Radiodensity Study of Hydroxyapatite Coated Porous Tantalum Implant Material of Rat Animal Model

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Radiodensity Study of Hydroxyapatite Coated Porous Tantalum Implant Material of Rat Animal Model

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Abstract. The aim of this study was to find out the in-vivo radiography density changes of hydroxyapatite coated porous tantalum biomaterial implant after surgical implantation in rats. Ten adult male Sprague Dawley rats were divided into two groups: hydroxyapatite-coated porous tantalum (pTa-HAp) and uncoated porous tantalum (pTa). The implants with dimension of 5 x 2 x 0.5 mm^3 was inserted into flatten bone defects drilled at the femur bone on latero-medial region. The implant density from right lateral view radiogram was analyzed at day 0, 7, 14 and 30 post-implantation. The results showed that the radiodensity of both pTa and pTa-HAp groups decreased in time of implantation. The radiodensity changes of pTa-HAp showed higher decrease compared to pTa.

Introduction

Metal biomaterial implant is quite important in orthopedic and dentistry. Corrosion resistance and biocompatibility of metals should be improved in order to utilize them as biomaterials implant [1]. Metal-based biomaterial have reactivity, free electron, surface reactive, corrosion, and mechanical property change [2]. Tantalum biomaterial is currently available for use in several orthopedic applications such as hip and knee arthroplasty, spine surgery, and bone graft substitute [3]. Tantalum biomaterials have a structure similar to that of bones [4], low bacterial adherence [5], has high biocompatibility, bioactivity and resistance to bio-corrosion [6]. However, the use of solid tantalum biomaterial as biomedical implants only stimulates low bone regeneration. Further improvement is done by making the metal biomaterial porous to improve osteogenesis process and tissue regeneration [7]. Porous tantalum metal is a new material that has characteristics similar to cancellous bone [3]. Tantalum trabecular metal offers several advantages over other current conventional materials used for implants due to its uniformity and structural continuity, strength, low stiffness, high porosity, and high friction coefficient[4].

In addition, the combination of metallic implant materials with calcium phosphate and hydroxyapatite bioceramics as coating material has an osteoinductive effect [8]. Bioceramics can improve the corrosion resistance and thus, the biocompatibility of the tantalum material [9]. The combination of the high mechanical strength of metals with the osteoconductive properties of bioceramics as coatings on titanium implants is widely used in orthopedic surgery [8]. Bioceramics has advantages such as non-toxic, does not contain carcinogenic substances, does not induce allergies, nor inflammation, as well as has good biocompatibility and bioactivity [10]. The surface of the implant could be improved to be optimally compatible by coating porous tantalum with bioceramic [9]. However, there currently is only few research data on the use of hydroxyapatite-coated porous tantalum implants in animal testing. Therefore, this *in-vivo* study aims to examine hydroxyapatite-coated porous tantalum implants in rat femur. The implants effects during implantation in rats was observed based on radiographic density changes.

Experimental

Implant preparation. Sample was prepared as reported elsewhere [9]. Briefly, hydroxyapatite coating on porous tantalum was done using plasma-spraying technique at Amrec-Sirim, Kulim, Malaysia. The coating layer thickness was about 10-15 um. The sample was cut by using high precision allied wire cutter. The surface dimension of porous tantalum samples (coated and uncoated) was 5 mm x 2 mm x 0.5 mm^3 dimension, with thickness of about 0.5mm for further in-vivo testing. Implants were then sterilized using oven hot air sterilization in 160-180 °C for 30-60 minutes prior to animal testing.

Animal implantation. Ten adult male Sprague Dawley rats of ±3 months of age were divided into two groups: hydroxyapatite-coated porous tantalum (pTa-HAp) and uncoated porous tantalum (pTa). They were anesthesized by injection of ketamine and xylazine prior to implantation procedure. The oven-sterilized implant was inserted into flatten bone defects drilled at the femur bone on latero-medial region.

Radiographic image analysis. The right lateral view radiography was obtained by a diagnostic X-ray at day 0, 7, 14 and 30 post-implantation. Then, the implant density from radiogram was analyzed by using line plot profile module in computer-aided image analysis software (ImageJ®,National Institutes of Health, USA) as a function of time of implantation (Fig. 1.).

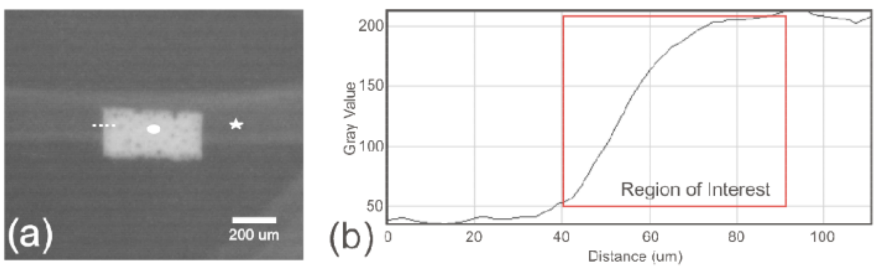

Fig. 1. Radiodensity analysis in porous tantalum implants. (a) plot profile radiodensity analysis at radiogram, (b) plot profile curve radiodensity, star= bone, circle= pTa-HAp implant, dash line= line plot profile analysis.

Results

Figure 2 shows that the radiodensity of coated porous tantalum (pTa-HAp) and uncoated porous tantalum (pTa) groups on day 0 and 7 post-implantation were not significantly different, statistically. The differences were shown at day 14 where pTa-HAp has a lower density than pTa. The graphic density value of pTa-HAp at day 30 showed significant different compared pTa group ($P<0.05$). These results showed that the density of hydroxyapatite coating on the implantation in animal can changes within a certain time.

Discussion

The inflammatory end-stage response of tissue-foreign body reaction that is composed of macrophages and foreign body giant cells usually follows implantation of a medical device, prosthesis, or biomaterial [11]. The implant materials, mechanical load, growth factors and hormone also affect the process of bone formation around an implant in implantation site [12]. It can be observe as changes in the radiographic images during monitoring of patients post-implantation [13]. Our results also show the same condition of radiographic density changes after further analysis (Fig. 2).Tantalum is a metal that have high density in the tissue [14]. Tantalum and tantalum oxide particles are usually used to improve the radio opacity of other materials [15].

The use of tantalum as the implant biomaterial showed the property of anti-corrosion and high radioopacity [14]. On the other hand, hydroxyapatite as coating materials will be absorbed into the bone after a certain time and will affect the opacity of the implant [16]. Coating properties such as thickness, porosity, hydroxyapatite content, and crystallinity as well as implant roughness can influence the performance of a hydroxyapatite-coated implant [17]. Hydroxyapatite-coated implant can enhance the stability of the implant by promoting early bone ingrowth, and facilitating the formation of bone structure because of its osteoinductivity [18]. Thus, our study showed that radiodensity changes of pTa-HAp has higher decrease compared to pTa after day 14 and 30 post implantation (Fig. 2).

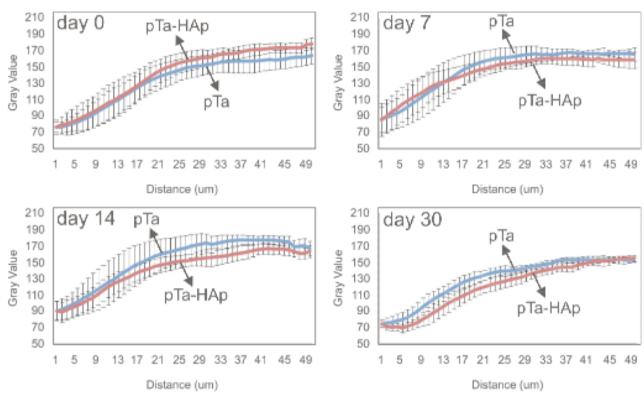

Fig. 2. Radiodensity analysis of coated porous tantalum (pTa-HAp) and uncoated porous tantalum (pTa) implants at day 0, 7, 14 and 30 post-implantation.

Conclusions

In conclusions, we have used plot profile to determine radiodensity changes during implantation of porous tantalum in Sprague Dawley rat radiograms. The radiodensity of pTa-HAp on day 0, 7, 14 and 30 post implantation decreased to lower radiodensity value compared to pTa.

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