

Hydroxyapatite Coating on New Type Titanium, TNTZ, Using Electrophoretic Deposition

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ABSTRACT

In order to improve bioactivity of new type of titanium alloy, TNTZ, Hydroxyapatite (HA) coating is applied. Electrophoretic Deposition (EPD) has chosen as coating method because the simplicity of the instrument and its making, inexpensive cost, and ability to coat things with complicated design. EPD used electric current to move the HA particle through electrode in the suspension of ethanol and HA. Desired HA coating quality can be adjusted with optimizing the voltage and coating time. This research aimed to analyzed the effect of voltage and coating time of EPD process toward the HA coating that produced on the surface of new type titanium implant prototype, Ti-29Nb-13Ta-4.6Zr (TNTZ). Voltages are in range of 3, 5, and 7 volt and coating times are in range of 3, 5, and 7 minutes. Based on the result it is known that the best HA coating that can be produced are on 7 minutes and 7 volt. This best result shows the good surface morphology, highest value of screw mass growth, coating thickness, and surface coverage. Enhancement of voltage will affect the surface coverage value of HA coating, however, coating time will affect the thickness. Based on this research it can be concluded that enhancement of the voltage can produced HA coating that spread more evenly that proved by the increasing of surface coverage value. The enhancement of coating time will produce thicker layer of HA coating and increase deposition rate of HA on the implant surface. This result shows that the EPD can be used to produce TNTZ titanium implant that coated with HA for orthopedic application.

1.0 INTRODUCTION

Hydroxyapatite (HA) had been used worldwide for coating material on metallic implant for orthopedic application due to biocompatibility and bioactivity properties that can increase implant ability to accelerate bone fracture healing[1]–[4]. The increasing cases of metallic implant failure made the hydroxyapatite coating become one of good solution for the problems such as aseptic loosening, metal ion release that can be the trigger for metal allergy, and chronic inflammation[5]–[7]. Electrophoretic Deposition (EPD) has chosen as coating method because the simplicity of the instrument and its making, inexpensive cost, and ability to coat things with complicated design[8]–[10]. EPD used electric current to move the HA particle through electrode in the suspension of ethanol and HA[10], [11]. Desired HA coating quality can be adjusted with optimizing the voltage and coating time[12], [13].

Ti-29Nb-13Ta-4.6Zr (TNTZ) is the new type of titanium alloy that designed to use for orthopedic implant application. This new material have mechanical properties that similar with bone mechanical properties such as low Young's Modulus and desired strength for load bearing and dynamic load. However, the inert properties of titanium made the TNTZ still have no bioactivity properties so that, it needs to be coat with HA for gaining bioactivity properties. This research aimed to analyzed the effect of voltage and coating time of EPD process toward HA coating that produced on the surface of new type of titanium, TNTZ.

2.0 MATERIAL AND METHOD

2.1 Sample Preparation

TNTZ Titanium bar in length of 400 mm and 4 mm in diameter was cut and lathe into screw shape with type M3 x 0.5. Screw length and diameter were 5 mm and 3 mm, respectively. Then, the screws were sandblasted to refine the screw surface and clean the remaining waste from lathe process. After that, screws were cleaned using ultrasonic cleaner in 15 minutes.

2.2 Coating Process using Electrophoretic Deposition

Pretreatment was conducted before coating process. Screws were submerged in ethanol, acetone, and HNO_3 in 15 minutes, respectively. After that, screws were remain in NaOH in one hour. HA suspension was made of 1.8g HA powder and 50ml ethanol, and pH was set about 4. HA powder that used was the commercial HA. The anode was graphite and katode was TNTZ titanium. Voltages were in range of 3, 5 and 7 volt and coating time were in range of 3, 5, and 7 minutes. After the coating process screws were sintered in vacuum furnace at 700°C with holding time about one hour.

2.3 Hydroxyapatite (HA) coating Characterization

Characterization of HA coating was conducted by optical microscope that directly connected with digital camera to obtain the microstructure images of HA coating and continued to assess surface coverage value using software ImageJ. In addition to, screws mass growth was also assessed to confirm the deposition of HA on the screws surface. After that, HA coating thickness was assessed using coating thickness gauges.

3.0 RESULT AND DISCUSSION

3.1 Surface Morphology of HA coating on TNTZ Titanium



Figure 1: Screws sample of Voltages variation (1). 3V, (2) 5V, (3) 7V



Figure 2: Screws sample of Coating Time variation (1) 3M, (2) 5M, (3). 7 M

Figure 1 and figure 2 shows the morphology of HA coating on TNTZ titanium that captured by optical microscope. Based on the image it is shows that the enhancement of the voltage will produce HA coating that spread more evenly. Sample from 7 volt treatment shows the best surface coverage of HA coating. In addition to, coating time variation also shows the same pattern with the voltage variation. Enhancement of coating time produce thicker layer of HA coating on screws surface. Sample from 7

minutes treatment had the thickest HA coating. A study also revealed same result with this recent study, it is known that the voltage and coating time influenced the deposition rate of HA on the titanium surface[14], [10].

3.2 Mass Increase of TNTZ Titanium

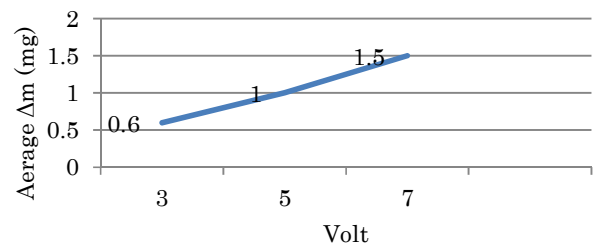


Figure 3: Screw Mass Growth versus Applied voltage at the same time (5 minutes).

Figure 3 shows the average of mass growth of screw samples at different applied voltages. The data shows that enhancement of applied voltage will increase the mass of screws. A study also revealed the same result with this research. The increasing of applied voltage on the EPD process will increase the deposition of HA on the surface of titanium[15]. Data from coating time variation (figure 4) also have same pattern with this data. Enhancement of coating time will increase the mass of screws. This data are in compliance with the microstructure data that shows the increasing of HA particle deposition on the surface of screws when the voltage and coating time are rise.

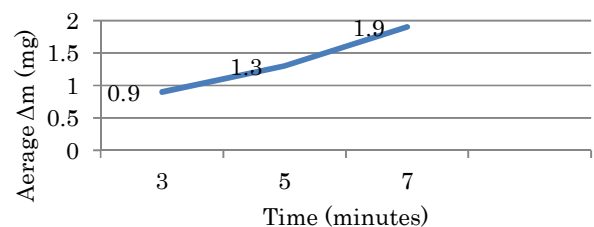


Figure 4: Screw Mass Growth versus Coating Time at the same Voltage (5 Volt).

3.3 Surface Coverage of HA Coating on TNTZ Titanium

Figure 5 shows the data of surface coverage versus applied voltage at the same time (5 minutes). Based on this data, it is known that increasing of voltage will produce higher surface coverage of HA coating. The data shows significant increase of surface coverage from sample of 3 volt treatment to 7 volt treatment. In compliance with this data, increasing of coating time also produce higher surface coverage of HA coating. The data shows in figure 6. However, there were no significant increase of surface coverage of HA coating in different coating times, it means that voltage had more great influence against surface coverage than coating time.

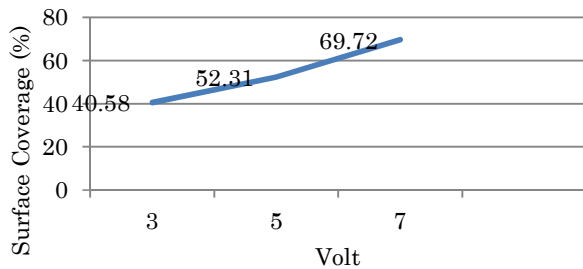


Figure 5: Surface Coverage versus Applied Voltage at the same time (5 minutes).

Many research also revealed the same result with this research. However, applied of ac and dc current will produce different character of HA coating on the titanium surface. DC current will produce uniform HA layer but, AC current will produce different HA coating topography, inner layer is consist by smaller particle of HA and outer layer will consist by greater HA particle. This kind of coating is believed will make a greater osseointegration [16].

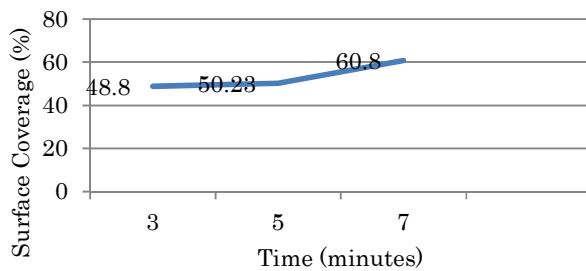


Figure 6: Surface Coverage versus Coating Time at the same Voltage (5 volt).

3.4 Thickness of HA Coating on TNTZ Titanium

Figure 7 and figure 8 shows the data of coating thickness at different voltage and coating time. Based on this data, it is known that enhancement of voltage and coating time will increase the coating thickness. The thickness of HA coating at 5 and 7 volt treatment have no significant differences and also at 5 and 7 minutes treatment. Based on this result, it can be concluded that voltage and coating time can affect the thickness of HA coating.

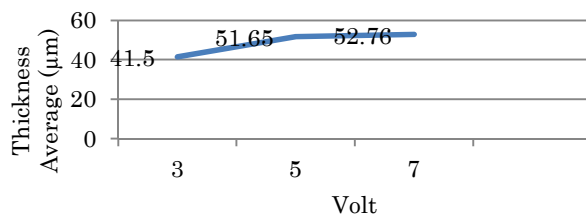


Figure 7: Coating Thickness versus Applied Voltage at the same time (5 minutes)

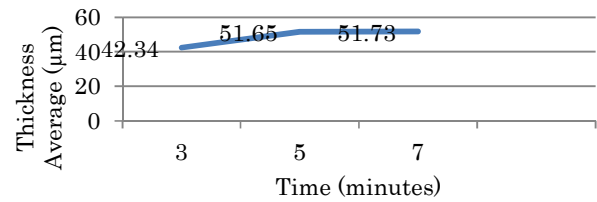


Figure 8: Coating Thickness versus Coating Time at the same Voltage (5 volt)

Another research explained that the coating thickness also have an important role for implant performance. HA coating thickness can affect the corrosion rate of metal when applied in the living tissue and also increase the shear strenght of the implant. In addition to, coating thickness believed can also affect the osseointegration of implant with bone tissue[17]–[19].

4.0 CONCLUSION

1. Electrophoretic Deposition (EPD) had been proved that can be the promising method to coat titanium implant with HA for orthopedic application.
2. Voltage and coating time are the most important parameter of EPD process.
3. Enhancement of voltage will affect the surface coverage of HA coating on the titanium surface.
4. Enhancement of coating time will affect the thickness of HA coating.

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