Healing of created circumferential gap defect around implants according to defect width, implant surface, defect morphology

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감사의 글

수련을 받으며 계획하고 진행했던 실험을 시작하였던 것이 얼마 전 같은데 시간이 지나 논문을 탈고하게 되었습니다.

이 논문이 완성되기까지 부족한 저에게 기회를 주신 김종관 교수님, 사랑과 관심으로 이끌어 주신 최성호 교수님께 깊은 감사를 드립니다. 그리고, 더 나은 논문을 위해 많은 조언과 따뜻한 관심으로 지켜봐 주신 채중규 교수님, 조규성 교수님, 김창성 교수님께 진심으로 감사 드립니다.

연구 내내 자기 일처럼 많은 도움을 준 정의원 선생님, 채경준 선생님, 그리고 치주과 수련의 선생님 여러분들께 고마움을 전합니다.

그리고, 제가 이 자리에 오기까지 뒷바라지 해주신 부모님께 진심으로 감사 드리며 부족한 저를 항상 아껴주시는 장인, 장모님에 대한 감사의 마음은 이루 말할 수 없이 큽니다.

마지막으로 누구보다 늘 아낌 없는 사랑과 헌신적인 도움으로 든든하고 따뜻한 버팀목이 되어준 사랑하는 나의 아내, 지은에게 진정으로 사랑과 고마움의 마음을 전하며 힘들 때에도 아빠의 힘이 되어준 사랑하는 아들 우진에게도 감사의 마음을 전합니다.

아울러, 더 나은 과학 지식 발전을 위해 희생된 동물들에게, 그 희생이 헛되지 않도록 더욱 더 열심히 연구할 것을 다짐해 봅니다.

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저자 씀

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Abstract

Healing of created circumferential gap defect around implants according to defect width, implant surface, defect morphology

Objectives: This study was to evaluate the factors affecting healing of created circumferential gap defect around implants in dogs

Material and Methods: In four mongrel dogs, all mandible premolars were extracted and after an 8 weeks of healing period, submerged type implants were placed. Groups were divided according to implant surface. Group A was placed turned surface implants and group B was placed rough surface implants. The defects in the left were performed surgically with a customized tapered step drill and the defects in the right sided were created surgically with customized paralleled drill. Groups were divided according to the width of the coronal gaps: 1.0 mm, 1.5 mm, or 2.0 mm. The dogs were sacrificed following an 8 week healing period. Specimens were analyzed histologically and histomorphometrically.

Results: During the postoperative period, healing was uneventful and implants were well-maintained. As the size of the coronal gap increased, the amount of bone-to-implant contact decreased. The bone healing was greater in rough surface implants compared to turned surface implants. Comparing to defect morphology, taped defect was found good bone filling and direct bone to implant contact even in smooth surface implants.

Conclusion: It can be concluded that healing of circumferential defects around implants is influenced by the implant surface, defect width, defect morphology. If using rough surface implants, circumferential gap defect within 2 mm does not need any kind of regenerative procedure, and tapered defect morphology showed more faster healing than paralleled defect morphology.

Key Words: defect width, defect morphology, implant surface, gap

Healing of created circumferential gap defect around implants according to defect width, implant surface, defect morphology

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I. Introduction

Placing an implant during the same visit at which the tooth is extracted will reduce morbidity, treatment costs, and treatment time. This approach has been termed the “immediate implant” (Wilson & Weber 1993) and was first reported using osseointegrated implants by Schulte et al. in 1978 (Schulte et al. 1978). Since then, many authors have studied and improved the clinical efficacy of immediate placement of dental implants into the extraction socket in human clinical studies (Lazzara 1989; Werbitt & Goldberg 1992; Gelb 1993; Lang et al. 1994; Becker et al. 1994, 1998; Watzek et al. 1995; Rosenquist & Grenthe 1996; Schwartz-Arad & Chaushu 1997, 2000; Botticelli et al. 2004a). The advantages of immediate implantation are as follows: Total treatment time can be reduced; the preservation of the residual socket’s horizontal and vertical level could be more easily achieved than in delayed implantation; implant positioning is optimized; the need for additional bone augmentation procedures is minimized; and the healing potential of residual periodontal ligament cells is helpful in successful osseointegration.

However, coronal gaps around the implants placed immediately into fresh extraction sockets make a problem and the lack of soft tissue makes it difficult to maintain a primary closure of the surgical site (Becker & Becker 1990; Gotfredsen et al. 1993, Becker et al. 1994, Goldstein et al. 2002).

Several studies have been published the relationship between gap width and healing pattern around implants in immediate implantation. Carlsson et al. (1988) studied titanium implants with initial gap widths of 0.00, 0.35, and 0.85 mm. When the initial gap between bone and implant was larger than 0.35 mm, histologic evaluation revealed no osseointegration. Knox et al. (1991) proved that gaps larger than 1 mm resulted in a smaller amount of direct bone to implant contact. Thomas et al. (1998) concluded in their clinical study that in a gap width of less than 0.5 mm there is no need of membrane, but in a gap width of more than 4 mm, no integration of bone and implant was observed. Akimoto et al. (1999) studied a smooth surface implant in surgically created bone defect sites after tooth extraction in a dog experimental model. Bone was regenerated in gap widths of more than 0.5 mm clinically, but histologically there was no direct contact of bone and implant.

A recent study suggested that implant surface characteristics can affect the healing of gap defect around implant. Botticelli et al. (2003a) studied a rough surface implant (SLA) in dogs by creating a bone defect with a 1 to 1.25-mm gap. A barrier membrane was used to cover the coronal defect. They suggested that the defect sites were healed by appositional bone growth from the lateral and apical bone walls of the defect. In a recent study, Botticelli et al. (2005) compared bone healing at implants with turned or rough surface topographies placed in self-contained defects using either a submerged or non-submerged installation technique. They suggested that healing of the bone defect around implants with a rough surface was superior to that with a turned surface.

Actually, a shape of fresh extraction socket is a conical shape. However, previous study model was a surgically created paralleled defect. Thus, the surgically created tapered defect is necessary to understand healing pattern of natural extraction socket.

The objectives of this study were to compare the healing pattern of defect morphology. Additionally, we observed the different healing pattern according to gap width and implant surface characteristics.

II. Materials & methods

1. Animals

Four male Mongrel dogs, 18 to 24 months old and weighing about 30 kg, were chosen. The animals had 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.

2. Experimental Design

Groups were divided according to implant surface. Group A was placed turned surface implants and group B was placed rough (RBM) surface implants. The defects in the left were performed surgically with a customized tapered step drill and those in right side were created surgically with customized paralleled drill. Groups were divided according to width of the coronal gaps: 1.0 mm, 1.5 mm, 2.0 mm (Fig.1, Fig. 2).

3. Surgical protocol

Teeth were extracted under general anesthesia under sterile conditions in an operating room using Atropine 0.05 ㎎/㎏ SQ, xylazine (Rompun®, Bayer Korea, Seoul, Korea.) 2 ㎎/㎏, and ketamine hydrochloride (Ketalar®, Yuhan Co., Seoul, Korea) of 10 ㎎/㎏ IV. Dogs were placed on a heating pad, intubated, administered 2 % enflurane, and monitored with an electrocardiogram. After disinfecting the surgical sites, 2 % lidocane HCl with epinephrine 1:100,000 (Kwangmyung Pharm., Seoul, Korea) was administered by infiltration at the surgical sites. Crevicular incisions were made and all premolars were carefully extracted. Prior to extraction, P2-P4 were sectioned to avoid tooth fracture. Flaps were sutured with 5-0 resorbable suture material (Polyglactin 910, braided absorbable suture, Ethicon, Johnson & Johnson Int., Edinburgh, U.K.) by the vertical mattress suture technique. On the day of surgery, the dogs received 10 ㎎/kg IV of the antibiotic Cefazoline.

The implants (Restore®, Lifecore, USA) were placed after a healing period of 8 weeks using the same surgical conditions as those for tooth extraction. A crestal incision was made to preserve keratinized tissue, and mucoperiosteal flaps were carefully reflected on the buccal and lingual aspects. The edentulous ridge was carefully flattened with a surgical bur and irrigated with sterile saline. Group A was used turned surface implants and group B was used RBM surface implant. Three submerged type implants (3.5 mm diameter, 10.0 mm length) were placed on the right side of the mandible Implant osteotomy was performed at 800 rpm under chilled saline irrigation and circumferential defects of 1.0 mm, 1.5 mm and 2.0 mm gaps were created surgically with a customized paralleled step drill, and same procedure was done on the left side of mandible using a customized tapered step drill. Implant placement was made without tapping to obtain good initial stability (Fig. 3).

Flaps were closed with 5-0 resorbable suture material and implants were submerged. Post-operative care was similar as that for tooth extraction. Sutures were removed after 7 to 10 days and a soft diet was provided throughout the study period.

Dogs were sacrificed 8 weeks after surgery. Euthanasia was performed by anesthesia drug overdose. Block sections including segments with implants were preserved and fixed in 10 % neutral buffered formalin.

The specimens were dehydrated in ethanol, embedded in methacrylate, and sectioned in the mesio-distal plane using a diamond saw (Exakt®, Apparatebau, Norderstedt, Germany). From each implant site, the central section was reduced to a final thickness of about 20 ㎛ by microgrinding and polishing with a cutting-grinding device (Exakt®). The sections were stained in hematoxiline-eosine.

4. Histologic analysis

General histological findings were observed with a stereoscope (LEICA MZFLIII, LEICA, WETZLAR, Germany) and microscope. After conventional microscopic examinations, computer-assisted histometric measurements were obtained using an automated image analysis system (Image-Pro Plus®, Media Cybernetics, Silver Spring, M.D.) coupled with a video camera mounted on a light microscope (LEICA DM-LB, LEICA, WETZLAR, Germany). The measuring points were as follows.

1) distance (mm) from the implant margin to the most coronal level of contact between bone and implant (Fig. 4):

2) bone to implant contact percentage (BIC %) in the coronal 5mm of the implant (Fig. 5)

III. Results

1. Clinical findings

During the postoperative period, healing was uneventful and implants were well-maintained. There were no signs of inflammation observed in the mucosa adjacent to the implants.

2. Histologic findings

1) defect width

The larger the defect width around implants, the larger the remaining unfilled area was. There was a remaining wedge shaped defect in 2 mm tapered defect of group A (Fig. 6).

2) implant surface

The healing of rough surface implants was superior to smooth surface implants. 2 mm width of paralleled defect in group A was found a wedge shaped defect in coronal portion, but group B showed good bone-to-implant contact (Fig. 7).

3) defect morphology

Most of tapered defect were found good bone filling rather than paralleled defect.

In taped defect, there was found good bone fill in the 1.0 mm gap of group A. However, in the paralleled defect, no direct bone-to-implant contact was found in the 1.0 mm gap of group A (Fig. 8).

3. Histomorphometric analysis

1) Distance (mm) from the implant margin to the most coronal level of contact between bone and implant (Table 1.) (N=2)

Data from the analysis are shown in Tables 1. With increasing size of coronal gap, the distance tended to be greater. Comparing to implant surface, turned surface implant showed greater distance than rough surface implant. Comparing to defect morphology, paralleled defect showed greater distance than tapered defect.

	Paralleled defect			tapered defect		
	1mm	1.5mm	2mm	1mm	1.5mm	2mm
Group A	3.05	3.52	3.99	0.28	1.50	2.05
Group B	0.65	1.75	2.04	0	0	0.95

(group A: turned surface, group B: rough surface)

2) Bone-to implant contact percentage (BIC %) in the coronal 5mm of the implant (Table 2.) (N=2)

	Paralleled defect			tapered defect		
	1mm	1.5mm	2mm	1mm	1.5mm	2mm
Group A	8.9	5.2	2.6	34.2	28.7	10.5
Group B	28.7	25.2	10.7	42.7	41.5	27.4

(group A: turned surface, group B: rough surface)

Data from the analysis were shown in Tables 2. With decreasing size of coronal gap, bone to implant contact tended to be greater. Comparing to implant surface, rough surface showed greater bone to implant contact than turned surface implant. Comparing to defect morphology, tapered defect showed greater bone to implant contact than paralleled defect.

IV. Discussion

The immediate implant technique was introduced to allow patients to have shorter rehabilitation periods and researches were carried out to explore the theoretical background. Many methods have been introduced to overcome the coronal gap associated with immediate implants (Becker 1990; Becker 1994; Caudill 1991; Werbitt 1992; Gotfredsen 1993; Lang 1994; Kohal 1998; Alliot 1999; Cornelini 2000; Schwartz-Arad 2000; Goldstein 2002; Botticelli 2004; Cangini 2005), but the critical size of defect allowing spontaneous healing has yet to be determined. Therefore, if this critical defect size could be determined, the treatment procedure could be simplified and the treatment period shortened, benefiting both the patient and practitioner. Besides defect width, implant surface and defect morphology can influence the healing of circumferential gap defect around implants.

Defect width

Akimoto et al. (1999) used a dog model to evaluate the bone fill that occurred in defects adjacent to implants designed with a machined surface. Implants were placed in simulated extraction sockets that had been prepared in such a way that gaps of between 0.5 and 1.4 mm separated the implants surface and the bone. A clinical examination performed after 12 weeks of healing showed that all defects, independent of size, had healed properly. Histological measurements made in biopsies obtained from the different defect sites, however, revealed that there was consistently a certain distance between the marginal border of the implant and the most coronal level of bone-to-implant contact. Further, it was observed that this distance varied with the initial size of the defect. Thus, the wider the defect, the longer the distance between the rim of the implant and the level of bone to implant contact.

In the present study, the 2 mm defect width tended to make the more wide and deep wedge shaped coronal defect than 1mm defect width. It suggests that the greater defect width will need more healing time to fill the bone defect.

Implant surface

In the present study, rough surface implants with resorbable blast media (RBM) were used. In order to obtain RBM surface, a machined titanium implant was blasted with calcium phosphate ceramic and then passivated to completely remove the residual media. The surface roughness ranged from 3.09±0.38 microns, and micro-pit diameter ranged from 5 to 10 microns.

Osteoblasts may lay down bone on the old bone surface or on the implant surface itself. This distinction was explored by Osborn and Newesley (1980).

Davies (1998) suggested that there are two different phenomena by which bone can become juxtaposed to an implant surface: distance and contact osteogenesis. Distance osteogenesis is that in which new bone is formed on the surfaces of bone in the peri-implant site through appositional growth and contact osteogenesis or osteoconduction is that in which *de novo* bone formation occurs directly on the implant surface. Davies suggested that an implant with a roughened surface, as opposed to an implant with a smooth surface, may ‘promote osteoconduction by both increasing available surface area for fibrin attachment and by providing surface features with which fibrin could become entangled’.

Davies(2003) explained that the implant surface design will play an important role in the fibrin retention. Fibrin retention is so critical to osteogenic cell migration to the implant surface. Bone cells will reach the implant surface by migration through fibrin, and these cells will then be available to synthesize *de novo* bone on the implant surface itself.

Akimoto (1999) studied marginal bone defects of varying dimensions that occurred following placement of implants with turned surface failed to heal with proper osseointegration, In contrast, similar experiments (Botticelli 2003a) was done with rough surface implants demonstrated that marginal bone defects were resolved by de novo formation of hard tissue.

Botticelli et al. (2005) compared bone healing at implants with turned or rough surface in self-contained defects using dogs. After 4 months of healing, the marginal defects around rough surface implants exhibited substantial bone fill and a high degree of osseointegration, but healing at turned implants was characterized by incomplete bone fill and the presence of a connective tissue zone between the implant and the newly formed bone.

In the present study showed that bone healing was superior in bone defects adjacent to implants with a rough compared to smooth surface implants, and it is similar to a previous study (Boticelli 2005). The reason can be explained that the defect healing of rough surface implants is occurred by combination of contact osteogenesis and distance osteogenesis, but healing of smooth surface implants is done only by distance osteogenesis. Therefore, the remodeling of defect will be faster in the rough than smooth surface implants.

Defect morphology

Several studies have been published the relationship between gap width and healing pattern around implants in immediate implantation. Most of these studies used a paralleled defect model. However a shape of fresh extraction socket is a conical, so this study created a tapered stepped drill to reproduce an actual extraction socket.

In a present study, most of tapered defect were found good bone filling rather than paralleled defect. In taped defect, there was found good bone fill in the 1.0mm gap of group A. however, in the paralleled defect, no direct bone-to-implant contact was found in the 1.0 mm gap of group A. Bone healing of paralleled defect was similar to findings reported by Akimoto (1999), but tapered defect was different. This can be explained that a lateral wall at defect base is more closer in tapered defect than paralleled defect. That means appositional bone growth occurred more faster in tapered defect than paralleled defect.

Botticelli et al. (2003 a.) explained bone-to-implant contact was first established in the apical portion of the gap. This new bone tissue was in the coronal direction continuous with a dense, non-mineralized implant-attached soft tissue which, over time, also became mineralized and, hence, the height of the zone of bone-to-implant contact was increased.

Therefore, the morphology of defect base is an important factor to determine healing of self-contained defect.

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V. Conclusion

It can be concluded that healing of circumferential gap defects around implants is influenced by the implant surface, defect width, defect morphology. If using rough surface implants, circumferential gap defect within 2 mm does not need any kind of regenerative procedure, and tapered defect morphology showed more faster healing than paralleled defect morphology.

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Figure Legends

Figure 1. schematic drawing of experimental design.

Figure 2.

a. created stepped paralleled drill From the left, a 5.5-mm diameter drill for the 1.0-mm gap defect, a 6.5-mm diameter drill for the 1.5-mm gap defect and a 7.5-mm diameter drill for the 2.0-mm gap defect are represented, respectively.

b. created stepped tapered drill From the left, a 5.5-mm diameter drill for the 1.0-mm gap defect, a 6.5-mm diameter drill for the 1.5-mm gap defect and a 7.5-mm diameter drill for the 2.0-mm gap defect are represented, respectively.

Figure 3. Clinical photograph representing the experimental design. From the left, 1.0-mm, 1.5-mm and 2.0-mm gaps were prepared, respectively.

Figure 4. Schematic drawing of the method to measure the distance from the implant margin to the most coronal level of contact between bone and Implant.

Figure 5. Schematic drawing of the area to measure the bone-Implant contact in coronal 5 mm.

Figure 6. Histologic view of group A (turned surface) taperd defect with different gap width. The left side is 1mm defect, and the right side is 2mm defect (magnification X8).

Figure 7. Histologic view of 2mm paralleled defect with different implant surface. The left side

is rough surface, and the right side is turned surface (magnification X8).

Figure 8. Histologic view of group A (turned surface) 1mm defect with different defect morphology. The left side (tapered defect) is found a good bone filling compared to the right side (paralleled defect) (magnification X8).

Figures

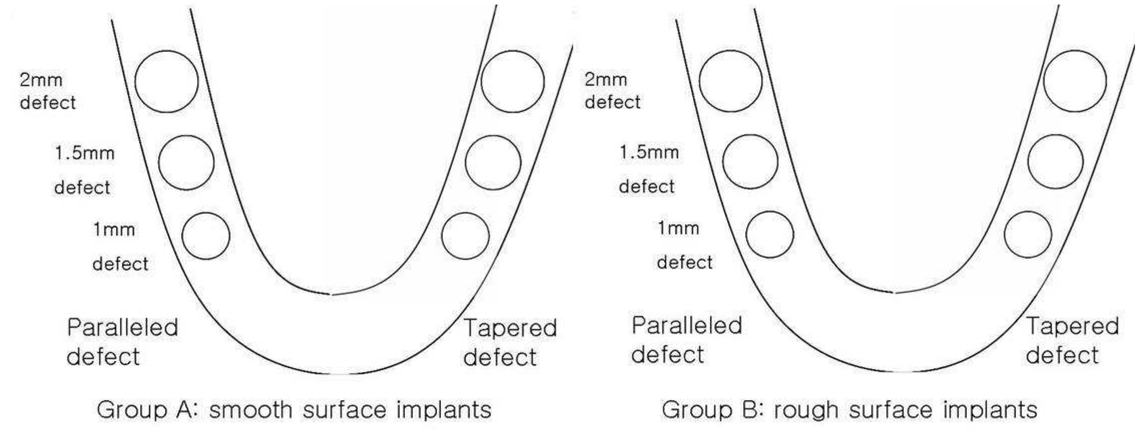
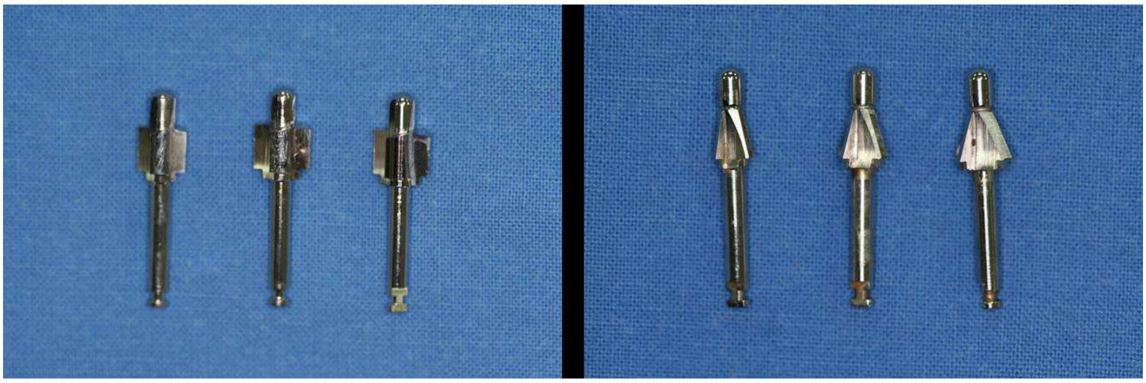


Figure 1.



a. b.

Figure 2.

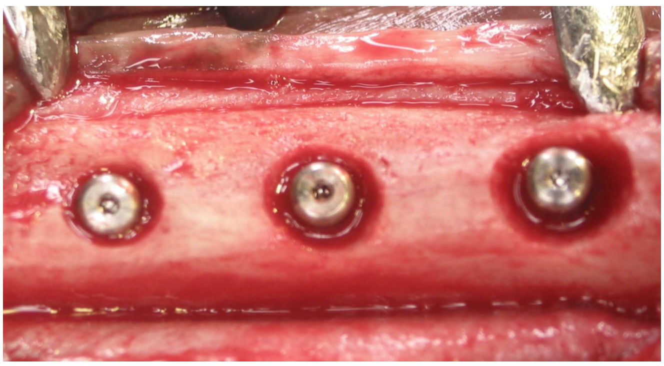


Figure 3.

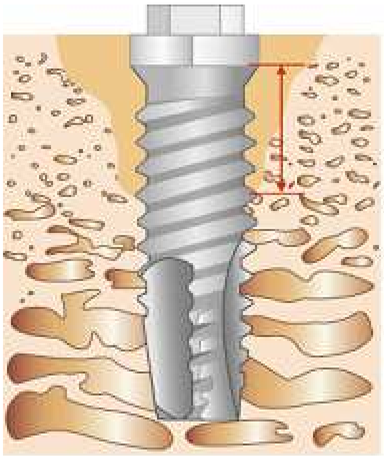


Figure 4.

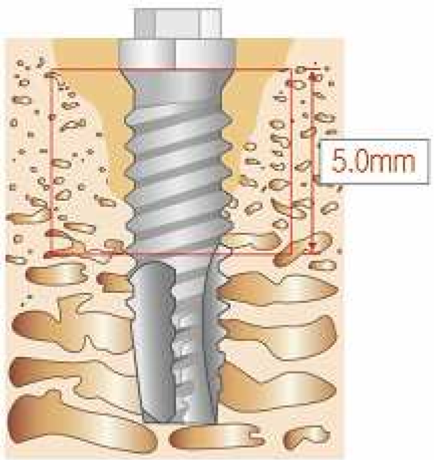
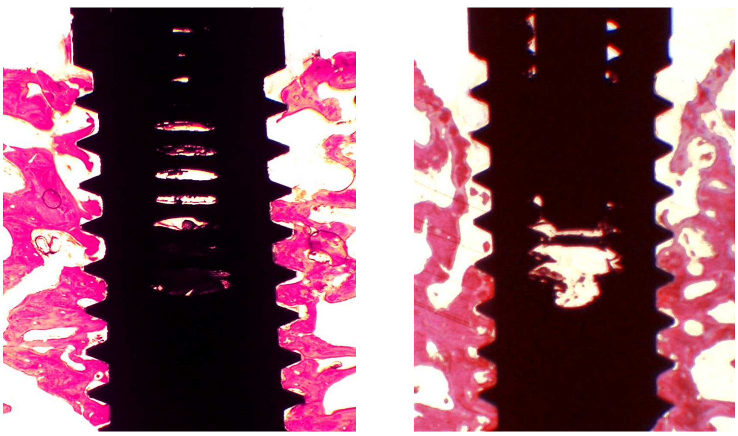
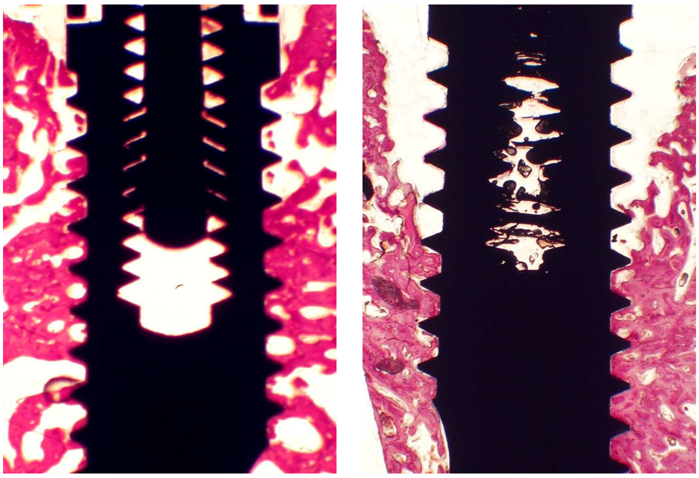


Figure 5.



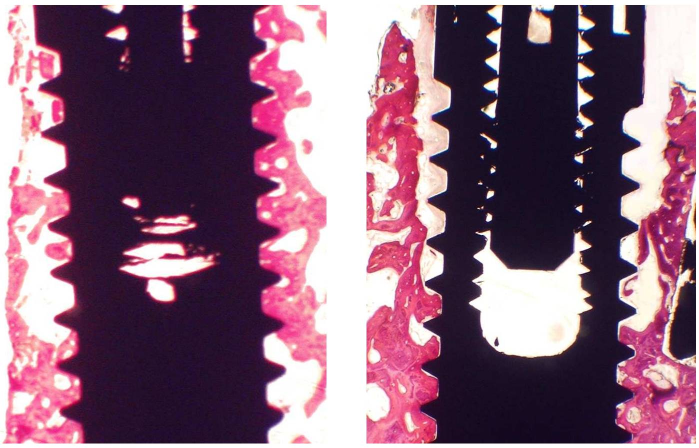
a. b.

Figure 6.



a. b.

Figure 7.



a. b.

Figure 8.

국문요약

임프란트 주위에 형성된 환상 결손부의 결손 폭, 임프란트 표면, 결손 형태에 따른 치유

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임 세 웅

상실된 치아의 수복에 있어서, 임프란트가 기존의 전통적인 보철 수복을 대체하고 있다. 좀 더 빠르고 간편한 임프란트 치료를 위해 발치 즉시 식립하는 임프란트 술식이 소개되었고, 그 이론적 배경이 되는 많은 임상 실험 및 동물 실험들이 보고 되어 왔다. 이 실험은 목적은 성견에서 수술적으로 형성한 환상 결손부의 치유에 영향을 미치는 요소들을 분석하였다.

총 4마리의 수컷 잡견에서, 모든 하악 소구치를 발거하고 8주 동안 치유시킨 후, 매몰형 임프란트를 식립 하였다. 두 마리에서는 표면처리 되지 않은 임플란트를 식립하였고, 나머지 두 마리에서는 거친 표면 임플란트를 식립하였다. 하악 좌측은 주문 제작한 쐐기형 드릴을 이용하여 치관부에 환상형 결손부를 형성하였고, 우측은 주문 제작한 평행형 드릴을 이용하여 수술적으로 환상형 결손부를 형성하였다. 결손부의 폭에 따라 다음과 같이 군을 나누었다: 1.0 mm, 1.5 mm 그리고 2.0 mm. 8주의 치유기간 후에 희생하여 조직 절편을 얻었다. 이를 조직학 및 조직계측학적으로 관찰하였다.

실험 결과, 치관부 결손 폭이 증가함에 따라, 채워지지 않은 면적이 넓어지는 양상을 보였다. 거친 표면의 임플란트는 표면처리 되지 않은 임플란트에 비해 골 형성이 우수하였으며 쐐기형 골 결손은 평행형 골 결손에 비해 우수한 골 형성이 관찰되었다.

이상의 결과를 통해, 임플란트 주위의 환상형 골 결손 치유에 있어 임플란트의

표면성질, 골 결손의 결손 폭, 결손 부 형태 등은 중요한 영향을 미치며, 표면 처리된 임플란트 주위에 2 mm 이내의 환성 형 골 결손은 특별한 재생 술식이 필요 없으며 쐐기형 골 결손은 평행형 골 결손에 비해 빠른 치유가 관찰된다는 결론을 얻었다.

핵심되는 말: 결손부 크기, 결손부 형태, 임플란트 표면, 간극