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The Healing of Circumferential Bony Defects Around SLA Implants with Different Coating Thicknesses of Calcium Phosphate. (Pilot Study)

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Implants with SLA surface, implants with SLA surface coated with 200 nm thickness of Calcium Phosphate, and implants with SLA surface coated with 500 nm thickness of Calcium Phosphate were fabricated with ion- beam assisted deposition (IBAD) method. Dental implants were placed with surgically created circumferential 2 mm gap defects in four male Mongrel dogs. The animals were sacrificed after 8 weeks. Specimens were evaluated histologically. The aim of study was to evaluate the bone healing around SLA (Sandblast, Large grit, acid-etched) implants with different coating thickness of Calcium Phosphate (CaP) in 2 mm circumferential bony defect. Irrespective of nano-coating thicknesses, SLA implants coated with Calcium Phosphate (I-CaP200, I-CaP500) didn't show any difference in tissue response from SLA implant without coating (I-SLA).

Key words: Dental implants, SLA, Calcium Phosphate coating, ion beam-assisted deposition

Introduction

Formation of direct contact between implant and surrounding bone is one of the most important parameters for clinical success of dental implants. The stability of dental implants is determined by this direct contact at the implant-bone interface.[1] Implant-bone response which is important for direct contact was thought be influenced by implant surface topography.

As a consequence, a variety of dental implants with different surface topographies have been introduced. The existence of surface roughness increased bone-to-implant contact.[2] The roughness seems to favor the migration of undifferentiated mesenchymal cells, which cover the implant surface and maximize new bone formation.[3] A variety of surface treatments have been proposed to increase roughness of dental implant. The surface treatments include acid etching, application of titanium plasma spray, blasting with different substances, oxidizing titanium oxide surface, and incorporating hydroxyapatite.[4] When compared with smooth surface titanium implants, the experimental studies using implants with these various rough surfaces showed significantly higher removal torques, and a higher percentage of direct bone-implant contact.[5,6]

Calcium phosphates (CaP), and hydroxyapatite (HA) are examples of osteoconductive materials which have been coated on the surface of dental implants. Improved cellular response and increased bioactivity were noticed on bone tissue around modified implant surface with CaP, or HA.[7-15] When coating implant surface with CaP, the dissolution rate of coating layer is affected by Ca/P ratio and cyrstallinity of the particles. The dissolution rate of coating layer should be reduced for maintaining ideal cellular activity of bone. The reduction in the dissolution rate of the coating layer could be achieved by Ion-beam-assisted deposition(IBAD) method.[14,15] IBAD method is one of the most popular methods due to the outstanding bonding between coating layer and substrate.[16,17] The CaP coating with IBAD method can increase the Ca/P ratio forming a layer similar to crystalline HA.[14]

The aim of this study was to evaluate bioactivity of CaP coating on SLA surface implant by IBAD method with two different coating thickness in surgically created defects of dogs.

Material and method

Implant sample preparation

Implants with SLA surface (I-SLA), implants with SLA surface coated with 200 nm thickness of Calcium Phosphate (I-CaP200), and implants with SLA surface coated with 500 nm

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thickness of Calcium Phosphate (I-CaP500) were fabricated with ion- beam associated deposition (IBAD) method. The detailed procedure for CaP coating followed the method of our previously published papers.[14,15] CaO (Cerac, USA) and HA(Alfa, USA) were sintered at 1200 °C for 2 hours in air to prepare calcium phosphate evaporates. An electron beam evaporator (8.5 Kv rated power supply, Telemark, USA) and an end-hall type ion gun(Commonwealth Scientific, USA) were employed for ion deposition.

Animals

Four male Mongrel dogs, 18 to 24 months old and weighing about 30 kg, were used. All of them had the intact dentition and healthy periodontium. Animal selection, management, preparation and surgical protocol followed the routine procedure approved by the Animal Care and Use Committee, Yonsei Medical Center, Seoul, Korea.

Surgical procedure

All mandibular premolars and the first molar were extracted. Implant surgery was performed after 8 week healing period. A crestal incision, and full thickness mucoperiosteal flap was made. Implant ostectomy was prepared with additional circumferential coronal defect (2 mm gaps) on the top by a customized paralleled step drill. I-SLA, I-CaP200, and I -CaP500 were placed for each mandible (Implantium®, Dentium, Korea). The diameter was 3.4 mm and the length was 10 mm. The flaps were repositioned, and sutured with a resorbable suture material. The sutures were removed after 10 days. After 8 weeks of healing, the animals were sacrificed and block sections were obtained for histological analysis.

Histological analysis

The block sections were fixed in 10% buffered formalin. The specimens were dehydrated in ethanol, embedded in methacrylate, and sectioned in the mesio-distal plane. From each implant site, the central section was reduced to a final thickness of about 20 μm. The sections were stained in hematoxylin and eosin and histological analysis was performed using a stereoscope and microscope.

Result

Mild inflammation in soft tissue, and favorable bone response around the coronal part of I-SLA, I-CaP-200, and I-CaP500 was noticed. (Figure1, 2, 3) Newly formed bone was noticed around implants and osseointegration was also found. Implants from all groups showed bone to implant contact at the apical area. Osteoblasts were found around newly formed bone representing bone formation activity. Reversal lines were also found at the area distant from implant surface. The density of newly formed bone was comparable to that of existing bone.

Figure 1. Histological view of the control group. Minimal amount of defect fill observed at the coronal defects with no bone to implant contact at the coronal micro-thread area (magnification × 8).

Figure 2. Histological view of I-CaP200. Limited amount of bone formation observed at the coronal defect area (magnification × 8).

Irrespective of coating thicknesses, SLA implants coated with Calcium Phosphate (I-CaP200, I-CaP500) failed to show any difference in tissue reaction around implant from SLA implant without coating (I-SLA).

Coating with CaP was performed to improve tissue reaction

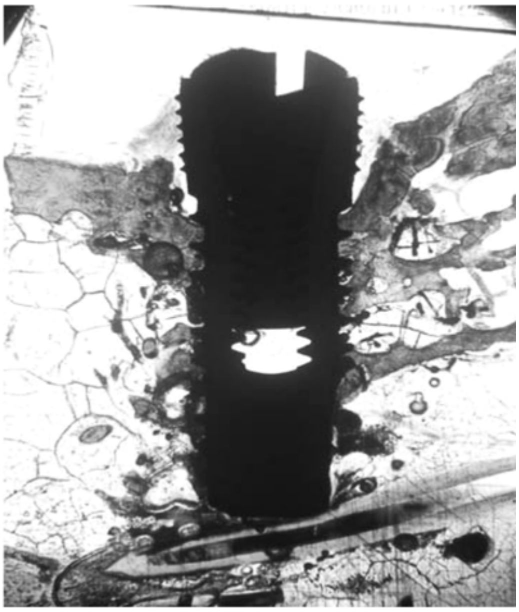

Figure 3. Histological view of I-CaP500. Bone to implant contact observed on coronal micro-thread area (magnification × 8).

of I-SLA. However, in this study, the tissue reaction wasn't affected favorably by the surface modification with CaP. The surface of I-CaP200 and I-CaP500 has to be investigated further.

Discussion

As a result of scientific researches, osseointegration between bone tissue and titanium implant was ascertained. Replacing missing teeth with dental implants could be one of the predictable treatment modalities in the present generation due to this osseointegration. Conventional protocol with smooth surfaced dental implant in the early days was 2 separate surgical procedures and delayed loading. Several months after first surgery, and additional several weeks after second surgery were recommended before loading. Since the enhanced early healing with rough surfaced implant was clarified, there have been trials to reduce healing period. Immediate or early loading with one stage surgery became a common protocol for implants with modified surfaces. Surface topography and chemical composition of dental implants could be most important for early healing of bone around dental implants. Bone apposition following oseoblastic proliferation can be improved with these modified surfaces. Surface modification of dental implants includes blasting, etching, oxidizing, plasma spraying, and coating with osteoconductive materials. In the present study, SLA implants were coated with two different coating thickness of CaP by IBAD method. Bone healings around these implants in the circumferential coronal defects were evaluated. The thickness of coated CaP can vary from micro to nano size according to selected coating techniques. The final CaP coating layer should have a sufficient thickness. If the thickness is too thick, the outer layers may detach. If the thickness is too thin, the coating layer would be unstable due to poor cyrstallinity. The ideal thickness of HA coating for implants is approximately 50 μm.[18,19] The coating thickness can be reduced to nano size with IBAD method. This nano size thickness could be sufficient for cellular activity because cells interact with the top of coating layer.[20] Post heat treatment is recommended for better stability of the coating layer when using IBAD method. Several researches presented that post heat treatment after CaP coating by IBAD method increases the crystallinity of CaP particles.[21,22] In the study by Li et al.[15] when post heat treatment was performed at 350 ^{o}C to anodized implant coated with CaP, the particle grew larger and the crystalline phase changed to HA phase. A stable coating layer could be achieved with this high HA crystalline phase. When post heat treatment was performed to CaP coated implant, improved bone healing was noticed without any separation of the coating layer from the implant surface.[23] Improved bone response was also founded in the study by Chae et al.[24]

In this study, CaP was coated on SLA implants with a thickness of 200nm and 500nm by IBAD technique. More favorable tissue reaction of coated implant was expected. Different tissue response according to the particle sizes was expected. There was no difference of tissue response between coated implant (I-CaP200 and I-CaP500) and non coated implant (I-SLA). In addition, there was no difference of tissue reaction according to the particle sizes. The healing time of 8 weeks probably was not enough to see the difference because the histologic finding showed ongoing healing in bone tissue around implants. Further experiments are needed with a larger sample size and comparison with post heat treated implants in order to confirm these results.

Conclusion

In the self-contained gap defect, implants with SLA surface coated with CaP (I-CaP200, I -CaP500) by the IBAD method failed to show improved bone healing compared with non coated SLA surface implants. Technique combining SLA and CaP by IBAD method should be modified for more favorable tissue response.

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