Vertical Ridge Augmentation Using Xenogenous Bone Blocks: A Comparison Between the Flap and Tunneling Procedures

Feng Xuan

Department of Medicine

The Graduate School, Yonsei University

Vertical Ridge Augmentation Using Xenogenous Bone Blocks: A Comparison Between the Flap and Tunneling Procedures

Directed by Professor Byung-Ho Choi

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Feng Xuan

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This certifies that the doctoral dissertation of

Feng Xuan is approved.

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Thesis Supervisor: Prof. Byung-Ho Choi

____

Thesis Committee Member: Prof. Jae-Ha Yoo

____

Thesis Committee Member: Prof. Seung-Mi Jeong

____

Thesis Committee Member: Prof. Won-Gyun Chung

____

Thesis Committee Member: Prof. Byoung-Young Choi

The Graduate School

Yonsei University

July 2013

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ABSTRACT

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(Directed by Professor Byung-Ho Choi, D.D.S., M.S.D., Ph.D.)

Objective. Previous studies have shown that the subperiosteal tunneling procedure accelerates post-grafting healing and prevents graft exposure with minor post-operative complications because it is minimally invasive. It is conceivable that new bone formation would be greater with the tunneling procedure than with the flap procedure. This hypothesis was tested in this study by comparing new bone formation between the flap and tunneling procedures after vertical ridge augmentation using xenogenous bone blocks in a canine mandible model.

Study design. Bilateral, edentulated, flat alveolar ridges were created in the mandibles of 6 mongrel dogs. After 3 months of healing, 2 Bio-Oss® blocks were placed on the edentulated ridge in each side of the mandible. The blocks in each side were randomly assigned to 1 of the following 2 surgical techniques: 1) grafting with a flap procedure (flap group) or 2) grafting with a tunneling procedure (tunneling group). Six months later, biopsy specimens of the graft sites were obtained and prepared for ground sectioning and analysis.

Results. In the flap group, the newly formed bone was mostly observed in the apical portion of the block. In the tunneling group, the newly formed bone was observed not just at the base of the block but also in the more coronal regions of the graft. Some of the specimens in the tunneling group showed fairly extensive bone formation close to the top of the graft. The mean percentage of newly formed bone within the block was 15.3 ± 6.6 % in the flap group and 46.6 ± 23.4 % in the tunneling group. The difference was statistically significant.

Conclusion. Based on the data presented in this study, when a tunneling procedure is used to place xenogenous bone blocks for vertical ridge augmentation, bone formation in the graft sites is significantly greater than when a flap procedure is used. Based on these results, ridge augmentation using a subperiosteal tunneling procedure with Bio-Oss® blocks might be useful for implant placement in atrophic alveolar ridges.

Key Words: ridge augmentation, block bone graft, xenogenous bone, tunneling technique, minimally invasive surgery

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I. Introduction

Vertical augmentation of the alveolar ridge is necessary in cases with extensive resorption of the alveolar ridge to perform aesthetic prosthetic rehabilitation and implant insertion. The crown height space increases with inadequate bone height for proper length implants. The crown height space affects the force factors. The force applied to the implants increases with increasing height space.[1-3] .Under these conditions, a greater lever action is applied to the implant, which can cause bone loss around the implant, and finally lead to implant failure. Vertical ridge augmentation will reduce the crown height space and improve the implant biomechanics. In addition, the crown height space affects esthetics. As a result, the vertical ridge augmentation will allow an esthetic prosthesis.

Several surgical techniques have been used to increase bone height including distraction osteogenesis, particulate bone grafts with a titanium mesh or barrier membranes, and onlay block bone grafts. Distraction osteogenesis is technically demanding and often unacceptable for patients who cannot tolerate intraoral distraction devices.[26] Some major complications of this technique are basal bone fracture, transport of segments, loss of fixation screws, mal-union or non-union, premature consolidation, and lingual positioning of segments. Grafts of particulate bone with a titanium mesh or barrier membranes offer predictability in providing bone augmentation in both horizontal and vertical directions.[4-6] However, it is technically complex because of the premature exposure of the barrier membrane or titanium mesh resulting in secondary infections and consequently failure of bone regeneration.[7,8] Nystrom et al.[9-11] studied the use of onlay block bone grafts, harvested from the iliac crest in the reconstruction of severely resorbed maxillae in 30 human subjects. The authors observed that the height of the bone grafts decreased from a mean 8.2 mm to 6.2 mm during the first 24 months after surgery. In addition, the width of the grafts significantly reduced from a mean 12.2 mm to 8.7 mm. Similar findings were previously presented by Stoelinga et al.[12,13] and Davis et al.[14] In a recent study, Widmark et al.[15] described the use of bone tissue harvested from the mandible and used as an onlay graft in the anterior maxilla to allow placement of single-tooth implants. The width of the augmented ridge was clinically determined before and after the grafting procedure, as well as at implant installation and abutment connection. The authors reported that the amount of bone resorption (measured by buccal/palatal direction) that occurred between the time of grafting and abutment connection amounted to 60%. Similar observations were made by Ozaki and Buchman[16] in an experiment with rabbits. They studied the resorption that occurred following the placement of onlay grafts of cortical bone (form the mandible) or cancellous bone (from the ilium) on the cranium of rabbits. Four months after the grafting procedure, the cortical bone graft had retained only 56% of its original volume, while the cancellous graft was almost completely resorbed. From the above findings, it may be concluded that autogenous block bone grafts undergo marked resorption during healing. In recent studies, xenogenous bovine bone (Bio-Oss®) blocks have been considered an alternative to the above-mentioned autogenous bone blocks because it reduced resorption and morbidity.[17-20] Bio-Oss® is deproteinized bovine cancellous bone with a similar structure to human bone and with osteoconductive properties. The material is available in either particulate or block forms. One of the main advantages of the block-type material is that it can be shaped to fit in the anatomical structure of the recipient site. Bio-Oss® is chemically and physically identical to human bone and is highly osteoconductive.[21] It provides an ideal scaffold for new bone formation.[21-24] Bio-Oss® contributes to the osteoconductive effect of bone formation because new bone forms by creeping substitution.[25] Bone growth by resorption or apposition from the surrounding bone is known as creeping substitution.

Current surgical trends are towards minimally invasive surgical techniques that minimize surgical trauma, post-operative discomfort and morbidity. Such techniques have been reported for periodontal regeneration and alveolar ridge augmentation procedures.[26-28] A subperiosteal tunneling technique, which was performed with a small incision and minimal tissue dissection, has been reported using particulate hydroxyapatite and a particulate human mineralized bone allograft to enhance the thin alveolar ridges.[4-6] In previous studies, both tunneling and block bone grafting procedures have been independently evaluated in humans and animals. No study has yet directly addressed the effect of block bone grafting combined with a tunneling technique on vertical ridge augmentation. In this study, a subperiosteal tunneling technique using Bio-Oss® blocks was performed for bone augmentation in an atrophic alveolar ridge. Previous studies have shown that the subperiosteal tunneling procedure accelerates post-grafting healing and prevents graft exposure with minor post-operative complications.[29-32] It is conceivable that new bone formation would be greater with the tunneling procedure than with the flap procedure. This hypothesis was tested in this study by comparing new bone formation between the flap and tunneling procedures after vertical ridge augmentation using Bio-Oss® blocks in a canine mandible model.

II. Material and Methods

1. Animal model

A total of 6 healthy mongrel dogs, each weighing ≥15kg and with an mean weight of 18kg were used in this study. The experimental protocol was approved by the Animal Care and Use Committee of Yonsei University, Wonju, Korea.

2. Edentulated flat ridge induction

All surgical procedures were performed under systemic and local anesthesia. For systemic anesthesia, 5 mg/kg ketamine (Ketara® , Yuhan, Seoul, Korea) and 2 mg/kg xylazine (Rompun® , Bayer, Seoul, Korea) i.m. were used. For local anesthesia, 2% lidocaine (Yuhan, Seoul, Korea) with 1:80,000 epinephrine was used. After removing all of the mandibular premolars, bilateral flat alveolar ridges were surgically created. Briefly, a mucoperiosteal flap was raised to expose the alveolar bone. Burs were then used to flatten the alveolar crest under sterile saline irrigation to create an appropriate bone width for graft placement. The mucoperiosteal flap was replaced and sutured, and the resulting edentulated flat alveolar ridge was allowed to heal for 3 months (Fig 1).

Antibiotic therapy with an intramuscularly injection of cefazolin at a dose of 25 mg kg day was administered 1 hour before surgery and once daily after surgery for 2 days. After the surgery, the dogs were fed a soft-food diet.

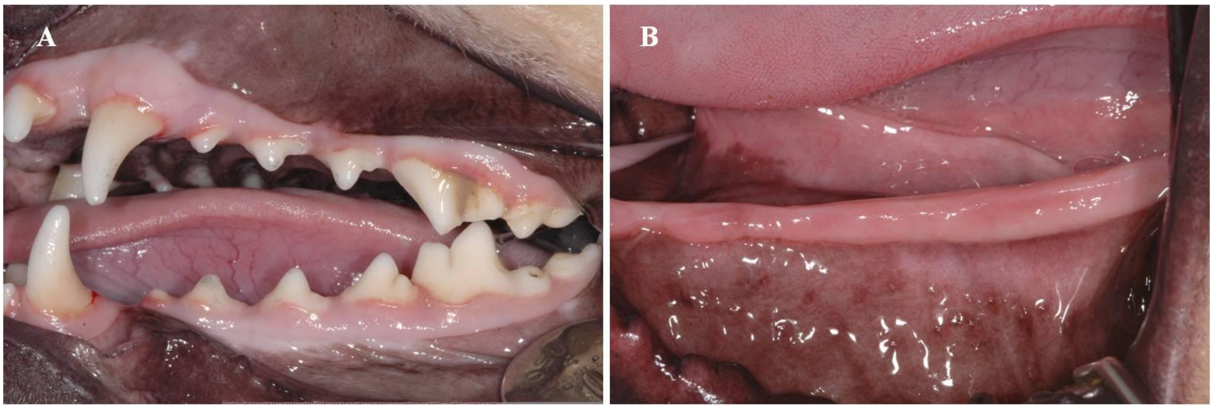

Fig 1. Animal model of mongrel dog. A: Before extraction B: After edentulated flat ridge induction.

3. Grafting procedure

After a 3 month of healing period, 2 Bio-Oss® blocks (Geistlich Pharma AG, Wolhuser, Switzerland) were placed on the edentulated ridge in each side of the mandible. The graft was 0.5 x 0.5 x 1 cm in size (Fig. 2). The blocks in each side were randomly assigned to 1 of the following 2 surgical techniques: 1) grafting with a flap procedure (flap group) or 2) grafting with a tunneling procedure (tunneling group). In the flap group, a buccal incision was made along the mucogingival junction on the buccal side of the edentulous ridge. A relieving incision was made in the mesial and distal edges of the buccal incision, allowing for the elevation of a mucoperiosteal flap. A Bio-Oss® block was placed in the defect area. An incision was made through the periosteum to advance the flap over the graft material. The periosteum incision was necessary to achieve primary closure without tension. The flap was repositioned with 4-0 silk sutures (Fig. 3). In the tunneling group, a vertical incision was made approximately 8 mm from the defect site on the buccal side of the alveolar ridge. A subperiosteal tunnel to the defect site was established. Tunneling was performed by lifting the periosteum using a periosteal elevator without any releasing incision on the periosteum. After establishing the tunnel, a Bio-Oss® block was placed in the defect area through the tunnel. Neither fixation screws nor barrier membranes were used to retain the graft in the position. The vertical incision was closed with interrupted silk sutures (Fig 4). Cefazoline was administered 1 hour before surgery and once daily for 2 days following after the surgery. The dogs were fed a soft-food diet to reduce trauma to the surgical sites.

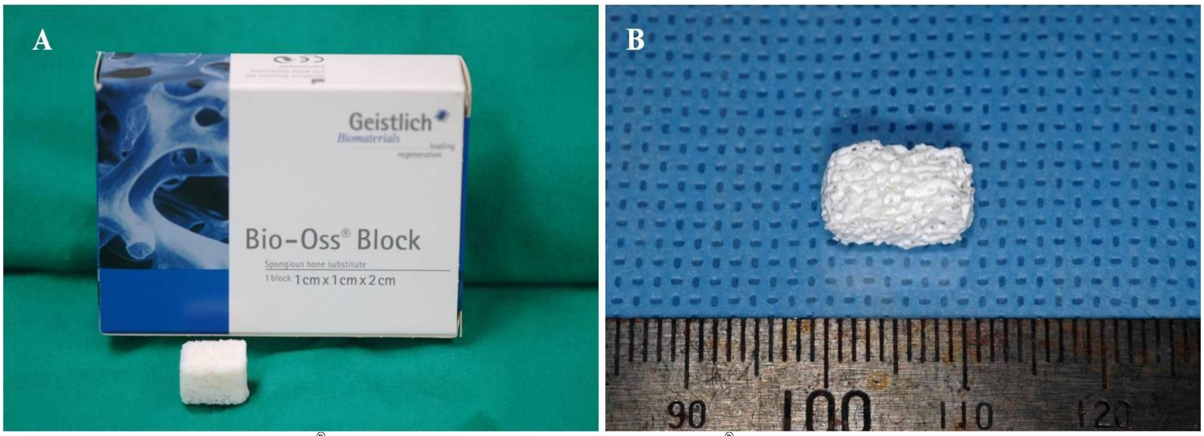

Fig 2. A: A Bio-Oss® block, B: The shaped Bio-Oss® block.

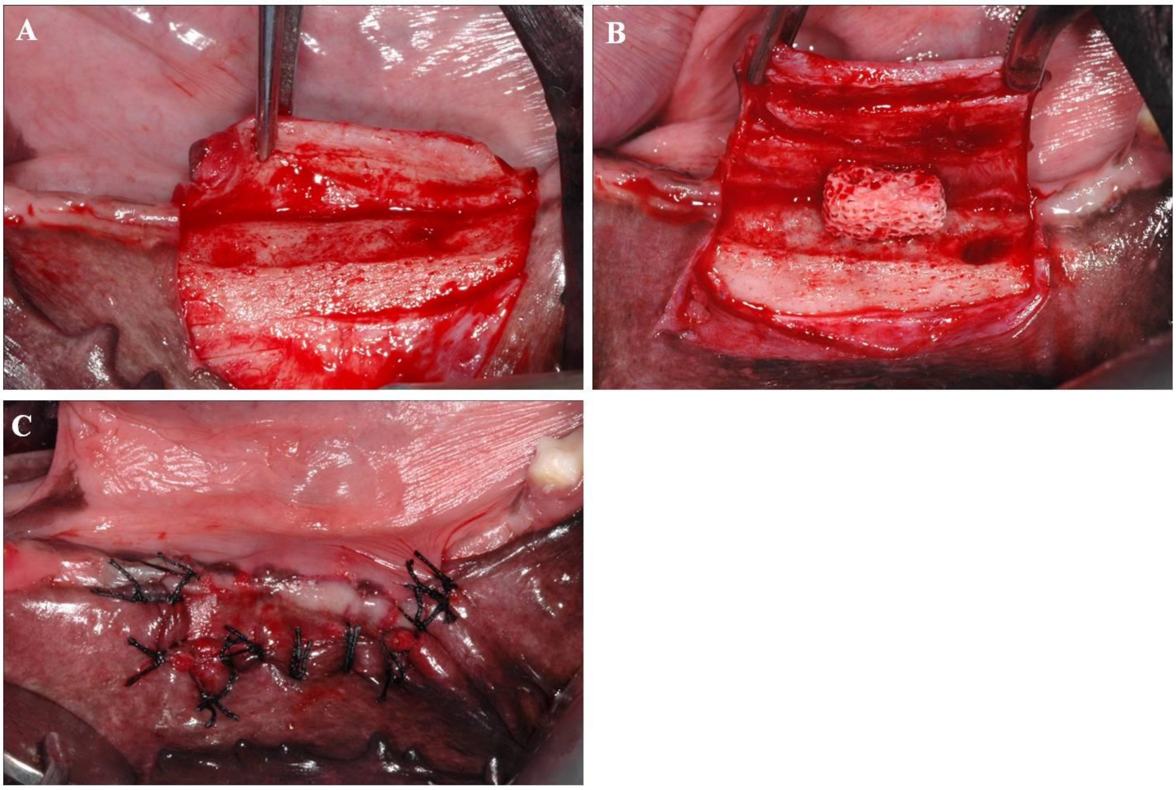

Fig 3. Intraoral view of the flap procedure after flap elevation (A), after grafting a Bio-Oss® block (B) and after reposioning the flap (C).

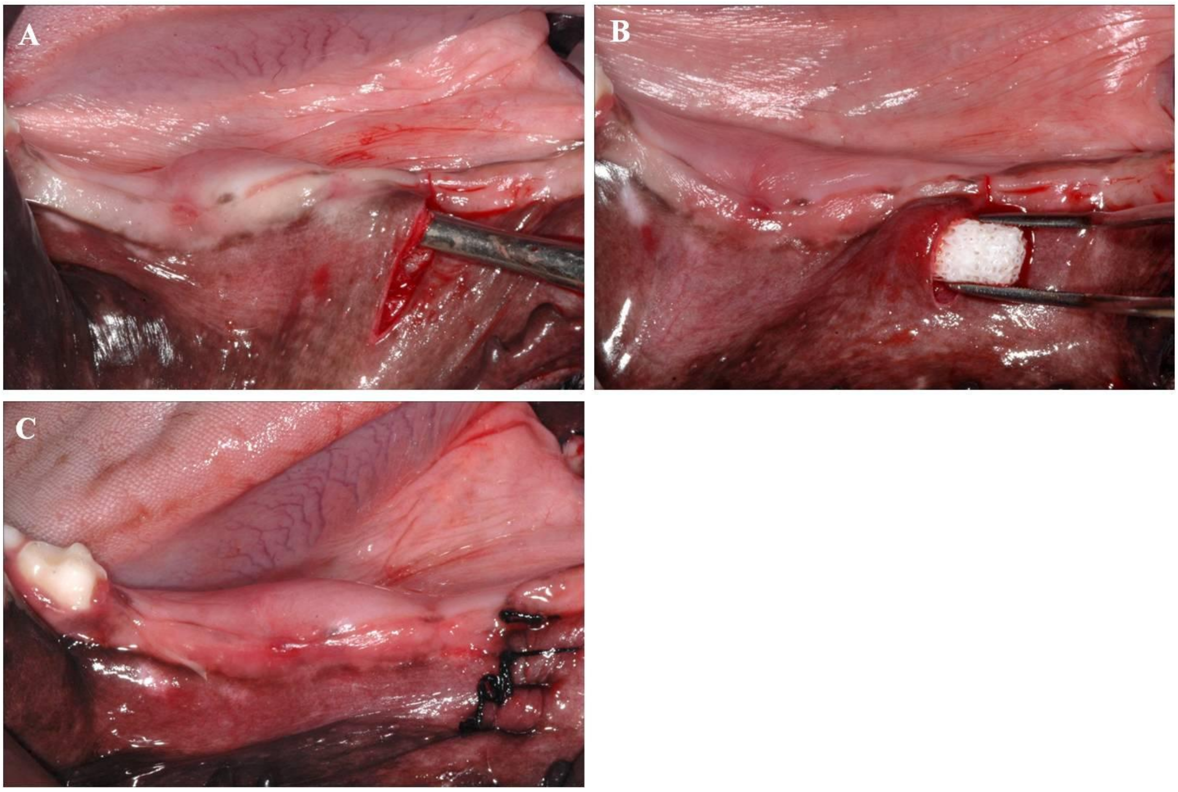

Fig 4. Intraoral view of the tunneling procedure. A: A subperiosteal tunnel to the defect area was established, B: A Bio-Oss® block was placed in the defect area through the tunnel, C: The vertical incision was closed with interrupted silk sutures.

4. Preparation of specimen

After 6 months of healing, the dogs were sacrificed and biopsy specimens of the graft sites were obtained and prepared for ground sectioning and analysis. The resected specimens were fixed in 10% buffered formalin for 7 days and embedded in methyl methacrylate resin. The blocks were sectioned in a bucco-lingual plane using a cutting-grinding unit. Histological sections were stained with hematoxylin and eosin (H-E staining).

5. Clinical evaluation

Clinical evaluation was performed 6 months after the grafting procedures to document any signs of complications such as wound dehiscence, infection, or fistula formation.

6. Radiographic evaluation

Conventional dental radiographs were obtained at the time of implant placement and after the 6-month healing period to observe radiographic changes of the Bio-Oss® block in the defect area.

7. Histomorphometric analysis

A morphometric study using an image analysis system (IBAS, Contron, Erching, Germany) was performed to quantify the newly formed bone in the Bio-Oss® blocks. Firstly, the outer border of the original block was traced and the area of the newly formed bone was also traced. The percentage of the newly formed bone area within the block area was then calculated .

8. Statistical analysis

Statistical analysis was performed using SPSS program version 20 (SPSS Inc., Chicago, IL, USA). Independent *t* -test was used to calculate the statistical differences between groups. Values of $p < 0.05$ were considered statistically significant.

III. Results

1. Clinical evaluation

Healing after grafting procedures was uneventful in all animals. None of the dogs developed complications such as wound dehiscence, infection or fistula formation. The gum over the graft material was in good condition in all animals (Fig. 5). No macroscopic movement or displacement of the blocks was detected.

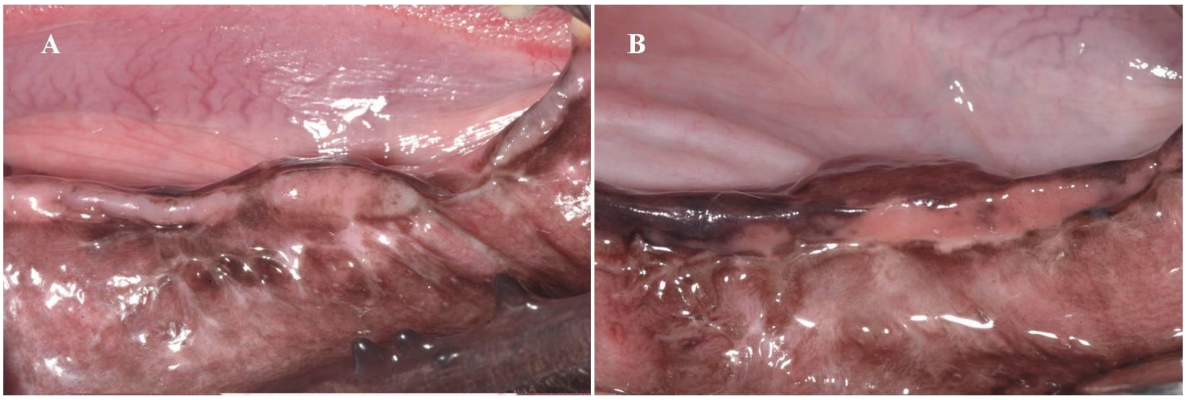

Fig 5.The gum condition over the graft material at 6 months after the flap (A) and tunneling (B) procedures.

2. Radiographic evaluation

In the radiographic evaluation, the bovine block bone hardened over time and was integrated with the basal bone, and its initial shape was maintained in all animals. In terms of radiographic evidence of ossification in the block, the blocks in the tunneling group showed higher bone density than those in the flap group (Fig. 6).

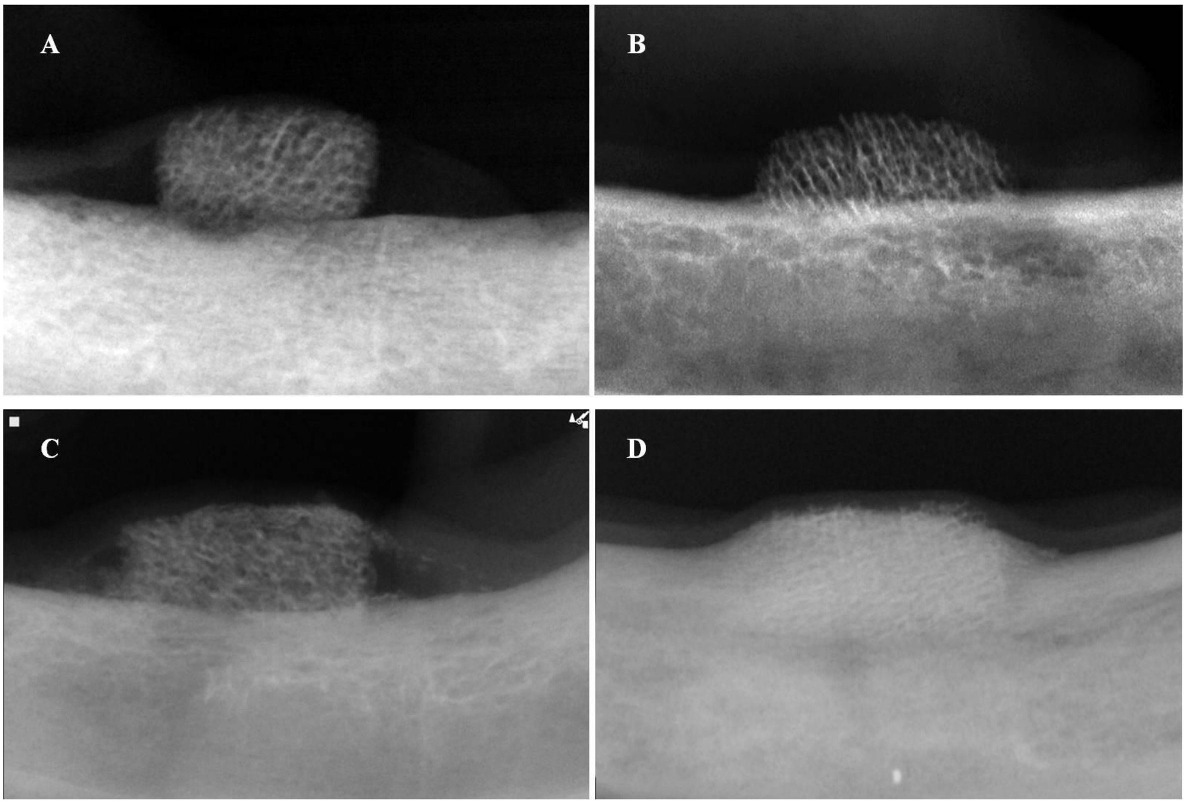

Fig 6. Radiographic evidence of ossification in the blocks. A: Immediately after the flap procedure, B: Six months after the flap procedure, C: Immediately after the tunneling procedure, D: Six months after the tunneling procedure.

3. Histomorphometric analysis

The histological examination of the Bio-Oss® grafted sites disclosed the presence of a block of biomaterial characterized by its trabecular structure. As a result, the outer border of the original block was easily identified (Fig. 7). The outer portion of the graft was separated from the mucosa by dense layers of connective tissue. Close to the interface between the graft and the host bone, a varying amount of newly formed bone had established contact with the biomaterial and the graft was well integrated with the basal bone. New bone formation was observed around the Bio-Oss® graft, and direct deposition of bone was found on the surface of the material (Fig. 8). This new bone occupied the inter-trabecular areas and was continuous with the bovine bone. New bone filled the spaces between the Bio-Oss® trabeculae, most of which were buried within new bone. Osteoid was detected in some cases, indicating active bone formation within the graft material. No infiltration of inflammatory cells was detected.

In the flap group, the newly formed bone was mostly observed in the apical portion of the block (Fig. 9). In the more coronal regions of the graft, fibrous connective tissue was found to occupy the inter-trabecular regions (Figs. 10 and 11). In the tunneling group, histological examination of the sites revealed that during healing, the transplanted block had increased new bone formation. Thus, newly formed bone was observed not just at the base of the block but also in the more coronal regions of the graft (Fig. 12). Some of the specimens showed fairly extensive bone formation close to the top of the graft. The results of the histomorphometric analysis are given in Table 1. The mean percentage of the newly formed bone within the block was 15.3 ± 6.6% (range: 6.7-23.1) in the flap group and 46.6 ± 23.4% (range: 21.1-74.7) in the tunneling group. The difference was statistically significant.

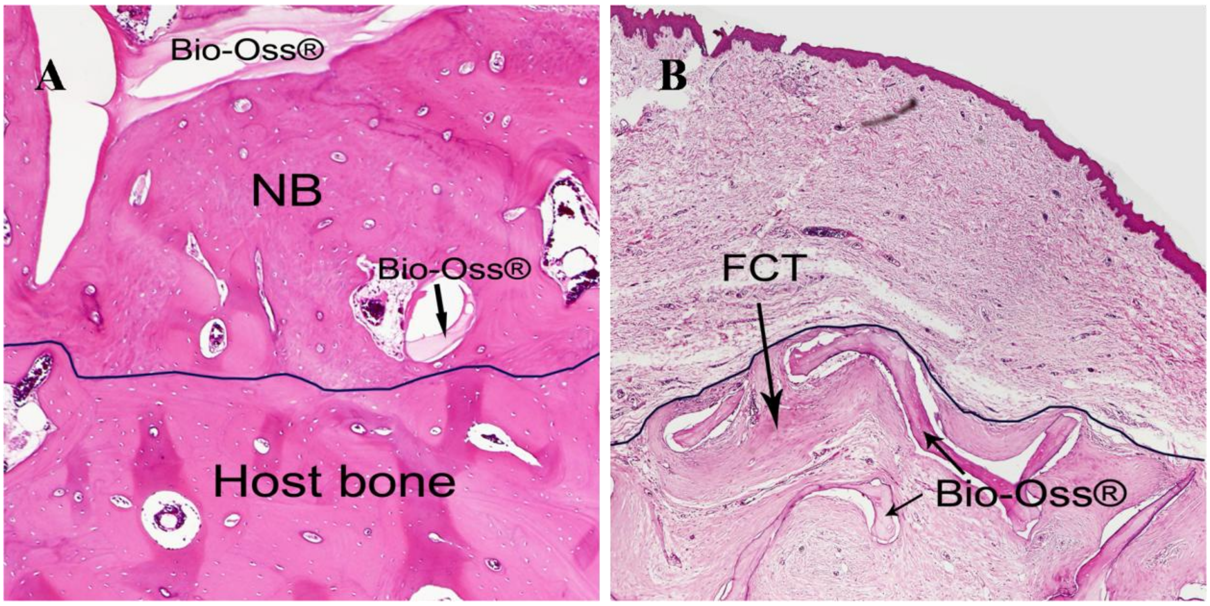

Fig 7. The outer borders (black line) of the original block at the base (A) and the top (B). NB: New bone, FCT: Fibrous connective tissue. Original magnification x40.

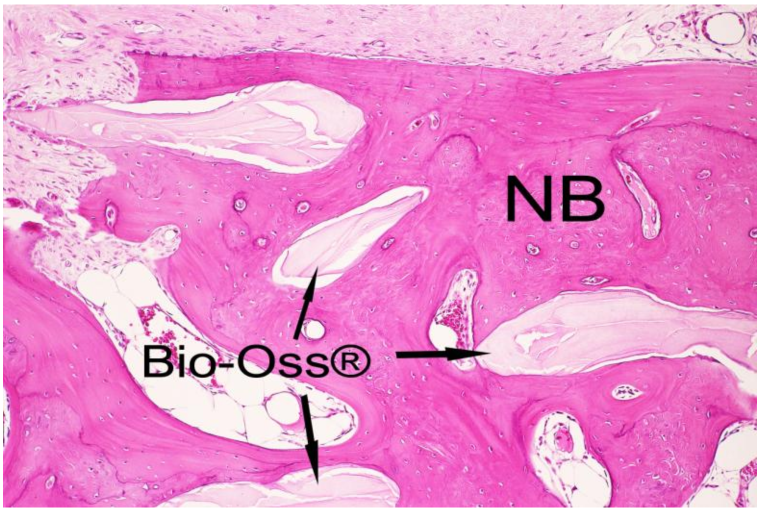

Fig 8. Histological view of the Bio-Oss® graft. Note that new bone formation was observed around the Bio-Oss® graft and there was direct deposition of bone on the surface of the material. NB: New bone. Original magnification x40.

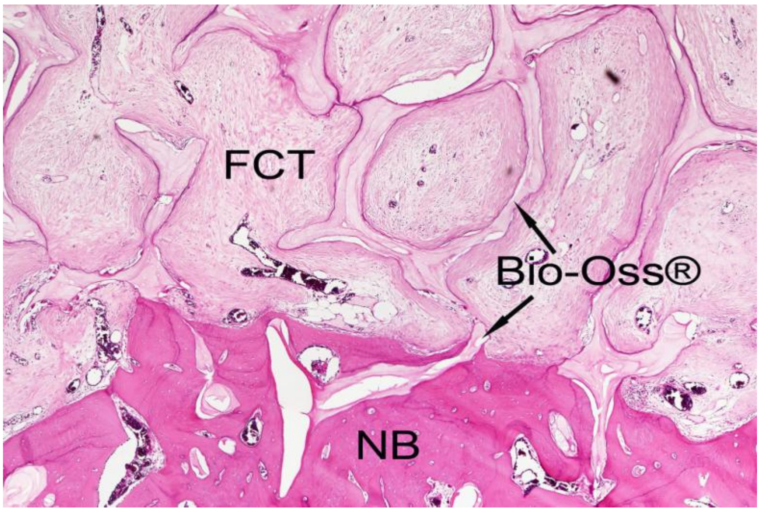

Fig 9. Histological view of the Bio-Oss® graft at the apical level of the graft in the flap group. Note that the newly formed bone was mostly observed in the apical portion of the block. NB: New bone, FCT: Fibrous connective tissue. Original magnification x40.

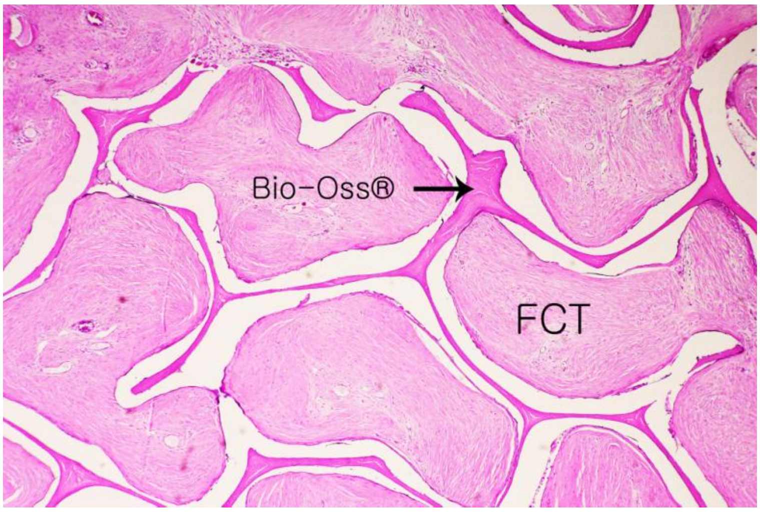

Fig 10. Histological view of the Bio-Oss® graft at the coronal level of the graft in the flap group. Note the presence of fibrous connective tissue in the inter-trabecular space. FCT: Fibrous connective tissue. Original magnification x40.

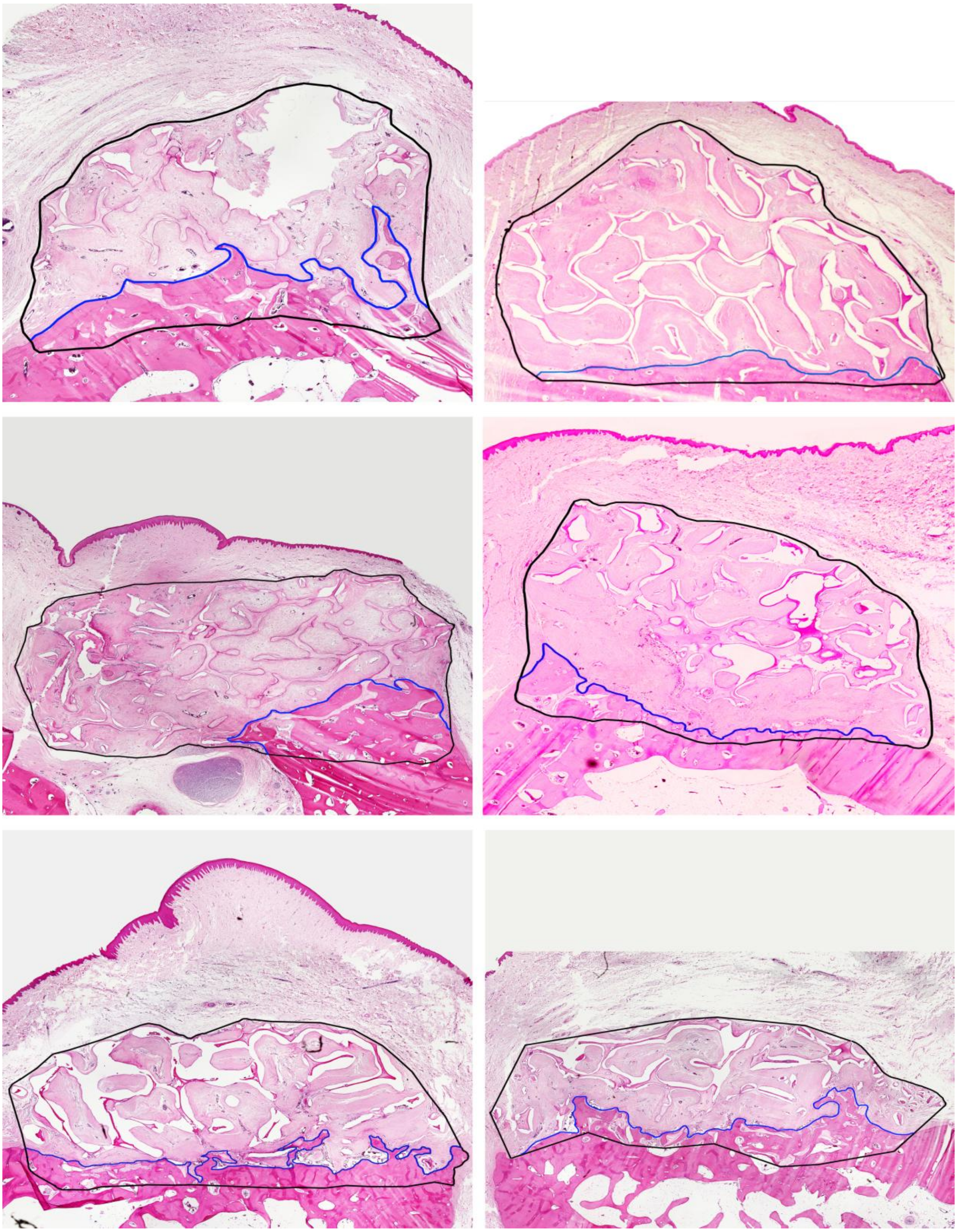

Fig 11. View of the specimens in the flap group showing new bone formation mostly in the apical portion of the block. The black line illustrates the outer border of the block and the blue line illustrates the border of the newly formed bone. Original magnification x12.

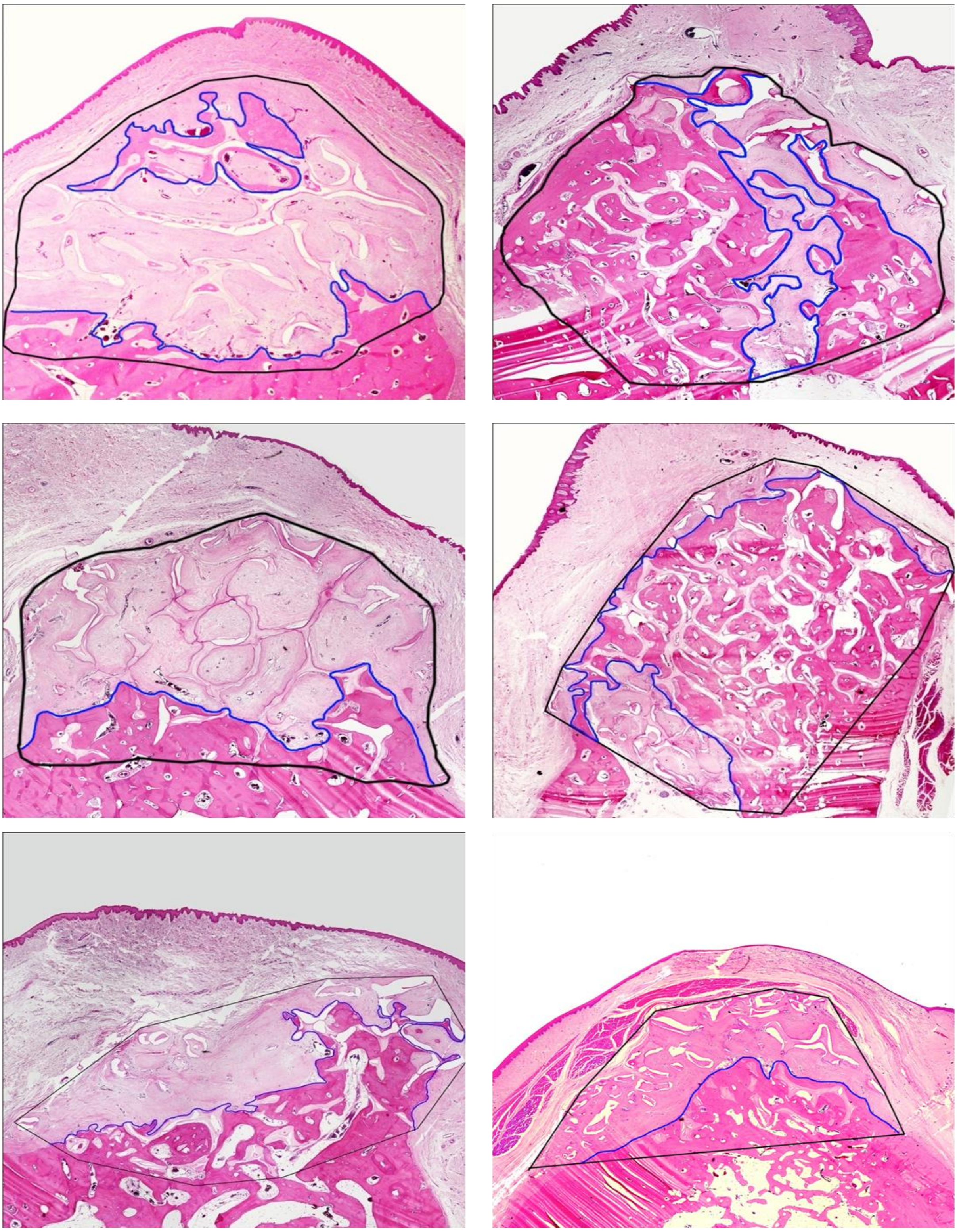

Fig 12. View of the specimens in the tunneling group showing extensive bone formation in the coronal regions of the Bio-Oss® graft. The black line illustrates the outer border of the block and the blue line illustrates the border of the newly formed bone. Original magnification x12.

Table 1. Results of the histomorphometric analysis describing the percentage of the newly formed bone within the block per dog.

Dog number	Flap	Tunneling	*P*-values
1	23.1	21.1	
2	6.7	73.8	
3	17.3	24.4	
4	8.4	74.7	
5	15.4	47.3	
6	21.1	38.5	
Mean ± SD	15.3 ± 6.6	46.6 ± 23.4	< 0.05

IV. Discussion

The present study demonstrated that there were marked differences between the flap and tunneling procedures, regarding new bone formation within Bio-Oss® blocks placed on the surface of an edentulous ridge in the flap group, the new bone generally formed at the base of the block, whereas in the tunneling group, the new bone formed not just at the base of the block, but also in the more coronal regions of the graft. Some of the specimens in the tunneling group showed fairly extensive bone formation close to the top of the graft. The reason for the different outcomes in both procedures is most likely explained by the effect of the periosteum. In the flap procedure, an incision is made through the periosteum to advance the flap over the graft and to achieve primary closure without tension, which allows the graft material to be covered without the periosteum. In contrast, with the tunneling procedure, the periosteum is lifted without flap elevation or a releasing incision of the periosteum. The preservation of the periosteum might help optimize bone formation. The role of the periosteum in osteogenesis, in which it serves as a source of pluripotent mesenchymal cells and osteoblasts, is well documented.[33-36]

Several studies have reported the use of the Bio-Oss® block for ridge augmentation. In a study by Araujo et al.,[17] a Bio-Oss® block was fixed on the buccal aspect of the jaw of dogs and covered with a collagen membrane using mucoperiosteal flap elevation. The authors found that after a 6-month healing period, large portions of the blocks were filled with connective tissue, with only moderate amounts of new bone formed at the base of the graft. Furthermore, most of the newly formed bone was observed to be continuous with the host bone at the recipient site. The amount of new bone that formed within the trabecular network of the Bio-Oss® block during the 6 months interval amounted to 23% of the original graft volume. These findings are in accordance with those of our study, showing 15.3% (range: 6.7-23.1) of the new bone formation at the base of the block. However, after the tunneling procedure with the Bio-Oss® block, the mean percentage of newly formed bone was 46.6% (range: 21.1-74.7) in the block. The results of this study suggest that bone formation in the graft sites is significantly greater when a tunnelling procedure is used to place a Bio-Oss® block for vertical ridge augmentation than when a flap procedure is used. In view of the fact that there was no bone formation in the remaining 53.4% of the block after the tunneling procedure with the Bio-Oss® block, there is still a need to improve bone formation with the tunneling technique, as the remaining graft material is likely to be infected. The tunneling technique is believed to become one of the most vital methods for enhancing bone formation.

In the present experiment, the Bio-Oss® graft maintained the volume and framework of the trabecular bone. This finding is in agreement with previous observations that documented that this graft material is only slowly resorbed when placed in humans and experimental animals.[37] In addition, osteoclast-like cells were observed on the surface of the Bio-Oss® material. This finding demonstrates that 6 months after the grafting procedure there was some bone-forming activity in the Bio-Oss® material. Therefore, it may be speculated that with longer periods of healing a more comprehensive bone formation could have occurred within the graft. Such an assumption is, however, not in agreement with previously published studies.[38-41] These studies concluded that the beneficial effect of deproteinized bovine bone mineral was limited to the initial stage of healing and that at later stages, the biomaterial may have been an obstacle to bone formation.

In terms of structural rigidity, Bio-Oss® block grafts have benefits over Bio-Oss® particulate grafts because they are strong and can be shaped to match the host site. However, the fragility of the bovine bone block should be noted to prevent a fracture of the integrity of the block. In the present study, the Bio-Oss® block that was 0.5 x 0.5 x 1 cm in size could be safely placed in the defect area through the subperiosteal tunnel. There were some limitations in the bone augmentation height in the subperiosteal tunneling procedure for ridge augmentation, possibly because of the limitations in lifting the periosteum. It is important to elevate the periosteum without perforation when using this technique. Based on our data, a subperiosteal tunneling procedure with a Bio-Oss® block onlay graft is suggested when <6 mm of bone augmentation in an atrophic area of the mandible is needed.

Unlike traditional guided bone regeneration (GBR) procedures, in which the placement of an appropriate barrier membrane is integral to the success of the procedure, this study showed that new bone formation through the bovine trabecular bone block could occur in the absence of a barrier membrane. This supports the hypothesis that barrier membranes are not required in xenogenous block grafting. The concept of a barrier membrane to create a secluded space and prevent the ingrowth of competing non-osteogenic cells into the defect area has been challenged by recent studies.[18,20,42,43] Preclinical and clinical studies have supported the use of xenografts without a membrane for significant ridge augmentation in both horizontal and vertical defects, showing no significant differences in the sites treated with a xenogenous block with or without a mechanical barrier membrane.[18,20,42,43] In addition, a membrane might inhibit progenitor cell migration and angiogenesis by presenting a physical barrier to chemotaxis.

The current procedures for the treatment of atrophic alveolar ridge often require intraoral or extraoral bone harvesting, inferior alveolar nerve transposition, or distraction osteogenesis. These procedures have increased morbidity and discomfort in patients.[16] In the present study, a Bio-Oss® block was placed in an atrophic alveolar ridge through the subperiosteal tunnel. No soft tissue complications were encountered during the 6-month post-grafting healing phase, such as soft tissue wound dehiscence, infection, or fistula formation. The subperiosteal tunneling procedure is preferred because it is minimally invasive. The technique offers the advantages of a more conservative surgical entry and lower postoperative morbidity, thereby reducing surgery time and minimizing the level of post-operative pain, edema, and infection. Therefore, the use of Bio-Oss® block grafting combined with a tunneling technique avoids many of the difficulties associated with current therapies.

In the previous studies, both tunneling and block bone onlay grafting procedures have been independently evaluated in humans and animals. No study has yet directly addressed the effect of the block bone onlay grafting combined with a tunneling technique on vertical ridge augmentation. Araujo et al.[17] and Rothamel et al.[20] reported on the use of a Bio-Oss® block for ridge augmentation using flap elevation. Kent et al. [44] reported on the subperiosteal tunneling technique using particulate bone. They described that the location of the vertical incision was dependent on the region of the jaw to be augmented.[44] In the present study, a vertical incision was made approximately 8 mm from the defect site on the buccal side of the alveolar ridge. In the mandible, damage to the mental nerve must be carefully avoided while detaching the periosteum and placing the block. In this series of 6 dogs, we performed a highly successful procedure to augment the vertical bone height in the edentulous mandible. In all test sites, grafting blocks were well settled, wound healing was improved, and bone formation was enhanced. Ridge augmentation using a subperiosteal tunneling procedure with Bio-Oss® blocks might be useful for implant placement in atrophic alveolar ridges.

V. Conclusion

Based on the data presented in this study, bone formation in the graft site is significantly greater when a tunnelling procedure is used to place Bio-Oss® blocks for vertical ridge augmentation than when a flap procedure is used. Based on these results, ridge augmentation using a subperiosteal tunneling procedure with Bio-Oss® blocks might be useful for implant placement in atrophic alveolar ridges.

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Abstract in Korean (국문요약)

이종골 이식을 이용한 치조골 수직증대에 관한 연구: 플랩 방법과 터널링 방법 비교

현 봉

연세대학교 대학원 의학과

(지도교수 최병호)

목적. 이전에 보고된 연구결과에 의하면 터널링 방식으로 골 이식 했을 때 수술 후 치유기간이 단축되고, 골이식재료의 노출 등 술 후 합병증이 최소화 한다고 보고되었다. 이러한 결과에 기초할 때 터널링 방법으로 골이식을 시행할 때 플랩 방법보다 더 많은 신생골이 형성되리라 추론된다. 이러한 추론을 증명하고자 본 연구에서는 성견의 하악 무치악치조골에 터널링 방법과 플랩 방법으로 이종골을 이식하여 수직증대를 시행한 후 두 방법의 신생골 형성효과를 비교분석 하였다.

연구설계. 여섯 마리의 성견에서 하악의 양측에 무치악의 평편한 치조제를 형성하였다. 3 개월 동안의 치유 기간 후, 두 개의 Bio-Oss® 블록을 각각 무치악인 하악 양측에 이식하였다. 한 측에는 플랩 방법으로 블록골을 이식하였고 (플랩 그룹), 반대 측에는 골막하 터널링 방법으로 블록골을 이식하였다 (터널링 그룹).

골이식후 6 개월 후 표본을 채취하여 조직학적 분석을 시행하였다.

결과. 플랩 그룹에서는 신생골 형성이 대부분 이식한 블록의 밑바닥 부분에서 관찰된 반면, 터널링 그룹에서는 신생골 형성이 블록의 바닥 부분뿐만 아니라 상부에서도 관찰 되었다. 터널링 그룹 일부 표본에서는 상당히 많은 신생골 형성이 이식골의 상단까지 관찰되었다. 이식골의 내부에 형성된 신생골의 평균비율은 플랩 그룹에서 15.3 ± 6.6 % 이고 터널링 그룹에서는 46.6 ± 23.4 % 이였다. 두 그룹의 신생골 형성비율은 통계학적으로 유의성있는 차이를 보였다.

결론. 본 연구의 결과에 의하면 치조골의 수직골 증대를 위해 이종 블록골 이식을 시행할 경우 플랩 방법보다 터널링 방법을 사용하면 더 많은 신생골이 형성된다. 그러므로 골막하 터널링 방법과 이종 블록골을 이용하는 치조골 수직증대 술식은 위축된 치조 능선에서 임플란트 식립을 위해 유용하게 사용될 수 있다고 사료된다.

핵심 되는 말: 치조골 증대, 블록골이식, 이종골, 터널링, 최소 침습수술