Bioactivity and Biocompatibility of Titanium and Composite Titanium/Bioglass Coatings

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Introduction:

One of the common failures of implants is related to the inability to achieve a rigid fixation between the implant and the surrounding bone [1]. Osseointegration, a method used in achieving the rigid fixation requires natural bone growth into the surface of the implant. For osseointegration to take place, the surface must be bioactive in order to help promote bone growth during implantation and is bonded to living tissues upon the formation of a layer of bone phase known as a hydroxyapatite (HA).

A wide range of coatings have been researched in order to maximize osseointegration while maintaining an acceptable corrosion rate. In the present work, plasma sprayed commercially pure titanium (CP-Ti) and commercially pure titanium with bioglass (CP-Ti/bioglass) coatings were studied. A four-week in vitro immersion test in simulated body fluid (SBF) was conducted to determine the bioactivity and biocompatibility. The bioactivity was measured using SEM/EDS to determine the increase in calcium content, and XRD to identify any HA formation. The biocompatibility of the coatings, in terms of corrosion, was evaluated using the weight change method based on ASTM G 31.

Materials and Methods:

CP-Ti powder and 45S5 Bioactive Glass powder were used in this study. CP-Ti/bioglass composite powder was prepared by mixing 15wt. % of 45S5 bioactive glass powder with 85wt. % CP-Ti powder. The plasma spraying process was conducted in air using Axial III plasma spray system and the CP-Ti substrate plates were pre-heated to avoid thermal stresses in the coatings.

The ion concentration and the pH of the SBF (Hank's balanced salt solution) closely resembled that in human blood plasma. Before being immersed in the SBF, the samples were rinsed in acetone and ultrasonically cleaned for 15 minutes. The specimens were then dried in an oven for 6 hrs at 60˚C to ensure there was no moisture in the samples. The sample's weights were measured using a scale accurate to ±0.0001 g. After weighing, each sample was then immersed in 50 mL of SBF separately. The beakers were sealed to remain sterile and placed in a water bath kept at 37˚C. The solution was agitated weekly to help maintain uniform ion concentration. After immersion for 30 days, the samples were removed from the SBF solution, gently rinsed with distilled water and dried for 6 hrs at 60˚C.

The elemental analysis of the coated samples was conducted using the SEM/EDS and the existence of HA phase was determined using XRD. Samples after immersion in the SBF were weighed in order to calculate the mass change. The specimen preparation, apparatus set up, test conditions, methods of cleaning specimens, and evaluation of results were based on the methods and procedures described in ASTM G 31 - *Standard Practice for Laboratory Immersion Corrosion Testing of Metals.*

Results:

The results showed that after four weeks of immersion in SBF the percentage of calcium measured on the CP-Ti/bioglass coating increased from 4 to 16 wt. % while no noticeable increase in calcium was observed on the CP-Ti coating. Furthermore, a growth of HA was observed on both the CP-Ti and the CP-Ti/bioglass coatings (Figures 1 and 2), however, the relative intensity of HA on the XRD spectrum was higher for the CP-Ti/bioglass coating – an indication of better bioactivity. It was also found that CP-Ti experienced a mass gain of 0.753 mg/cm³ while CP-Ti/bioglass underwent a mass loss of 1.703 mg/cm³ after SBF immersion. The mass loss of CP-Ti/bioglass is believed to be associated with the dissolution of calcium and phosphate in the bioglass. While this process helps form HA, it could be detrimental if excessive amounts of calcium and phosphate are being released in the surrounding environment.

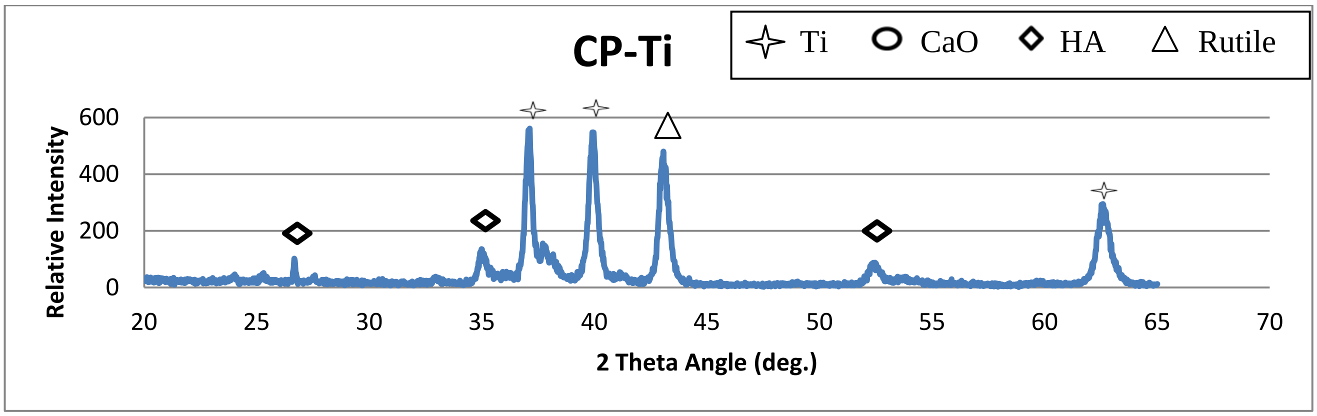

Fig.**1**: XRD pattern of CP-Ti coating after 30 days in SBF.

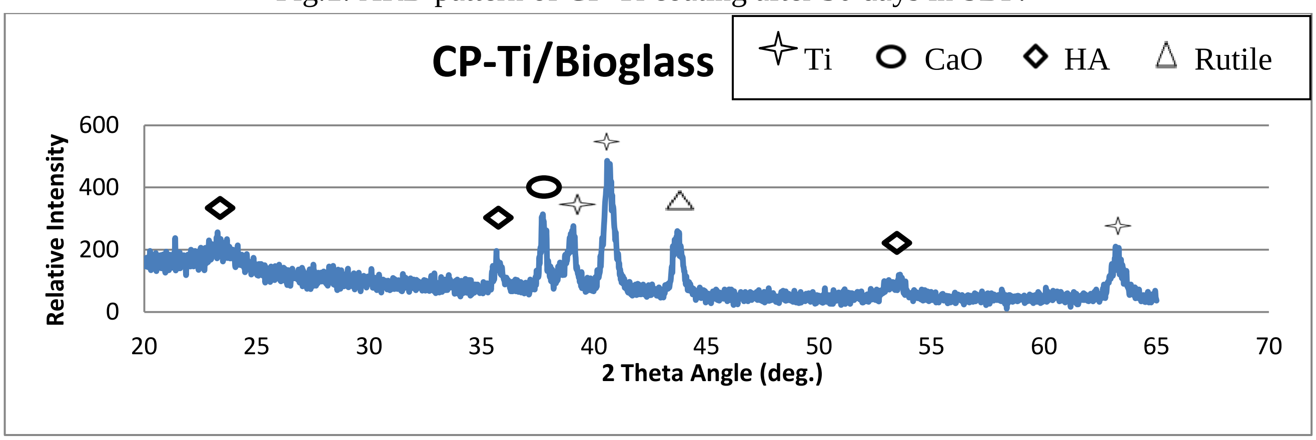

Fig. **2**: XRD pattern of CP-Ti/bioglass coating after 30 days in SBF.

Discussion:

This study showed that the CP-Ti/bioglass composite coating is superior to CP-Ti coating with regards to its bioactivity due to increased HA formation on the surface. However, the CP-Ti/bioglass coating has experienced some weight loss; this may impact the coating's potential biocompatibility. Further study is needed to address the weight loss issue associated with bioglass coatings.

References:

[1] Paital S.R, Dahotre N.B. Calcium Phosphate Coatings for Bio-Implant Applications: Materials, Performance Factors, and Methodologies. Materials Science and Engineering 2009; July, pp.1-20.