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RESEARCH ARTICLES

Observation of new bone penetration into titanium rods with various thread pitch

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ABSTRACT

Titanium is a gold standard material in dental implant treatment due to its biocompatibility and excellent mechanical strength. However, titanium has no bioactivity and osteoconductivity. This has led to studies to develop the osteoconductivity by modifying the surface morphology, such as the thread pitch, which affect the implant stability and bone formation around the implant. This study aims to evaluate the effect of various size of gaps (equivalent to thread pitch) on the bone formation in titanium rods implantation. Initially, titanium rods were cut with different blade sizes: 0.2, 0.3, and 0.4 mm. The gaps were equivalent to dental implant thread pitch. Titanium rods were implanted in the rat's femur and inserted into the bone marrow. After 2 and 4 weeks of implantation, the rats were euthanized and the implanted femur were extracted. The femurs were resin-embedded and cut into 1-mm thickness. The specimens were observed by backscattered SEM. Two weeks after implantation, new bone started to form and penetrated the pitch. In the wider gaps, the bone penetration was found to be particularly high, and vice versa. After 4 weeks, the new bone formation was greater compared to 2 weeks of implantation, and more bone penetration was observed in the wider pitch. This study is an observational research with qualitative reading of the backscattered SEM images. In conclusion, wider pitch could increase osseointegration by providing larger space for bone formation.

Keywords: bone regeneration; dental implant; osseointegration; thread pitch; titanium

INTRODUCTION

Titanium and titanium alloys are the materials of choice in dental or orthopedic implant treatment. This material is popular due to its biocompatibility and advanced mechanical property. Titanium is essentially bio-inert; therefore, it requires a long healing duration after implantation.[1,2] Healing duration of the host bone affects the bone formation surrounding the dental implant. Due to its bio-inert property, there would be minimal integration between the new bone with the implant surface. However, the osseointegration between implant and host bone is affected by surface morphology of the implant materials, such as surface topography, thread geometry and thread size.

Tang et al[3] stated that surface topography increases osteoconductivity of a material. Porous materials stimulate new bone formation better than dense materials. With the present gaps, the bone cells penetrate them and promote osteogenesis. The features of dental implant, such as its thread geometry, affect its stability for a successful long-term implantation.[2–5] Thread pitch, the distance between threads, is an important factor in thread geometry that affects bone-implant interface, load distribution, and primary stability.[6–10] Bone regeneration involves bone induction and conduction that spatially formed as a response to injury.[11–13] Prior to dental implant treatment, alveolar bone is drilled, and the implant is placed. Injury made in this process induces the host response which leads to bone regeneration.[4]

Orsini et al[7] investigated the bone-to-implant contact (BIC) on the narrow and wide pitch titanium implant, and the results showed that narrower pitch has better osteoconductivity and osseointegration, which produce better implant stability.[7] Reinaldo et al[6] also evaluated the implantation into a trabecular-like materials and confirmed that shorter pitch has higher surface area, which leads to higher stability of the implant.

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These previous studies evaluated the readily applicable implant. However, the parameter is limited to thread size. The thread and pitch size differential is significant, and it only compares two types of dental implant. Evaluation of more samples with different sizes needs to be conducted. Furthermore, the thread structure, such as the pitch size, needs further evaluation to better understand the new bone formation path into the pitch. Therefore, this study aims to investigate the effect of various size of gaps on new bone penetration as an equivalent to thread pitch in titanium rods implantation.

MATERIALS AND METHODS

Titanium rods with a length of 23 mm and diameter of 1.4 mm were prepared and cut with different blade thickness, which were 0.2, 0.3, and 0.4 mm. Animal experiment was conducted by the Animal Care and Use Committee of the Kyushu University (approval number: A30-343-0).

Three 12-week-old male Wistar rats (Japan SLC Inc., Shizuoka, Japan) were used in this experiment. The rats were injected with 75 mg/kg of ketamine and 10 mg/kg of xylazine. Incision area was shaved and cleaned with iodine. Incision with a length of 15 mm was made on the femur, which allowed the opening of the joint capsule of the femur. A hole was made in the middle of the condyle with a diameter of 1.5 mm. The titanium rods were then inserted into the hole which then penetrated the bone marrow. The implantation was conducted bilaterally in each rat.

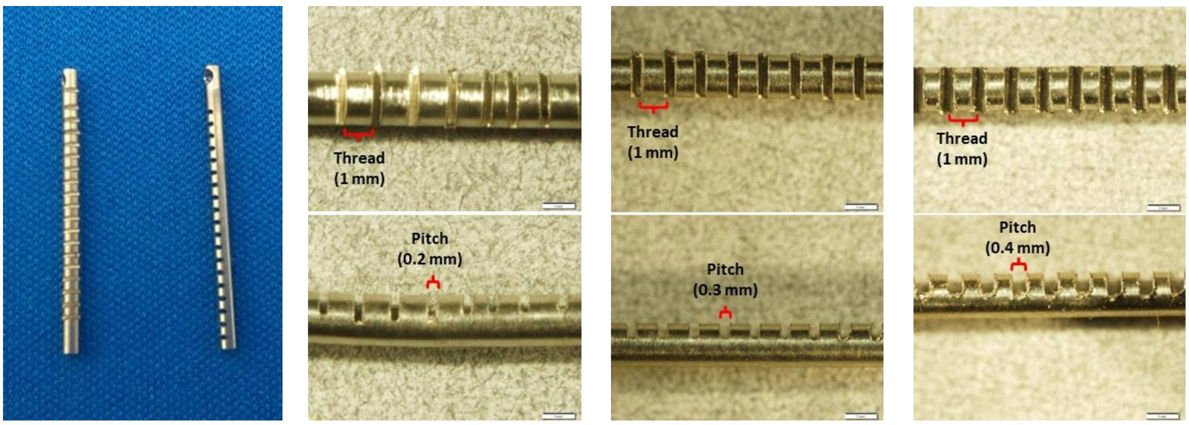
The rats were euthanized at week 2 and week 4, and the implanted femurs were harvested for analysis. The harvested femurs were gradually dehydrated with an ethanol solutions from 70% to 100%, and fixed in poly(methyl methacrylate) resin. The embedded femurs were cut longitudinally with a thickness of 1 mm.

The specimens were observed by backscattered scanning electron microscope (SEM; S-3400 N, Hitachi High Technologies, Tokyo, Japan). Before observation, the samples were coated with gold-palladium using magnetron sputtering (MSP-1S, Vacuum Device Co., Ibaraki, Japan).

The images of the specimens were qualitatively analyzed. The white appearance indicated a new bone. Comparison was made between all gap thickness at weeks 2 and 4 to evaluate which samples had better penetration of new bone.

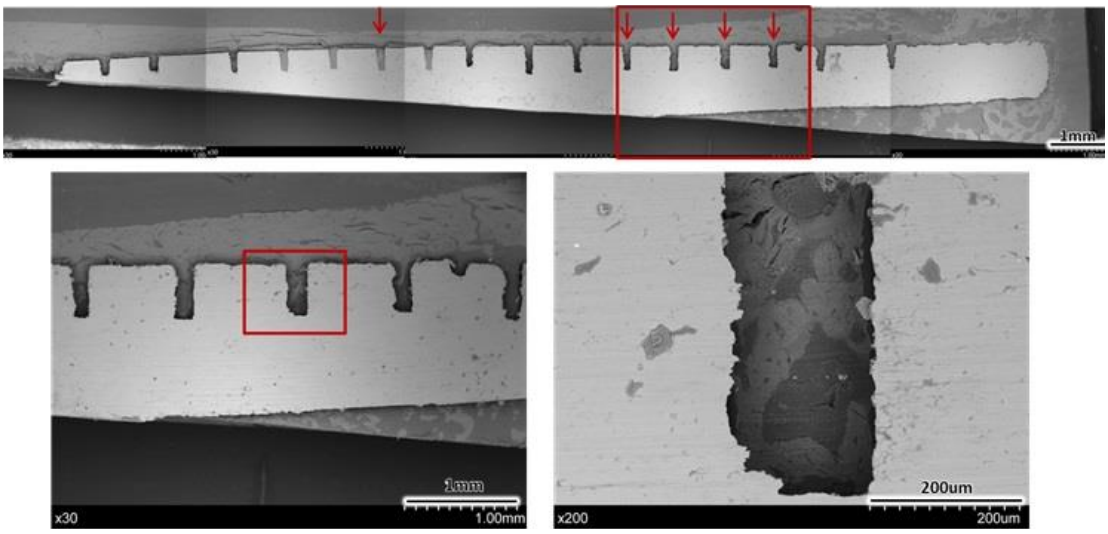
RESULTS

The titanium rods with different gap (pitch) thickness are shown in Figure 1. The distance between the cuts (thread) were 1 mm. There were visible differences in the size of the pitch. The thicker the blade, the bigger the pitch could be seen in the images.

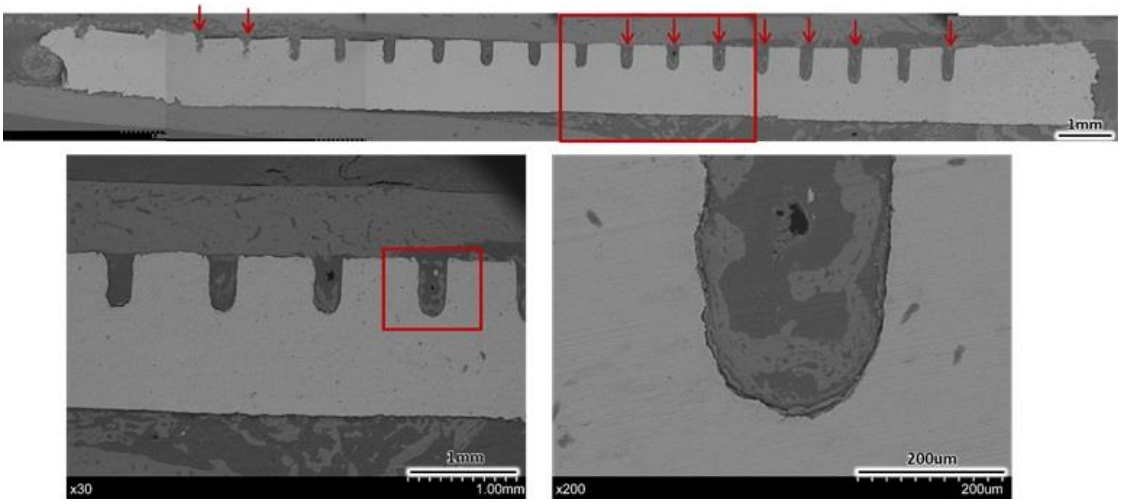


(A) Titanium rod (B) Blade 0.2 mm (C) Blade 0.3 mm (D) Blade 0.4 mm

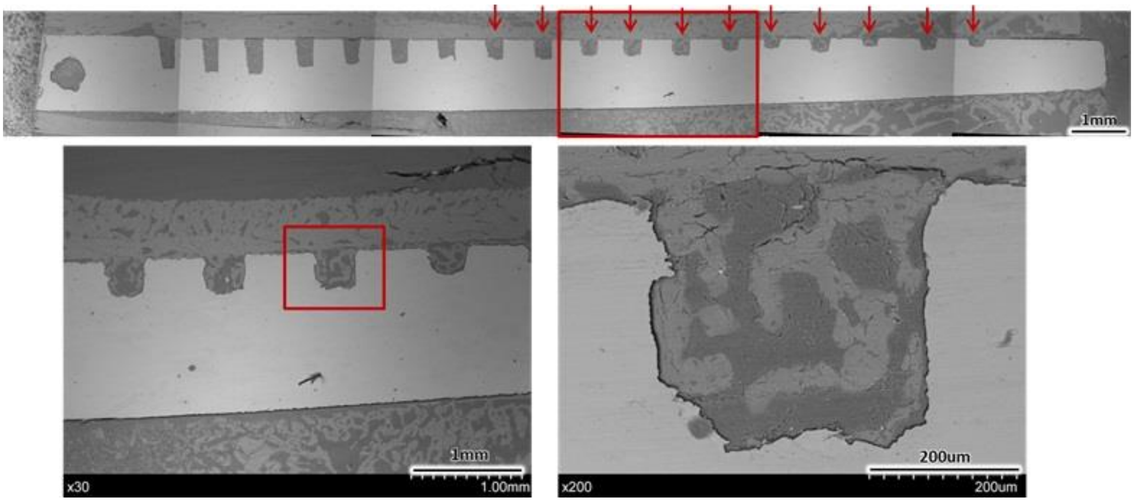
Figure 1. Images of (A) typical titanium rods that have been cut, and magnified images of titanium rods that were cut with the blade sizes of (B) 0.2 mm, (C) 0.3 mm, and (d) 0.4 mm



(A)

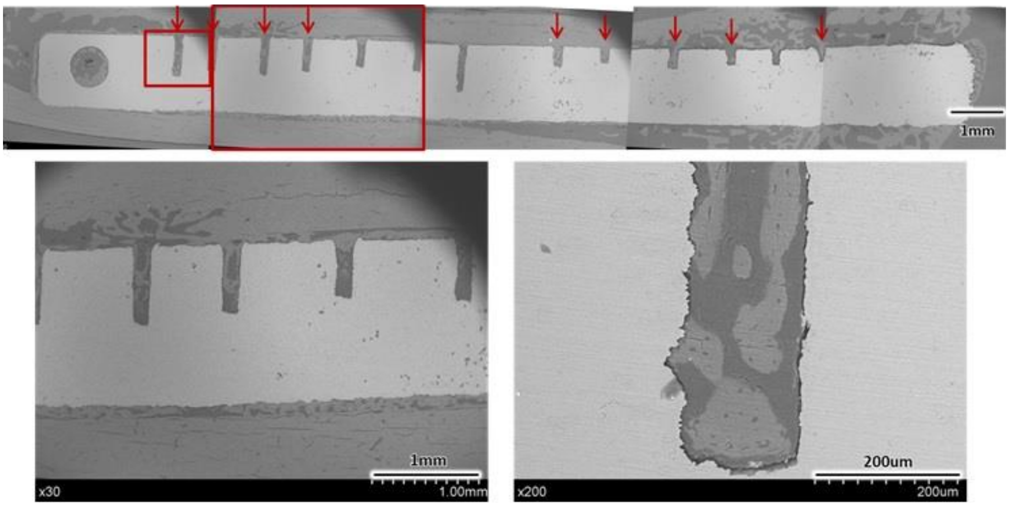


(B)

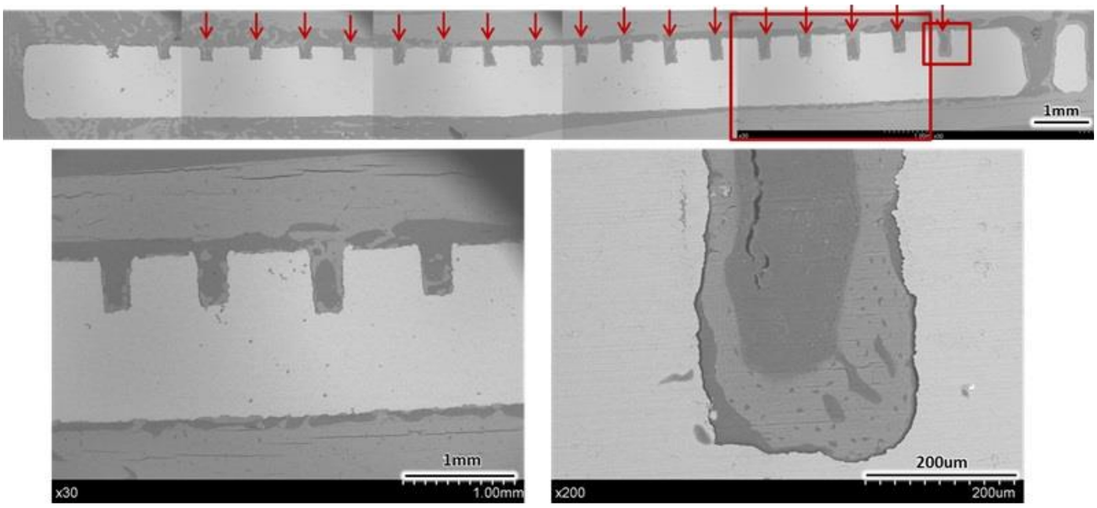


(C)

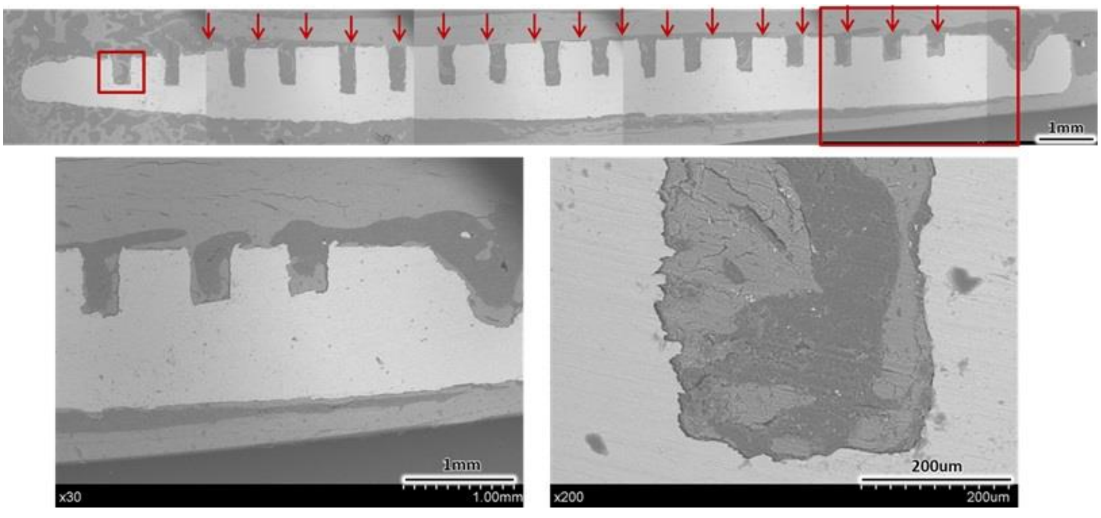
Figure 2. Backscattered SEM images of the implanted titanium rods with the sizes of (A) 0.2 mm, (B) 0.3 mm, and (C) 0.4 mm after 2 weeks of implantation



(A)



(B)



(C)

Figure 3. Backscattered SEM images of the implanted titanium rods with the sizes of (A) 0.2 mm, (B) 0.3 mm, and (C) 0.4 mm after 4 weeks of implantation

Backscattered images showed bone penetration into the titanium rods at 2 weeks. At higher pitch, white appearances indicated that bone formation was more visible compared to thinner pitches (Figure 2). The highest amount of bone penetration occurred with a 0.4 mm pitch.

Figure 3 shows that after 4 weeks of implantation, the amount of bone penetration increased compared to the 2-week implantation (Figure 3). Similar to the 2-week implantation, the amount of bone penetration was higher in the larger pitch, with the 0.4 mm pitch showing the highest amount of bone penetration.

DISCUSSION

This study applied the cutting treatment on the titanium surface and evaluated the bone penetration where various sizes of the pitches were created on the surface. The bone formation intensified with increasing pitch. The space provided by the larger pitch was found to facilitate the bone formation to fill the space. Higher surface area also promoted the bone cells to fill in the space, then formed a new bone through bone remodelling process.

Fabbro et al[2] reported that the surface roughness could improve the osseointegration between titanium and host bone. The result of their study indicated that the modified titanium surface has higher osteogenesis on its surface. Besides roughness, surface structure that has pores is reported to induce more bone formation compared to dense surface. The pores accommodate bone cells, body fluid, blood vessels, and nutrients that would later play a role in the bone remodelling. The optimum pore diameter for bone regeneration ranges from 200 to 500 μm.[3,14,15] This study found that by providing space or pitch on the titanium surface, the osteogenesis improved due the availability of the space. The pitch size was 200 to 400 μm, which satisfied the optimum pore diameter. Osteogenesis occurred based on the spatial growth.[16] The findings of this study indicate that larger pitch provides more space for the growth of the new bone. Bone cells and bodily fluid automatically occupy the space followed by cells proliferation and differentiation, which result in new bone formation.

Orsini et al. compared the osseointegration process on the narrow pitch and wide pitch implant. It was found that narrow pitch implant has higher surface area leading to higher contact between bone and implant. Moreover, the bone ingrowth in the narrow pitch was also higher compared to the wide pitch. This resulted in higher primary stability of narrow pitch implant.[7] The results of their study are in contrast with those of the current study. In this study, bone penetrated more in the wider pitch. A possible explanation for this might be due to the location of the placement of the implant. The titanium rods in this study were implanted into the bone marrow, while in the experiment done by Orsini et al.[7], the implant was placed in the iliac crest which consisted of cortical and trabecular bone. The bone marrow is softer than cortical or trabecular bone and contains a lot of blood vessels. The soft tissue of bone marrow that was implanted by titanium rod was immediately filled in the pitch. The bigger the pitch, the easier it was to be filled by the bone marrow tissue. This led to an increase in the formation of new bone in the wider pitch. Quantitative analysis and mechanical evaluation need to be conducted to achieve a statistically valid result and comparable to other studies.

CONCLUSION

Different size of gaps made on titanium rods may affect the amount of new bone formation penetrating the gaps. These gaps are equivalent to the thread pitch in dental implant. Wider gaps have more bone penetration compared to the narrow gaps, thus increasing the osseointegration.

CONFLICT OF INTEREST

The authors declare no conflict of interest with the data contained in the manuscript.

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