Optimization of cost effective of nano-hydroxyapatite coating on titanium alloy implant

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INTRODUCTION:

A high incidence of radiolucent line around 3D porous cups has been reported [1], and the improvement of osteconductivity of implant is required, since the osteoconductive coating such as hydroxyapatite was demonstrated to fill in a bone-implant gap [2]. Nano-hydroxyapatite coating could be a candidate technology for enhancement of 3D porous cups. Our previous study revealed that nano-hydroxyapatite coating promoted bone ingrowth into the 3D porous structure with the high porosity [3]. Thus, the nano-hydroxyapatite coating is expected to reduce the occurrence of radiolucent lines around 3D porous cups. On the other hand, the cost effective as well as the performance of technology is an important factor in terms of product development. In this study, we investigated the effect of the amount of nano-hydroxyapatite raw material used in manufacturing on osteoconductivity. The *in vitro* osteoconductivity was assessed using Kokubo's simulated body fluid (SBF).

METHODS:

Ti-6Al-4V alloy samples (ϕ14 mm × 2 mm) were additively manufactured via electron beam melting process. Nano-hydroxyapatite (SofSera) was coated on the samples referred to the previous method [3]. In order to change the amount of nano-hydroxyapatite raw material, four different concentrations of nano-hydroxyapatite suspensions were prepared in this study; 0, 0.03, 0.3, and 3.0% (0%-, 0.03%-, 0.3%-, 3.0%-group). Non-coated Ti-6Al-4V sample was used as a Control group. The surface structure of the samples was analyzed using a scanning electron microscope (SEM). After SEM analysis, the coated nano-hydroxyapatite was completely dissolved in nitric acid solution, and the calcium concentrations of the dissolved solutions were measured using inductively coupled plasma atomic emission spectroscopy (ICP-AES) to determine the coating amount of nano-hydroxyapatite. Kokubo's SBF was prepared to evaluate *in vitro* osteoconductivity according to the standard procedure [4]. Each sample was soaked in SBF at 36.5 ˚C for 24 h, and then the samples were rinsed. The surface morphology of the samples was analyzed using SEM. The deposited weight of apatite by SBF immersion was measured. For statistical analysis, the Tukey's test and Dunnet's test over 0% was used in ICP-AES and SBF analysis, respectively. $P < 0.05$ was considered statistically significant.

RESULTS SECTION:

Figure 1 shows the result of ICP-AES analysis. The weight of calcium ion altered depending on the concentration of nano-hydroxyapatite suspensions. 0.3%-group and 3.0%-group showed the significantly higher calcium ion weights than 0%-group and 0.03%-group, while no significant differences between 0% and 0.03% were observed. Figure 2 (a) shows SEM images of all samples before and after SBF immersion. Control-, 0%- and 0.03%-group showed no apatite deposition in SBF. On the other hand, apatite was deposited in 0.3%- and 3.0%-group in SBF. The deposited weight of apatite by SBF immersion is shown in Figure 2 (b). The weights of deposited apatite on 0.3% and 3.0%-group were significantly greater compared with Control group.

DISCUSSION:

SBF is widely used to evaluate osteoconductivity of an implant *in vitro*. Various materials in which apatite deposited in SBF were reported to have excellent osteoconductivity [5]. In the present study, the apatite depositions in SBF were shown in 0.3% and 3.0%-groups. 0.3% and 3.0%-group exhibited the significantly greater deposited weight of apatite in SBF compared with 0%-group, while no significant differences between 0% and 0.03% were observed. This suggests that the samples coated with nano-hydroxyapatite using over concentrations of 0.3% suspensions possesses the high osteoconductivity. For ICP-AES analysis, 0.3% and 3.0%-groups showed the significantly greater coating amount of nano-hydroxyapatite than 0% and 0.03%-groups, and there were no significant differences between 0.3% and 3.0%-groups. This indicates that the high osteoconductivity of 0.3% and 3.0%-groups was resulted from the greater coating amount of nano-hydroxyapatite. Overall, the concentration of nano-hydroxyapatite suspensions could reduce to at least 0.3%.

SIGNIFICANCE: The acetabular cup being capable of apatite deposition ability such as Alkali-heat treatment was reported to disappear radiolucent lines within 1 year of surgery [6]. Our finding suggests that the 3D porous cup coated with nano-hydroxyapatite that is treated over concentrations of nano-hydroxyapatite suspensions of 0.3% could suppress the occurrence of radiolucent lines.

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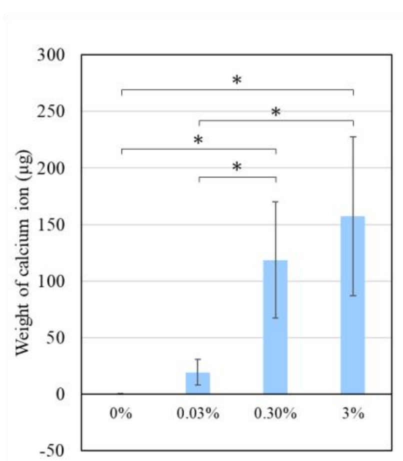

Figure 1. The result of the calcium ion weight on the samples analyzed using ICP-AES. (* $P < 0.05$)

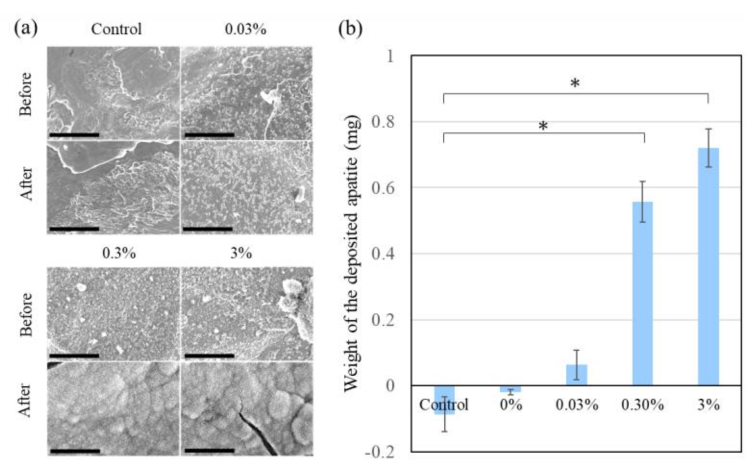

Figure 2. (a) SEM images of the samples before and after SBF immersion. Scale bars: 5 µm. (b) The result of deposited apatite weight on the samples in SBF. (* $P < 0.05$)