치의과학박사 학위논문

Supplemental Periodontal Regeneration by Vertical Ridge Augmentation around Dental Implants

수직골 증대술을 동반한 임플란트 식립이 인접치아의 치주조직 재생에 미치는 영향

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서울대학교 대학원

치의과학과 치주과학 전공

이 창 석

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지도교수 구 영

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2019 년 12 월

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- Abstract -

Supplemental Periodontal Regeneration by Vertical Ridge Augmentation around Dental Implants

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Objectives: To evaluate the supplemental periodontal regeneration on adjacent teeth by vertical ridge augmentation around dental implants.

Material and methods: The second premolar and the fourth premolar were extracted from both sides of the mandible in four beagle dogs. After 2 months, defects 3 mm and 5 mm deep were formed. In the test group, vertical ridge augmentation was performed around a dental implant, and in the control group, vertical ridge augmentation was performed without implant placement. The animals were euthanized 3 months after the procedure, and radiographic, histomorphometric analyses were performed.

Results: Overall, the test group showed better results than the control group. The presence of new cementum in the histological examination of the test group confirmed that vertical ridge augmentation with proper space maintaining could contribute to periodontal regeneration of adjacent teeth. Statistically significant difference in new bone height (%) was found in group I (5 mm defect depth and implant placement, GBR) when compared with group III (5 mm defect depth, GBR), IV (3 mm defect depth, GBR). New bone area (%) was statistically different between groups I and IV.

Conclusions: In conclusion, within the limitation of this study using mandibular residual ridges after extraction of a single tooth in dogs, grafted space was maintained by dental implants better in the deep defect (5 mm depth) than the shallow defect (3 mm depth). Vertical ridge augmentation around dental implants also promoted neighboring periodontal regeneration.

Key words: Guided tissue regeneration, Bone regeneration, Bone substitutes, Bone implant interactions, Periodontology

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Introduction

The biological basis of guided tissue regeneration (GTR) is that epithelial and gingival connective tissue are prevented from occupying the defect area by placing a physical barrier, which provides an isolated space for the repopulation of periodontal ligament cells and mesenchymal cells on the instrumented root surface (Karring et. al., 1985; Villar et. al., 2010; Sculean et. al., 2008). It was thought that there were four connective tissue components in the periodontal tissue: gingival corneum, cementum, periodontal ligament and bone tissue. And it was assumed that the regeneration of periodontal ligament only comes from the periodontal ligament cells. It can be said that GTR research originated from this assumption. (Melcher., 1976) Treatment of the first human tooth with GTR was reported by Nyman. et al. in 1982. Since then GTR has been used in various clinical situations. GTR has been applied in degree II and degree III furcations (Jepsen et al., 2002). GTR could also be successfully used for intrabony defects and gingival recessions (Yen et. al., 2014; Wang et. al., 2012). Guided bone regeneration (GBR) was developed based on the GTR principle. The application of the GBR was first investigated in an experimental study in rats (Dahlin et al., 1988). Ever since GBR has undergone lots of research, it become an essential technique for replenishing scarce bones around implants. Vertical ridge augmentation is one of various GBR techniques. With GBR, the osteogenic cell populations from the parent bone colonize the wound space and restore the bony deficiency if invasion by undesirable soft tissue is mechanically impeded (Dahlin et. al., 1989; Retzepi et. al., 2010). A barrier membrane is used for GBR with or without bone graft. When a proper space is formed by the membrane, blood clots surrounded by the membrane are replaced with granulation tissue. Bone remodeling follows in a pattern similar to bone development and growth (Schenk et. al., 1994). GBR has been successfully used for the treatment of peri-implant bony defects and for ridge preservation of the alveolar socket after tooth extraction (Retzepi et. al., 2010). The success rate of implant is reported to be more than 90% when GBR is applied simultaneously (Clementini et. al., 2012), and fewer complications have been reported compared to other types of surgery such as onlay grafts or sinus grafts (Jensen et. al., 2016).

The success of GBR depends on the fulfillment of certain criteria; 1) exclusion of epithelium and connective tissue, 2) space maintaining, 3) stability of the fibrin clot, and 4) primary wound closure (Liu et. al., 2014). Among these, space maintaining is considered the most crucial factor. Various methods and combinations of methods, including the use of a reinforced titanium membrane or titanium mesh, distraction osteogenesis, and a tenting screw have been used. A dental implant could also be used as a tent pole for securing space. A novel surgical technique using autogenous cancellous marrow graft and a dental implant as a tent pole was proposed (Marx et. al., 2002). Vertical ridge augmentation by bone graft, using a titanium-reinforced membrane and a dental implant in a “tenting” fashion to support the soft tissue matrix, was also tried (Suzuki et. al., 2017). In a prospective study of 20 patients, it was concluded that the tent pole technique is safe and effective for vertical bone augmentation (Daga et. al., 2015). The barrier membranes used for GBR have several desirable characteristics including biocompatibility, cell-occlusion properties, integration by the host tissues, clinical manageability, space-making ability, and adequate mechanical and physical properties (Elgali et. al., 2017). The barrier membranes can be classified as resorbable or non-resorbable membranes (Rakhmatia et. al., 2013). Additional surgery is required for removal of the membrane if a non-resorbable membrane is used. In this study, resorbable membranes were used to eliminate the need for this additional surgery. Equally successful treatment outcome of vertical ridge augmentation could be expected by either resorbable membrane or non-resorbable membrane (Merli et. al., 2010). However, for edentulous ridge by multiple missing teeth vertical ridge augmentation with non-resorbable membrane could be safer and more predictable treatment than resorbable membrane (Urban et. al., 2009). In the present study, vertically deficient edentulous ridge was made experimentally after the extraction of a single tooth. For this short span of edentulous area, resorbable membrane could be applied for vertical ridge augmentation. Although resorbable membranes may have a tendency to collapse, they have been successfully used for vertical ridge augmentation (Merli et. al., 2014; Beitlitum et. al., 2010). Specifically, vertical ridge augmentation was performed using resorbable collagen barriers supported by an osteosynthesis plate (Merli et. al., 2014). Additionally, particulate mineralized freeze-dried bone allograft covered by a resorbable cross-linked collagen membrane was used for vertical ridge augmentation (Beitlitum et. al., 2010). It has been proposed that an implant tent pole and particulate graft materials can block the collapsing of the membrane.

Based on these, we hypothesized that the use of vertical ridge augmentation on the edentulous ridge could assist periodontal tissue regeneration around the adjacent teeth in a fashion similar to GTR. Since GTR and GBR share similar biological concepts, it may be assumed that GTR effects occur in adjacent teeth when GBR is performed. However, we thought that it should be verified as much as possible. We further hypothesized that space for tissue regeneration could effectively be maintained with a dental implant used as a tent pole. The purpose of this animal study was to evaluate the supplemental periodontal regeneration by vertical ridge augmentation around dental implants. To our knowledge, this is the first reported study to assess this use of the GBR method. In addition, as recent researches tended to focus on implants, this paper was designed to divert interest into natural teeth.

Materials and Methods

Animals

This study was approved by the Seoul National University Institutional Animal Care and Use Committee (SNU-180605-2). This study adhered to the ARRIVE guidelines. Four male beagle dogs between 1-2 years old and weighing 10-12 kg were used. The experimental procedures were carried out as previously reported (Lee et. al., 2016). Specifically, all surgical procedures were performed under general anesthesia by sedation with 8.0 mg/kg zoletil (Zoletil50, Virbac S.A., Carros, France) and 0.25 mg/kg xylazine (Rompun, Bayer Korea, Ansan, Korea). All of the dogs had fully- erupted permanent dentitions. The dogs were housed individually under ambient temperatures of 20-25^{o} C and relative humidity of 30-70% and were fed a soft diet. The surgical sites were locally anesthetized using 2% lidocaine hydrochloride with 1:100,000 epinephrine (Lignospan; Septodont, Cedex, France).

Surgical Procedure

Mandibular second premolars (P_2) and fourth premolars (P_4) were extracted at baseline by sectioning in the buccolingual direction at the bifurcation area using a high-speed handpiece with a diamond point. After 2 months of healing, 3-mm- or 5-mm-deep defects were formed in the edentulous area between the two teeth (Figure 1,2,3,4,5). Defect depth was based on the critical-size defect model (Wikesjo et. al., 2006). The bony wall was removed in order to simulate a vertical defect. Proximal root surfaces of adjacent teeth neighboring bony defects were exposed and planed carefully with hand instruments without any damage by rotary instruments. Bucco-lingual root surfaces of adjacent teeth were not exposed. Pristine bone at least 5 mm high was secured for stabilization of the implant. Animals were grouped according to defect depth (3 mm or 5 mm). In the test group, dental implants (IS III, Neo Biotech, Seoul, Korea) with a diameter of 3.5 mm and a length of 10 mm were placed in the bony defect site and vertical augmentation was performed. In the control group, vertical augmentation without a dental implant was performed in the defect area. A resorbable non cross-linked collagen membrane (Bio-Gide, Geistlich Pharma AG, Wolhusen, Switzerland) and deproteinized bovine bone mineral (BioOss, Geistlich Pharma AG, Wolhusen, Switzerland) were used for the vertical augmentation procedure.

Test and control group allocation

- **Test groups**

Group I. (5 mm defect depth and implant placement, GBR)(n=4)

Group II. (3 mm defect depth and implant placement, GBR)(n=4)

- **Control groups**

Group III. (5 mm defect depth, GBR) (n=4)

Group IV. (3 mm defect depth, GBR) (n=4)

Radiographic analysis (Periapical radiograph and Micro CT)

Periapical digital radiographs were taken using Port-XII (Genoray, Sungnam, Korea, 60 kv, 2 mA, 0.12 sec) 1 and 2 months after vertical augmentation to verify whether the augmented bone was securing space for new bone formation. Before the histologic examination, jaw blocks were radiographically evaluated (Hsu et. al., 2017). A micro computed tomography system (SkyScan1173, Bruker, Kontich, Belgium) was used at 130 kV and 60 μA with 500 ms of exposure time. The resolution was 13.85 μm pixels. Reconstruction of images and measurements on the image were performed according to the manufacturer's guidelines on the software (Nrecon [ver.1.7.0.4] and CTAn [ver.1.17.7.24], Bruker, Kontich, Belgium). Distance from CEJ to new bone was measured as follows. The first imaginary line was made connecting cementoenamel junctions (CEJ) of adjacent teeth on the approximate central mesiodistal plane showing center of adjacent teeth and implant. The second imaginary line which is parallel to the first imaginary line and contacting the top of new bone or bone substitute was made. The distance between the first and second imaginary line was measured.

Histologic Examination and Histometric Analysis

Following scheduled euthanasia of each animal, the mandible was surgically removed, and eight tissue blocks were prepared for each animal (Lee et. al., 2016). The mesial and distal area of each second and fourth premolar area were obtained. Specimens were immediately placed in 10% neutral-buffered formalin for 48 hours. After tissue fixation, the tissue blocks were trimmed and then the tissue containing the non-decalcified bone was embedded in polymethylmethacrylate. Each block was sectioned in the mesiodistal plane and parallel to the long axis of the neighboring tooth. Sections were ground to 50 μm thickness with a microgrinding unit. Each section was stained with Multiple Stain Solution (Polysciences, Inc. Warrington USA). Using an optical microscope (Olympus BX 50, Olympus Optical, Tokyo, Japan), histologic evaluation and histometric analyses were conducted at 1.25x and 4x magnification.

The data collected were as follows (Figure 6) : 1) New bone height (%) of the neighboring tooth; 2) New bone area (%) near the neighboring tooth. New bone height (%) was measured using an image processing program (TOMORO ScopeEye 3.6, Saram Soft, Gyeonggi, Republic of Korea). The new bone height was the distance from the top of the bone to the notch marked on the root surface. A point 2.5 mm away from the tooth surface was used as a horizontal reference point when measuring new bone area (%). Identified bone on the imaginary defect area was considered as new bone because it is difficult to differentiate new and old bone exactly. New bone and bone substitute were differentiated by presence of lacunae or lamella and continuity from pristine bone. The new bone area (%) was calculated using image processing and analysis programs (TOMORO ScopeEye 3.6, Saram Soft).

Statistical Analysis

For each group, mean, standard deviation (SD), median, and inter-quartile ranges were calculated. Overall comparisons among four groups were implemented using the Kruskal-Wallis test. When statistically significant differences among the groups were present, post-hoc multiple comparisons using the Mann-Whitney methods were made with adjustment of alpha level by the Bonferroni-correction method. Statistical software package SPSS Statistics for Windows, Version 18.0 (SPSS Inc., Chicago, USA) was used for all analysis. Results with $p<0.05$ were considered statistically significant.

Results

Clinical and radiographic evaluation

All surgical sites in the control and test groups demonstrated uneventful healing without any sign of serious inflammation. All of the cover screws were exposed in the test groups (Figure 7). Periapical radiographs showed that vertically augmented bone was well securing the space for new bone formation in the test groups (Figure 8 A and B). Relatively less amount of augmented bone was found in control groups (Figure 8 C and D).

Micro CT analysis

Overall, the distance from CEJ to new bone measured in the control groups was greater than that of the test groups (Table 1, Figure 9). This suggests increased bone formation in the experimental group compared to the control group. However, these differences were not statistically significant.

Histologic examination

Overall, the test groups demonstrated greater bone formation than their corresponding control group with a matched defect depth (Figure 10). The bone particles in the test groups were well integrated and stabilized. New cementum was observed on the adjacent tooth in the test groups (Figure 11).

Histometric analysis

New bone height (%) and area (%) are shown in Table 1. Overall, the new bone height (%) of neighboring teeth was also greater in the test groups than control groups. Statistically significant difference in new bone height (%) was found in group I when compared with group III, IV. Overall, the new bone area (%) was higher in the test groups than control groups. New bone area (%) was statistically different between groups I and IV.

Discussion

The goal of this study was to evaluate the supplemental periodontal regeneration by vertical ridge augmentation around dental implants. In the test group, an implant was used as a tent pole, and in the control group, vertical ridge augmentation was performed without implant placement. In this experiment, four dogs were tested. Although four samples are not sufficient numbers, we designed this based on a highly cited paper about healing patterns after GBR which deals with four dogs (Schenk et. al., 1994). Two months after extraction implant was placed. It was based on a study of extraction sites, which concluded that after 60 days, healing would be sufficient for placing the implant (Cardaropoli et al., 2003). Animals were sacrificed 3 months after GBR. It was based on the study of healing pattern after GBR, and assumed that after 3 months there would be a healing between woven bone and lamellar bone which would be sufficient for histological examination (Schenk et. al., 1994).

The quality of regenerated bone was histologically assessed by measuring new bone area (%) in the augmented region. The level of bone regeneration was evaluated by the distance from CEJ to new bone and new bone height (%). The distance from CEJ to new bone was measured by micro CT. New bone height (%) was assessed by measuring the distance from reference points to the most coronal level of regenerated bone by histology. Overall, new bone area (%), distance from CEJ to new bone, and new bone height (%) were greater in the test group than in the control group. Statistically significant difference in new bone height (%) was found in group I when compared with group III, IV. New bone area (%) was statistically different between groups I and IV.

New bone height (%), which means the amount of periodontal regeneration on adjacent teeth was greater in 5 mm test group (group I) than 5 mm control group (group III) or 3 mm control group (group IV). Dental implants played their role as a tent pole for assisting periodontal regeneration on adjacent teeth successfully in 5 mm defect. However, assisting effect for periodontal regeneration by implants in 3 mm defect was not as good as 5 mm defect. Although bone area (%) in 5 mm defects didn't show any difference between test and control group, periodontal regeneration in 5 mm defects was greater in test group than control group. This demonstrates that the dental implants may not be effective in space maintaining for severely resorbed ridge, these implants could still assist successfully periodontal regeneration of adjacent teeth. Therefore, even in a severely resorbed ridge, the use of a dental implant for space maintaining on the edentulous area could enhance periodontal regeneration on adjacent teeth. To the contrary, in shallow defect (3mm), implant in edentulous ridge could not support periodontal regeneration on adjacent teeth successfully; statistically significant difference in new bone height was not found between 3 mm test group (group II) and 3 mm control group (group IV). We could assume that supplemental periodontal regeneration by implant support is more effective in deep defect (5 mm) than shallow defect (3 mm). In other words, in shallow defect (3 mm), supplemental periodontal regeneration could not be expected more when implant was placed in edentulous ridge.

New bone area (%), which means quality of augmented bone, was more in 5 mm test group (group I) than in 3 mm control group (group IV). Dental implants played their role as a tent pole successfully in the deep defect (5 mm). In this study, space maintaining by dental implants was more effective in the 5 mm defect than in the 3 mm defect. Additional vertical support by dental implants was not required to minimize collapse of augmented bone in the shallow defect (3 mm). There is likely a certain critical defect depth in which a dental implant maintains space more effectively.

Bone quality could be compromised without proper space maintaining. Overall, new bone area (%) in control groups (group III and IV) was not as good as test groups (group I and II). This suggests that the quality of augmented area after vertical ridge augmentation could be compromised without proper space maintaining by dental implants. Specifically, in shallow defects (3 mm), the quality of bone was poorer than in deep defects (5 mm). This could be related to the amount of augmented bone. Although a deep defect provides a greater challenge than a shallow defect, more graft can be applied to a deep defect. Therefore, after the space collapses, more graft material may remain in a deep defect than a shallow defect, and this residual material could have created more new bone in a deep defect.

Several limitations of the present study were found and should be modified for the future study. In this study, defect size was not standardized completely. Edentulous ridges were made after extraction of mandibular second and fourth premolars. As a result, 2 different lengths of edentulous ridge were made. To overcome this limitation, test and control groups were distributed equally to defects with different length. It would have been better if defect with same length had been used. If mandibular second, third and fourth premolars had been extracted, edentulous ridge with same length could have been tested. However, this would be the study design for edentulous ridge with long span. In the future study, the effect of vertical ridge augmentation on edentulous area after several missing teeth could be evaluated.

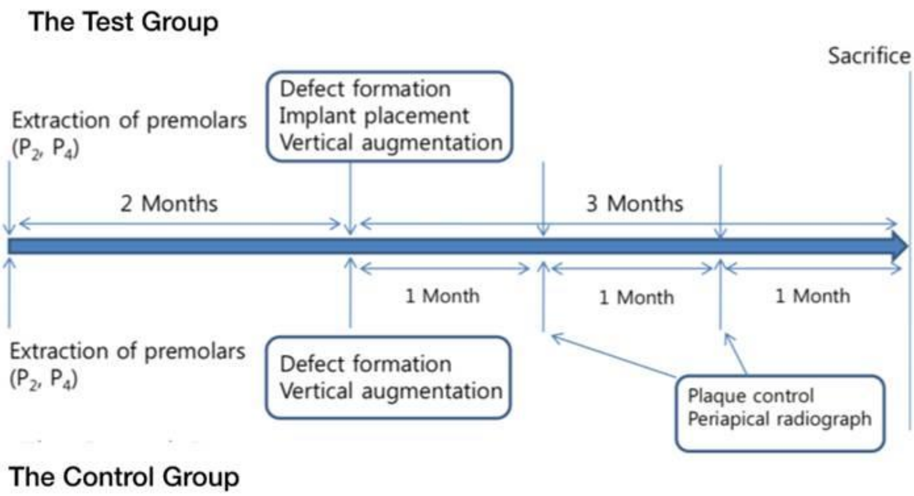
In this study, bone formation was less than expected. There are several possible explanations for this. First, the choice of membrane may have contributed (Rakhmatia et. al., 2013; Wang et. al., 2018). Specifically, a non-resorbable membrane may have been more effective in space maintaining, and a titanium-reinforced membrane or titanium mesh may have improved space maintaining and bone regeneration. However, in this experiment, a resorbable membrane was used to simplify the study design. Second, there might have been micro-movement in the augmented area (Hermann et. al., 2001; Becker et. al., 2012). It was reported that micro-movement has a greater detrimental influence on bone formation than other factors such as the micro-gap size of the implant abutment interface. In the augmented area, micro-movement could have interfered with new bone formation. Third, there was early exposure of the cover screw because of insufficient space maintenance. It was reported that exposure of the membrane inhibited bone formation (Garcia et. al., 2018). If the membrane and implant had not been exposed through soft tissue, the implant could have better fulfilled its role as a tent pole, and more new bone could have been formed (Cho et. al., 2018). Fourth, there might have been a huge surgical trauma during defect formation before implant placement. This trauma could have negatively affected new bone formation after ridge augmentation procedure. It would have been better if proper healing time (120 days) had been given before ridge augmentation procedure (Hsu et. al., 2017).

Despite these limitations, to the best our knowledge, this was the first study to assess the supplemental periodontal regeneration by vertical ridge augmentation around dental implants. It was well appreciated and published in Clinical Oral Implants Research (Lee C et al., 2019). Periodontal regeneration was observed in adjacent teeth, as evidenced by new bone and new cementum observed by histology. We hope that this research would be the new opportunity to divert attention to natural teeth. In future studies, vertical ridge augmentation on other types of bone defects and using other membranes could be tested to build upon these results.

Conclusion

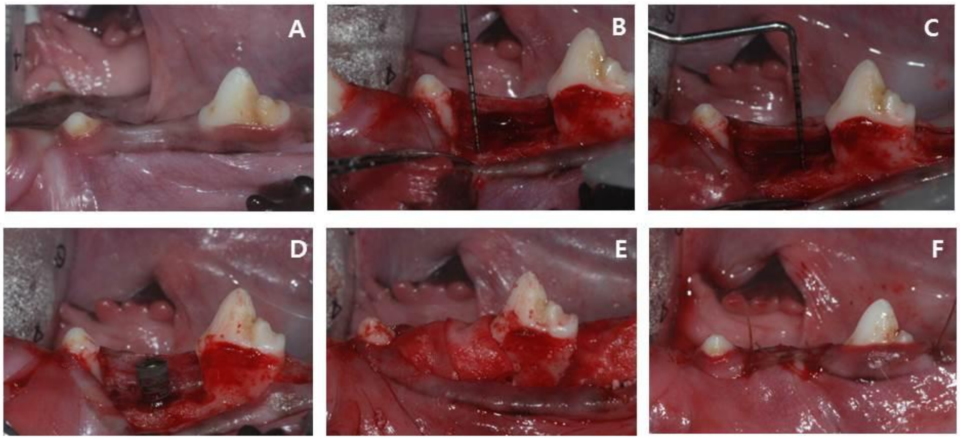
In conclusion, within the limitation of this study using mandibular residual ridges after extraction of a single tooth in dogs, grafted space was maintained by dental implants better in the deep defect (5 mm depth) than the shallow defect (3 mm depth). Vertical ridge augmentation around dental implants also promoted neighboring periodontal regeneration.

Figure 1. Experimental timeline



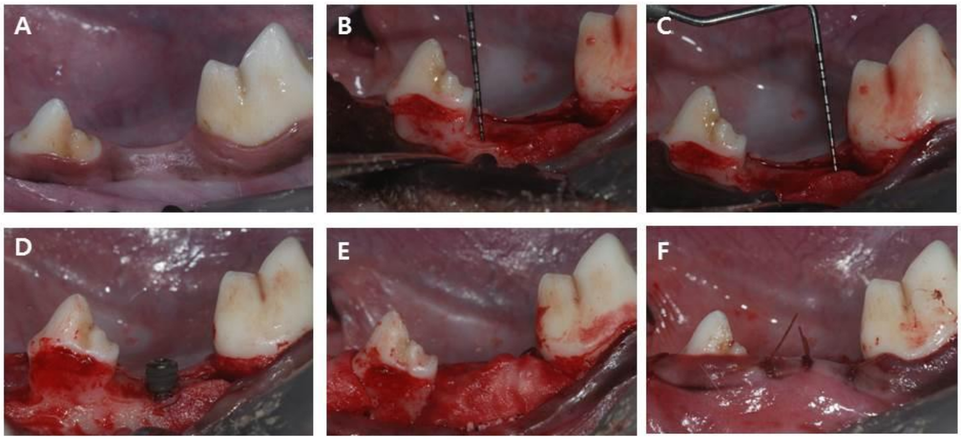
Plaque control and x-ray imaging were performed once a month throughout the experiment. All animals were sacrificed 3 months after implant placement and vertical ridge augmentation

Figure 2. Surgical procedure of group I (5 mm defect depth, implant placement with GBR)



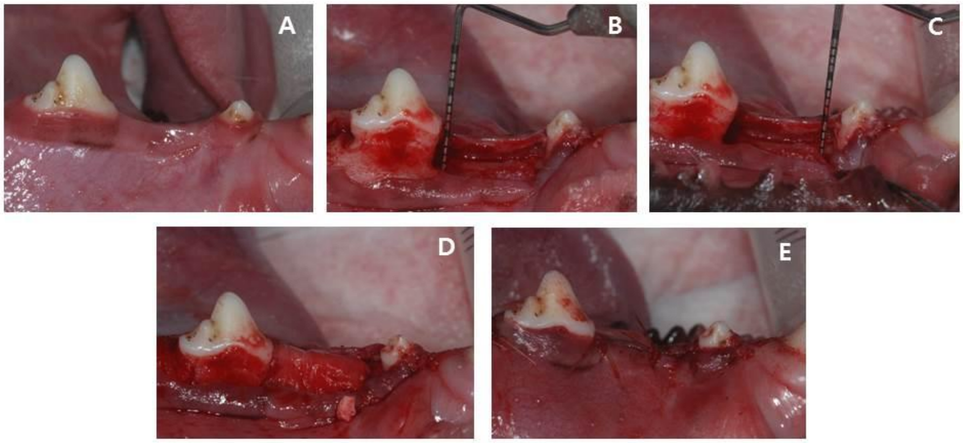
(A) Clinical photo was taken before surgery. (B and C) After 5 mm defect formation, defect depth was confirmed by dental probe. (D) Implant was placed and (E) guided bone regeneration was performed. (F) Postoperative suture was shown.

Figure 3. Surgical procedure of group II (3 mm defect depth, implant placement with GBR)



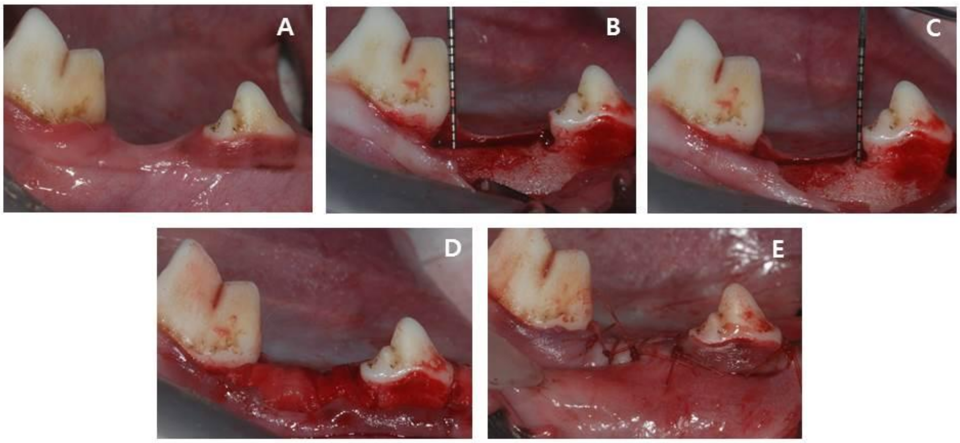
(A) Clinical photo was taken before surgery. (B and C) After 3 mm defect formation, defect depth was confirmed by dental probe. (D) Implant was placed and (E) guided bone regeneration was performed. (F) Postoperative suture was shown.

Figure 4. Surgical procedure of group III (5 mm defect depth, GBR)



(A) Clinical photo was taken before surgery. (B and C) After 5 mm defect formation, defect depth was confirmed by dental probe. (D) Guided bone regeneration was performed. (E) Postoperative suture was shown.

Figure 5. Surgical procedure of group IV (3 mm defect depth, GBR)



(A) Clinical photo was taken before surgery. (B and C) After 3 mm defect formation, defect depth was confirmed by dental probe. (D) Guided bone regeneration was performed. (E) Postoperative suture was shown.

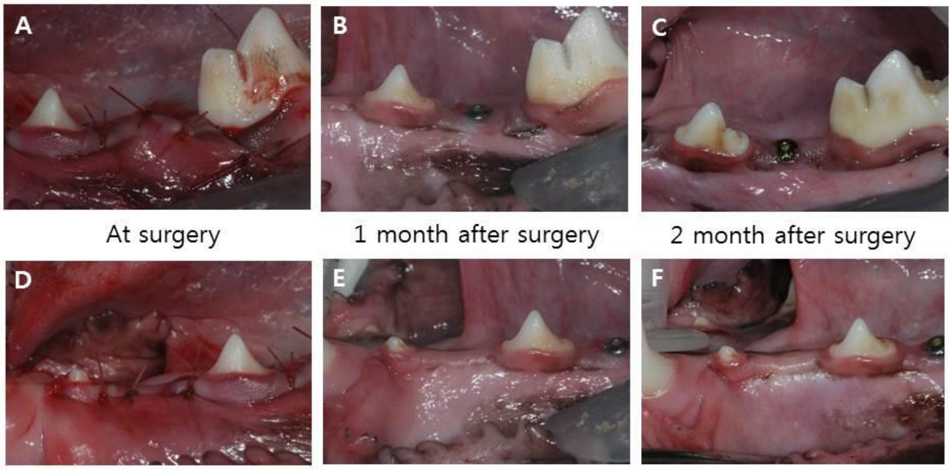
Figure 6. Histometric parameters

$$\text{New bone height (\%)} = \frac{\text{New bone height}}{\text{Defect depth}} \times 100$$

$$\text{New bone area (\%)} = \frac{\text{New bone area}}{\text{Defect area}} \times 100$$

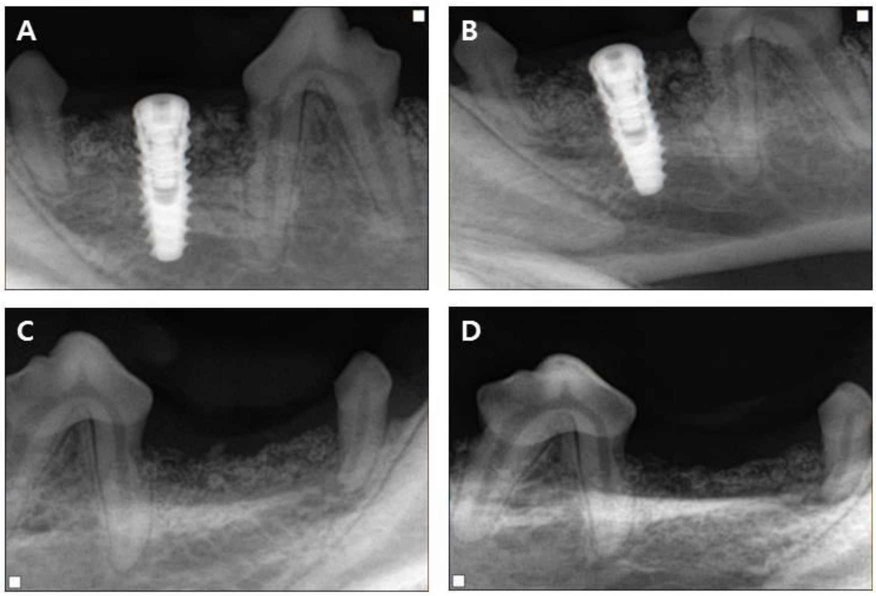
New bone height (%) was measured to evaluate the GTR effect. New bone area (%) was measured to evaluated the GBR effect.

Figure 7. Clinical examination at each time point



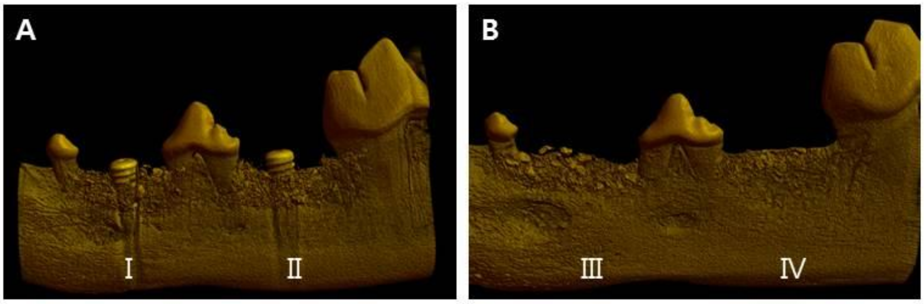
Clinical photos taken at surgery (A and D), 1 month after surgery (B and E) and 2 month after surgery (C and F). The photo above shows the experimental group and the photo below shows the control group.

Figure 8. Radiographs of test and control groups



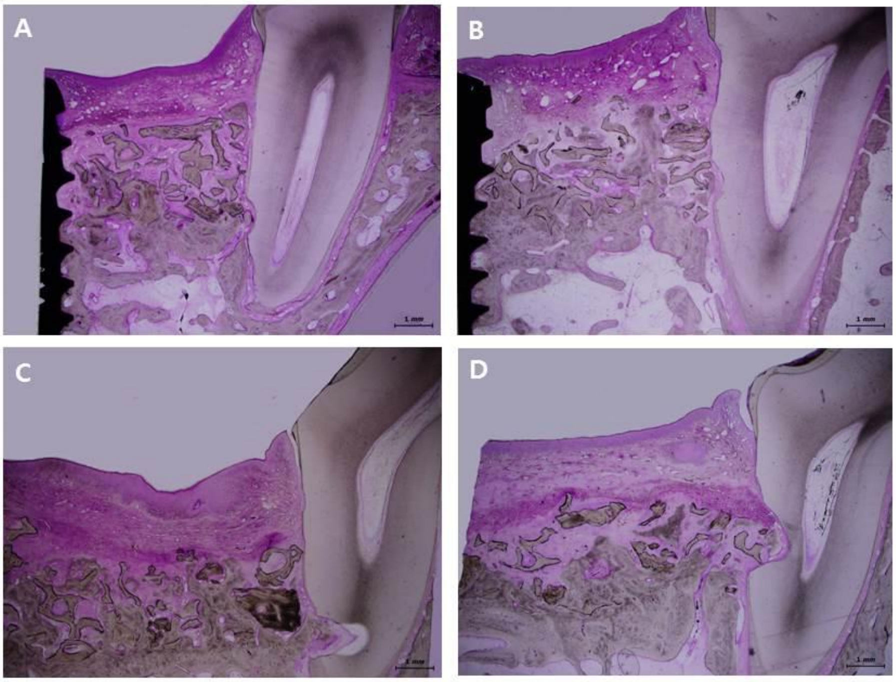
Radiograph was taken 1 month after vertical ridge augmentation with implant placement (A) and 2 months after vertical ridge augmentation with implant placement (B). Radiograph was taken 1 month after vertical augmentation without implant placement (C) and 2 months after vertical ridge augmentation without implant placement (D).

Figure 9. Micro CT analysis



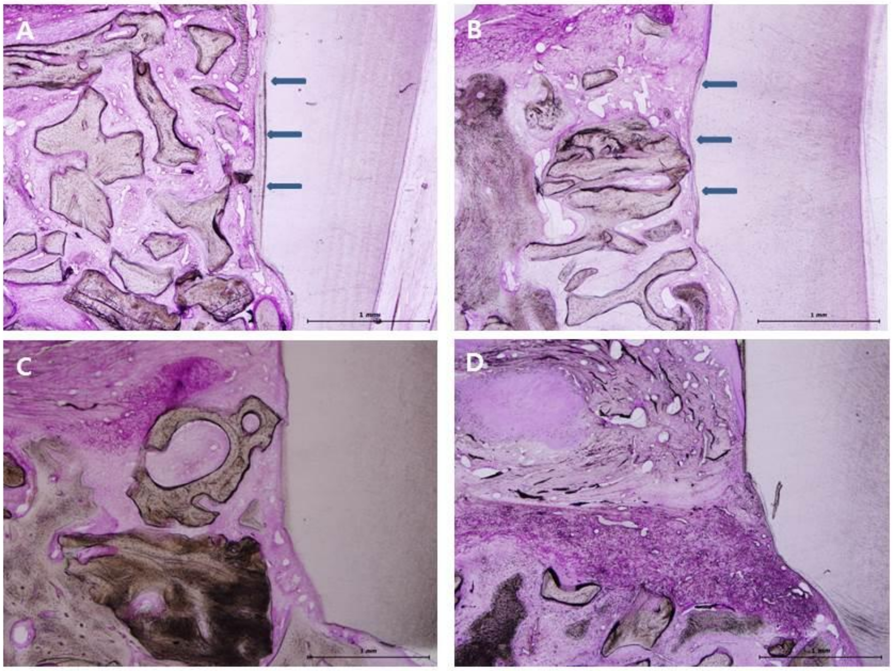
Representative micro CT 3D images of test groups I and II (A) and control groups III and IV (B).

Figure 10. Histologic examination



Representative microscopic images of group I (A), group II (B), group III (C), and group IV (D). Scale bar = 1 mm. Bone regeneration was observed above notch created on the root surface. The bone particles in the test groups were well integrated and stabilized compared to the bone particles in the control groups. (x1.25 magnification)

Figure 11. Histometric analysis



Microscopic images of group I (A), group II (B), group III (C), and group IV (D). In the test groups, new cementum was observed (arrows). In the control groups, new cementum was not identified. Scale bar = 1 mm (x4 magnification)

Table1. Mean, SD, Median and interquartile range (IQR)

	Group Ⅰ 5mm-test with implant	Group Ⅱ 3mm-test with implant	Group Ⅲ 5mm control	Group Ⅳ 3mm control	p-value
Distance from CEJ to new bone					
mean±SD (mm)	1.55±0.51	1.30±0.63	1.93±0.79	1.91±0.41	0.375
median	1.42	1.31	2.26	1.95	
IQR	1.21 - 1.76	0.86 - 1.75	1.80 - 2.38	1.61 - 2.24	
New bone height (%)					
mean±SD (%)	65.05±11.29 [a*]	47.61±20.71 [ab]	38.93±14.43 [b]	27.93±17.91 [b]	0.005
median	67.05	60.11	41.35	25.13	
IQR	57.31 - 72.98	32.56 - 63.15	29.69 - 48.19	22.81 - 30.75	
New bone area (%)					
mean±SD (%)	17.41±8.12 [a]	17.77±13.66 [ab]	9.25±9.08 [ab]	3.93±3.87 [b]	0.044
median	17.60	24.68	5.71	2.82	
IQR	11.08 - 23.84	5.02 - 25.90	3.47 - 7.38	1.91 - 4.36	

[*]Different alphabets, a and b mean significant difference at alpha error level of 0.05 by post-hoc comparison using the Mann-Whitney method with the Bonferroni-correction.

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-국문초록-

수직골 증대술을 동반한 임플란트 식립이 인접치아의 치주조직재생에 미치는 영향

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1. 목 적

이 연구의 목적은 치과 임플란트 식립시 수직골 증대술이 인접치아의 치주조직재생에 미치는 영향에 대하여 평가하는 것이다.

2. 방 법

4마리의 비글견을 대상으로 하악 양측 부위에서 제2, 4 소구치를 발거하였다. 발치 후 2개월 뒤 3 mm, 5 mm의 골결손부를 형성하였으며, 결손부의 깊이와 임플란트 식립 유무에 따라 총 4군으로 나누었다.

실험군에서는 직경 3.5 mm, 길이 10 mm의 치과용 임플란트 (IS III, Neo Biotech, Seoul, Korea)를 골결손부에 식립한 후 수직적 골이식술을 시행하였다. 대조군에서는 임플란트 식립 없이 수직적 골이식술을 시행하였다. 골이식술 시행시 흡수성 콜라젠 막 (Bio-Gide, Geistlich Pharma AG, Wolhusen, Switzerland)과 탈단백 우골 (BioOss, Geistlich Pharma AG, Wolhusen, Switzerland)을 사용하였다.

수술후 1개월 마다 방사선 검사와 임상검사를 시행하였고, 수술 3개월 뒤에 동물들은 안락사시켰다. 조직검사 전에 악골상에서 micro CT 검사를 시행하였고, 그 뒤에 조직표본을 제작하여 조직학적 검사와 조직계측학적 검사를 진행하였다. micro CT검사를 통해 CEJ와 신생골간의 거리를 측정하였고, 조직계측학적 검사를 통해 신생골의 높이와 면적 비율을 측정하였다.

각 집단마다 평균값, 표준편차, 중위값, 4분위간 범위를 계산하였다. 4개 집단 간의 전체적인 비교는 Kruskal-Wallis test를 사용하였고 집단

안에서 통계적인 차이가 존재할 경우에는 Bonferroni-correction 방법을 사용하여 사후검정을 실시하였다.

3. 결 과

실험군과 대조군의 모든 수술부위는 모두 염증소견 없이 치유가 되었지만, 실험군에서 임플란트 상방의 덮개나사 (cover screw)가 노출되었다. 대조군에 비해 실험군에서 더 많은 골재생이 관측되었다. 또한 조직학적 검사 결과 실험군의 수직골 증대술을 시행한 인접 치아에서 신생백악질이 관측되는 것으로 보아, 적절한 공간유지를 동반한 골유도재생술을 시행 시 인집치아에 치주조직 재생이 일어날 수 있음을 확인할 수 있었다. 통계적인 차이는 group I과 group III, IV사이의 신생골 높이 비율과 group I과 IV사이의 신생골면적 비율에서 발견되었다. 신생골 높이 비율을 통해 조직유도재생술의 효과를 볼 수 있었고, 신생골면적 비율을 통해서 골유도재생술의 효과를 볼 수 있었다. 따라서 이번 실험 결과를 통해 볼 때, 임플란트 지지대 (tent pole)등을 이용하여 공간유지를 강화하면 인접치아의 조직재생에 도움이 되며, 골결손부가 깊은 경우에 더 효과적이라고 유추할 수 있었다.

4. 결 론

적절한 공간유지를 동반한 골유도재생술 시행시, 인접 조직에 치주조직 재생이 일어날 수 있음을 확인하였다. 또한 3 mm 골결손부에 비해 5 mm 골결손부에서 골유도재생술과 조직유도재생술이 좀 더 효과적이다.

주요어: 조직유도재생술, 골재생, 골대체제, 골임플란트계면, 치주학
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