical properties of Ti surface from hydrophobic to hydrophilic for removal of the surface hydrocarbons without altering the surface topography. However, expensive special equipment was required for UV photo-functionalization.

Aim/Hypothesis: In this study, we focused on electrolyzed deoxidized and ionized water (S – 100) which can easily remove contamination such as carbon without special equipment. The aim of this study is to investigate the influence S-100 treatment on the recovery of the biological activity of the aged Ti surface.

Material and Methods: We prepared mirror polished Ti-6Al-4V discs. All the discs cleaned using an ultrasonic cleaner in acetone, ethanol, and double distilled water for 10 minutes each. And then the prepared Ti discs were aged by storing in the clean-bench at a room temperature for 1 and 4 weeks. After the aging, we divided the Ti disks into two groups. Half of the discs immersed in S-100 for 3 minutes and the remaining half of the discs immersed in saline water for 3 minutes as a control group. The contact angle on the disc surface were measured by digital contact angle measuring device. The chemical composition of the surface analyzed by X-ray photoelectron spectroscopy (XPS). As a protein adsorption assay, the discs were immersed into 500 μL of bovine serum albumin (1 mg/mL). After incubating for 24 hours, the amount of protein quantified using a micro plate reader at 595 nm. MC3T3-E1 cell were cultured on the control and S-100 treated disks for 24 hours, the cell growth were observed with a fluorescence microscope.

Results: Fig. 1 shows the contact angle. The dropping 0.5 μL DDW were formed hemispheric droplets with a contact angle of approximately 65.2 degree on the 4-week aged control surfaces, indicating that the surfaces were hydrophobic (Fig. 2). In contrast, water droplets on the surface treated with S-100 were spread immediately, and the contact angle was approximately 18.7 degree. Even on the 1-week aged surface, the contact angle on the S-100 treatment significantly decreased and changed to a hydrophilic surface. In XPS analysis, a decrease in C1s was observed on the surface treated with S-100 in all periods. On the other hand, O1s and Ti increased by S-100 treatment. The results of protein adsorption on the Ti surface, there were no significant difference between the S-100 treated surface and the control surface. However, the proliferation of osteoblastic cells on the S-100 treated surface were higher than on the control surface in 4-week of culture.

Conclusions and Clinical Implications: In this study, we compared the biological activity of untreated and S-100 treated Ti alloys surface. Aged Ti disks were immersed for only 3 minutes could easily improve the reduction of the surface energy due to carbon attached to the Ti surface. As a result, the hydrophobic Ti surface were changed to hydrophilic, and then the proliferation of osteogenic cells were accelerated. S-100 treatment suggested that the new bone formation on the Ti surface promotes at early stage of osseointegration.