# Dimensional alterations following vertical ridge augmentation using collagen membrane and three types of bone grafting materials: a retrospective observational study

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# Dimensional alterations following vertical ridge augmentation using collagen membrane and three types of bone grafting materials: a retrospective observational study

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## 감사의 글

설레고 부푼 마음으로 치주과학교실에 들어온 지 벌써 3년이라는 시간이 지났고, 언제 완성할 수 있을까 걱정하던 박사 학위 논문을 출판하게 되어 더없이 기쁜 마음입니다. 3년 동안 임상과 연구, 인생까지 모든 부분에서 높은 가르침을 주신 조규성 교수님께 이 영광과 감사한 마음을 올리고 싶습니다. 아울러 3년 동안 많은 가르침을 주신 채중규 교수님, 최성호 교수님, 김창성 교수님, 정의원 교수님, 이중석 교수님, 그리고 치과보철과 이근우 교수님께 감사의 말씀을 드립니다. 교수님들의 격려와 지도 덕택에 학위 과정의 결실을 맺을 수 있었습니다.

지난 2017년을 돌이켜보면 저에게는 많은 일이 있었습니다. 개인적으로는 결혼을 하고 한 아이의 아버지가 되었으며, 치주과에서 의국장을 지내고, 박사 학위 논문의 출판과 이제 남은 전문의 시험까지, 1년 동안 쉼 없이 달려온 것 같습니다. 이런 일들을 해낼 수 있었던 것은 비단 저의 힘이 아닌, 제 주변의 많은 분들의 도움이 있었기에 가능했다고 생각합니다.

묵묵히 지켜봐주시고 응원해주시는 사랑하는 어머니, 오빠보다 나은 여동생들 연재, 규조, 그리고 하늘에서 우리 가족 보살펴주시는 아버지께 감사드립니다. 마지막으로, 한결같이 밝은 모습으로 곁을 지켜주는 아내 주희, 그리고 사랑스러운 아들 연우를 위해 더 열심히 살겠습니다. 감사합니다.

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박 윤 호

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## Abstract

# Dimensional alterations following vertical ridge augmentation using collagen membrane and three types of bone grafting materials: a retrospective observational study

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**Purpose:** This retrospective study radiographically evaluated dimensional alterations of the vertically augmented alveolar ridge using collagen membrane and three types of materials: autogenous bone block, allogenous bone block, and particulated bone substitute.

**Materials and methods:** The electronic medical records of 32 patients who received vertical ridge augmentation using 3 types of materials were searched: 9 for

autogenous bone block, 12 for allogenous bone block, and 11 for particulated bone substitutes. The vertical bone gain, progression of bone resorption, and peri-implant marginal bone loss after prosthetic loading were measured on follow-up radiographs.

**Results:** The alveolar ridge was vertically augmented by 5.13±1.61, 4.54±2.48, and 3.90±0.85 mm (mean±standard deviation) after grafting with autogenous bone block, allogenous bone block, and particulated bone substitute, respectively. The radiographic vertical height of the augmented ridge that received autogenous bone block reduced continuously during the first year but was stable thereafter. Sites that received allogenous bone block or particulated bone substitute exhibited dimensional shrinkage for up to 1.5 years postsurgery. However, the peri-implant marginal bone loss did not exceed 1 mm throughout the observational periods in all groups.

**Conclusions:** The clinical findings of the present study suggest that the alveolar ridge can be vertically augmented using either allogenous bone block or particulated bone substitute. However, they require a longer healing period to ensure dimensional stability compared to the autogenous bone block.

**Key words:** alveolar bone remodeling, bone augmentation, autogenous bone graft, bone allograft, guided bone regeneration

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## I. Introduction

Vertical ridge augmentation is a surgical procedure aimed at increasing the alveolar ridge dimensions to ensure correct dental implant installation. In cases of a severely resorbed alveolar ridge, implant placement may damage anatomical structures such as the mandibular inferior alveolar nerve and the maxillary sinus. Furthermore, it results in an

abnormally long crown for the implant prosthesis, producing an unfavorable crown-to-implant ratio and proximity to the oral vestibule, which causes difficulties in maintaining oral hygiene.(Mecall and Rosenfeld 1991)

Autogenous bone block is the most widely used material for vertical ridge augmentation due to its characteristics of osteoconductivity, osteoinductivity, and osteogenecity. (Schwartz-Arad, Levin et al. 2005) However, harvesting the autogenous bone block is inevitably related to donor-site morbidity.(Raghoebar, Meijndert et al. 2007) Grafted autogenous bone block also results in excessive resorption after surgery when a barrier membrane is not used.(Johansson, Grepe et al. 2001)

Grafting particulated bone substitute with a membrane is a well-documented method that has been found to be effective for treating an atrophic alveolar ridge.(Simion, Jovanovic et al. 2001, Simion, Fontana et al. 2004) Bone particles are easy to manipulate in the ridge area during a bone grafting procedure, and they produce predictable clinical results.(Chiapasco, Romeo et al. 2004) However, particulated bone substitute shows poor three-dimensional stability because of its inherent physical characteristics, and accordingly demands the use of a space-maintaining barrier such as a titanium mesh or tenting screw with nonresorbable membranes.(Rocchietta, Simion et al. 2016)

Allogenous bone block is another candidate material that is reported on less often than the aforementioned bone grafting materials. The possibility of disease transmission might be the reasons for clinicians being reluctant to use this type. However, recently some clinicians have reported cases using allogenous bone block prior to implant surgery that demonstrated

its safety and effectiveness.(Leonetti and Koup 2003, Petrungaro and Amar 2005, Waasdorp and Reynolds 2010, Schlee and Rothamel 2013) Moreover, recent histomorphometric results revealed the excellent biocompatibility and vital new bone formation around allogenous bone block.(Jun and Yun 2016)

While these three types of materials have been used for vertical ridge augmentation over many years, few studies have performed comparative analyses of them. A clinically meaningful evaluation of vertical ridge augmentation might involve demonstrating the vertical bone gain and progression of bone resorption over a long-term follow-up. Therefore, the aim of this study was to retrospectively compare the dimensional resorption when using the aforementioned three materials for vertical ridge augmentation prior to implant surgery.

# II. Materials and methods

## 1. Study design and patient registration

Patients who received vertical ridge augmentation in the Department of Periodontics, Yonsei University Dental Hospital between 2009 and 2013 were searched for in the electronic medical records of the clinical database research system. Records consistent with the following Boolean word combination were selected: (‘vertical’ OR ‘vertically’) AND (‘augmentation’ OR ‘graft’) AND (‘resorbed ridge’ OR ‘resorption’ OR ‘defect’ OR ‘atrophy’). One researcher (Y.H.P.) manually searched all records of the selected data. Cases without implant installation in the augmented area due to patient nonattendance or nonconsent were excluded. Patients who received various types of grafting surgery for vertical ridge augmentation in the posterior region of the mandible or maxilla were finally included in this study.

The included patients could be categorized into the following three groups according to the grafted biomaterials: autogenous bone block, allogenous bone block, and particulated bone substitute. The following background and clinical information about the patients was obtained from their medical and dental records: age, sex, medical history, surgical records of vertical ridge augmentation and implant surgery, and complications. This resulted in 32 patients with the following graft types being included in the study: 9 for autogenous bone block, 12 for allogenous bone block, and 11 for particulated bone substitute. The demographic characteristics of the study population are presented in Table 1.

The dental records of the included patients were carefully reviewed, including for clinical complications (e.g., infection or wound dehiscence) and implant condition. Implant survival or failure was determined based on the study of Buser and colleagues: a functioning implant without clinical discomfort was designated as survival, while implant loss, presence of clinical mobility, or implant fracture were designated as implant failure.(Buser, Mericske-Stern et al. 1997)

The study design was reviewed and authorized by the Institutional Review Board of Yonsei University Dental Hospital (approval no. 2-2015-0049).

## 2. Surgical procedures of vertical augmentation

Surgical procedures were conducted under local anesthesia induced by 2% lidocaine with 1/100,000 epinephrine (Huons lidocaine-epinephrine®, Huons, Seoul, Korea), and all patients received premedication with antibiotics (Kymoxin®, Yuhan Corporation, Seoul, Korea). Midcrestal and vertical incisions were made in the planned augmenting area showing a vertically resorbed ridge, and a mucoperiosteal flap was elevated to exposure the entire margin of the defect. Cortical bone perforations were made on the defect floor in order to enhance angiogenesis. Three types of biomaterials were vertically grafted within the space between the defect floor and the imaginary line from the top of the adjacent bony wall to the other one. The surgical procedures performed with each material are described in detail below.

***Autogenous bone block***

Autogenous bone block was harvested from the mandibular ramus using a fissure-type bur and/or a piezoelectric device. The acquired corticocancellous bone block was trimmed to fit in the aforementioned space. The trimmed block was fixed with titanium machine screws (8 or 10 mm; Mid Screw®, Jeil Medical, Seoul, Korea), and porcine collagen membrane (Bio-Gide®, Geistlich Pharma, Wolhusen, Switzerland) was adapted to cover the reconstructed area.

***Allogenous bone block***

The procedures applied when using the allogenous bone block were the same as those for the autogenous bone block except for the biomaterial used. Allogenous bone block ($5\times10\times10$ $mm^3$; ICB®, Rocky Mountain Tissue Bank, Aurora, CO, USA) was prepared, which is irradiated frozen allogeneic corticocancellous bone. This bone block was grafted on the atrophic ridge and fixed with titanium machine screws to ensure their stability. Before fixation, the bone block was trimmed with a surgical blade to fit the defect morphology, and cortical bone perforation was performed at the defect floor. Also, the aforementioned resorbable collagen membrane was used to cover the allogenous bone material in all cases.

***Particulated bone substitute***

Two types of particulated bone substitutes were used for vertical ridge augmentation in

11 patients: deproteinized bovine bone mineral (*n*=8; Bio-Oss®, Geistlich Pharma) and synthetic biphasic calcium phosphate (*n=3*; Osteon II®, Genoss, Seoul, Korea). In all cases, titanium mesh (CTi-Mem®, Neo Biotech, Seoul, Korea) was used to stabilize the biomaterials and maintain the augmented space. Prior to grafting the materials, titanium mesh was trimmed and adapted to cover the defect and the defect margin. The mesh was fixed on the palatal or lingual side using metal pins, and the particulated bone substitute was grafted within the space beneath the titanium mesh. The aforementioned collagen membrane was placed to cover the mesh after fixation on the buccal side.

After performing a periosteal releasing incision to ensure complete coverage of the soft tissue on the augmented alveolar ridge, primary closure was applied for appropriate healing of the gingiva using a horizontal mattress suturing technique with 4-0 glyconate monofilament (Monosyn, B-Braun, Aesculap, Center Valley, PA, USA). Postoperative panoramic radiographs were obtained to confirm the surgical sites, and the sutures were removed at 7–10 days after surgery.

## 3. Implant placement and radiographic analysis

The bone healing period was 5.76±2.73 months (mean±standard deviation) across all of the sites: 5.13±2.03 months for the autogenous bone block group, 7.50±1.80 months for the allogenous bone block group, and 4.64±3.05 months for the particulated bone grafting group. After removing the fixation screws or titanium mesh, implants were installed using a conventional sequential drilling procedure. The prosthetics were finally connected at

6.02±2.06 months after the implant installation: 5.31±1.93, 6.28±1.82, and 6.31±2.35 months for the autogenous bone block, allogenous bone block, and particulated bone grafting groups, respectively. After prosthetic loading, patients were placed in a maintenance care program for monitoring their periodontal and peri-implant health. The procedures used for vertical augmentation and implant surgery are presented in Figure 1.

To assess the dimensional increase and resorption of the vertically augmented ridge, vertical bone gain and progression of bone resorption were measured on periodically obtained panoramic radiographs, while peri-implant marginal bone loss was measured on periapical radiographs. The observational periods were divided into 6-month intervals after vertical augmentation surgery (defined using times T0–T6) due to the variability in the visiting intervals of the included patients, and a radiological evaluation was performed for each time period.

## 4. Outcome variables

### *Vertical bone gain*

On postoperative panoramic radiographs, the augmented ridge was mesiodistally divided into four equal parts, with lines parallel to the axis of the mesial adjacent teeth drawn from each point of the quadrisection to the anatomical borderline such as the mandibular lower margin or maxillary sinus floor. After evaluating the heights of the pre-existing ridge and the newly grafted bone material at three sites, the differences were measured between them. The mean value of the three lengths was defined as the vertical bone gain (Figure 2).

### *Progression of bone resorption*

Measurements were made on panoramic radiographs after vertical augmentation to identify continuous vertical ridge resorption during the 3-year follow-up period using the aforementioned method. The progression of bone resorption was depicted graphically.

### *Peri-implant marginal bone loss*

Peri-implant marginal bone loss was defined as bone loss around the implant shoulder including bone remodeling. The mesial and distal levels of the implant were measured on periapical radiographs obtained after implant placement. After baseline setting, the peri-implant marginal bone loss was measured on each side of the implants, and their mean value was taken as the result. The peri-implant marginal bone loss was measured on follow-up radiographs obtained after prosthetic loading in accordance with the above-mentioned intervals.

### *Statistical analysis*

Standard statistical software (SPSS®23, IBM, New York, NY, USA) was used for statistical analysis. Mean values and standard deviations were calculated using all of the measurements made at three measuring points in the augmented area. The data for each material group were analyzed using one-way analysis of variance (ANOVA). The progression rates of bone resorption and peri-implant marginal bone loss were analyzed by repeated-measures ANOVA. Differences were considered to be statistically significant when $p<0.05$.

# III. Results

## 1. Clinical observations

None of the dental records included evidence of infectious complications. Five sites that received autogenous bone block showed wound dehiscence during the early healing period, which occurred at three sites in each group that received allogenous bone block or particulated bone substitute. All of these sites healed within 3 weeks without any other complications. There were no implant failures in any of the groups.

## 2. Radiographic observations

At the time of surgery, all of the grafted materials could be easily distinguished from the pre-existing alveolar ridge. However, the radiodensity in the grafted area increased continuously for up to 1.5 years postsurgery, with the original structure and the texture of the grafted materials both disappearing. The border between the pre-existing bone and the grafted material also disappeared over time in all groups. These observations are shown in Figure 3.

## 3. Outcome variables

### *Vertical bone gain*

The increases in the vertical heights of alveolar ridge were comparable in the groups with

different grafting materials: 5.13±1.61, 4.54±2.48, and 3.90±0.85 mm at sites that received autogenous bone block, allogenous bone block, and particulated bone substitute, respectively. One-way ANOVA revealed no statistically significant difference between the groups.

### *Progression of bone resorption*

As shown in Figure 4, the augmented height at sites that received autogenous bone block gradually decreased during the first year (from T0 to T2) but then stabilized thereafter. In contrast, sites that received allogenous bone block or particulated bone substitute showed a continuous resorption pattern for a longer period (for up to 1.5 years, from T0 to T3). At the latest follow-up time, T6, proportion of augmented ridge dimension was 87.21±9.00% for autogenous bone block, 68.70±25.09% for allogenous bone block, and 67.74±22.90% for particulated bone substitute. There was no statistically significant difference between the groups in repeated-measures ANOVA.

### *Peri-implant marginal bone loss*

All of the implants in all of the groups showed minimal bone loss of no more than 1 mm, and the amount of bony resorption around the implant occurred was smallest at sites that received autogenous bone block. At the end of the observational period, the marginal bone losses were 0.15±0.2, 0.38±0.64, and 0.43±0.48 mm at sites that received autogenous bone block, allogenous bone block, and particulated bone substitute, respectively (Figure 5). There were no statistically significant differences in repeated-measures ANOVA.

# IV. Discussion

The present retrospective study evaluated radiographic outcomes in terms of the augmented height and its maintenance following vertical ridge augmentation procedures using collagen membrane and different types of materials: autogenous bone block, allogenous bone block, and particulated bone substitute. The increases in the vertical heights of the alveolar ridge were comparable for all three surgical procedures. Dimensional resorption of the grafted sites occurred continuously for up to 1 year in the autogenous group and for up to 1.5 years in the other two groups, and the height was stably maintained thereafter along with the peri-implant marginal bone level.

The three types of vertical ridge augmentation techniques resulted in similar increases in the available bone height in panoramic views, with an average of 4–5 mm. These results are consistent with the findings of previous studies. Chiapasco et al. found a vertical bone gain of 5.0 mm for onlay grafting using autogenous bone block obtained from the mandibular ramus.(Chiapasco, Zaniboni et al. 2007) A case series of ridge augmentation using allogenous bone block found 3–4 mm of bone gain,(Nissan, Romanos et al. 2008, Waasdorp and Reynolds 2010) and several guided bone regeneration studies found mean bone gains of 2–7 mm when using particulated bone substitute.(Rocchietta, Fontana et al. 2008) There was a tendency for the mean height to differ by more than 1 mm between the groups in the present study, but there were no statistically significant differences. This could have been due to bias in the choice of treatment type for the vertically resorbed ridge, with a

preference for autogenous bone in cases with a severe vertical defect. This finding should therefore be interpreted conservatively, and further prospective randomized trials are needed to confirm the effectiveness of alternative vertical augmentation techniques such as the use of allogenous bone block or particulated bone substitute.

In previous studies, vertical ridge augmentation was performed using nonresorbable barrier membranes that provide mechanical support to the spaces both vertically and horizontally.(Rocchietta, Fontana et al. 2008, Mordenfeld, Johansson et al. 2014) In contrast, all of the cases in the present study involved the use of resorbable collagen membrane for wound stability and occlusiveness from the soft tissue, and three types of grafting materials (with the aid of titanium mesh in the particulated bone group) to maintain the spaces. Despite various advantages of nonresorbable membranes, their association with a higher risk of membrane exposure or wound dehiscence has reduced their clinical usage compared to resorbable collagen membranes.(Zitzmann, Naef et al. 1997, Verardi and Simion 2007) The collagen membrane can be replaced by the rapid resorption at the exposed site, which may limit the expansion in complicated situations. Therefore, even in cases of membrane exposure, the exposed area decreased during the early healing period and the augmented ridge volume was maintained.(Zitzmann, Naef et al. 1997) The present results—which are comparable to those obtained in previous studies using nonresorbable membrane—support the use of collagen membrane even in cases of vertical ridge augmentation.

The sites that received the various grafting biomaterials showed similar resorption patterns of the augmented alveolar ridge, with gradual resorption during the early healing

period and maintenance of the height after a certain period. The augmented ridge with autogenous bone block underwent gradual resorption (by about 1 mm) over 1 year, which is similar to the findings of previous studies using autogenous bone block.(Cordaro, Amade et al. 2002, Smolka, Eggensperger et al. 2006) Autogenous bone block obtained from the mandibular ramus presents a relatively high proportion of cortical bone, and may provide greater structural stability and density for maintenance of the augmented ridge,(Khoury and Hanser 2015) and it also stabilized faster than the other groups in the present study. On the other hand, continuous ridge resorption occurred during the initial 1.5 years (from T0 to T3) at the sites with allogenous bone block and particulated bone substitute, as shown in Figure 4. From the viewpoint of the proportional alteration, about 30% of the allogenous bone block and particulate bone substitute were resorbed from T0 to T6. This is probably because the two materials served merely as biologic fillers rather than vital bone structures. As a result, the healing period of the ridge has become longer, and the resorption of the ridge seems to have been further delayed. Dimensional alterations due to the remodeling process would have occurred over a longer healing period in the two latter groups. This might be caused by differences in the resorption rate between the grafted materials: higher resorbability of autogenous bone(Oh, Cha et al. 2011) and lower resorbabilities of allogenous bone, biphasic calcium phosphate,(Hong, Lee et al. 2014) and deproteinized bovine bone mineral.(Mordenfeld, Hallman et al. 2010, Mordenfeld, Johansson et al. 2014)

From a histologic point of view, several studies showed histologic results of unresorbed and non-vital allogeneous bone graft particles with minimal new bone formation.(Becker,

Becker et al. 1994, Becker, Urist et al. 1996) Compared to autogenous bone graft for vertical augmentation, allogenous materials resulted in reduced formation of blood vessels, osteoblasts, new bone, and greater number of islands of cartilage around the implanted particles.(Becker, Urist et al. 1996) On the other hand, recent clinical case reports demonstrated successful ridge augmentation both clinically and histologically using allogenous bone block, in which newly formed bone was observed on the surfaces of and the spaces between remaining allogenous materials.(Jun and Yun 2016) These might be caused from the differences of the time-points and the place for sample acquisition and it is difficult to generalize these two conflicting results because they are results within a limited period of time during the healing period. However, in the present result, minimal peri-implant bone loss was evident at sites that received any of the grafting materials during the observation period, despite the long-lasting remodeling process occurring at the augmented ridge: it was 0.1–0.4 mm in all groups over 2 years, which satisfied the usual success criteria for dental implantation.(Albrektsson, Zarb et al. 1986) A long-term (10-year) retrospective study that evaluated implants on the vertically augmented ridge found an average marginal bone loss of 0.58 mm,(Roccuzzo, Savoini et al. 2016) which is consistent with the present study.

# V. Conclusion

The clinical findings of the present study suggest that the alveolar ridge can be vertically augmented using either allogenous bone block or particulated bone substitute. However, they required a longer healing period to ensure dimensional stability compared to using autogenous bone block.

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# Figure legends

**Figure 1.** Representative clinical photographs of each vertical ridge augmentation procedure. An increase in the ridge volume is evident.

**Figure 2.** Schematic illustration of measuring the vertically augmented ridge height on a panoramic radiograph. The difference between the lengths of the red and yellow lines indicates the amount of vertical bone gain, which is depicted by the green line. The blue lines indicate a standard position drawn parallel to the axis of the adjacent tooth and vertically at the quadrisection point of the horizontal line connecting the healthy bone peak adjacent to the defect.

**Figure 3.** Representative radiographic images of each vertical ridge augmentation procedure. The radiodensity and the formation of a bone trabecular pattern increased with time.

**Figure 4.** Progression of bone resorption of the vertically augmented ridge during the 3-year follow-up.

**Figure 5.** Peri-implant marginal bone loss after implant prosthetic loading on the vertically augmented ridge during the 2-year follow-up.

# Table

**Table 1.** Demographic characteristics of the patient groups.

| | **Autogenous bone block** | **Allogenous bone block** | **Particulated bone substitute** |
|---|---|---|---|
| Sex | 6 males, 3 females | 4 males, 8 females | 6 males, 5 females |
| Mean age | 53.9 years | 53.5 years | 52.6 years |
| Sites | 9 | 12 | 11 |
| Implants | 15 | 26 | 18 |
| Source of bone material | Harvested from mandibular ramus | Allogenous bone block | Xenogenous particulated bone (n=8)<br>Synthetic biphasic calcium phosphate (n=3) |
| Stabilization of bone material | Screw | Screw | Titanium mesh |
| Membrane | Collagen membrane | Collagen membrane | Collagen membrane |

# Figures

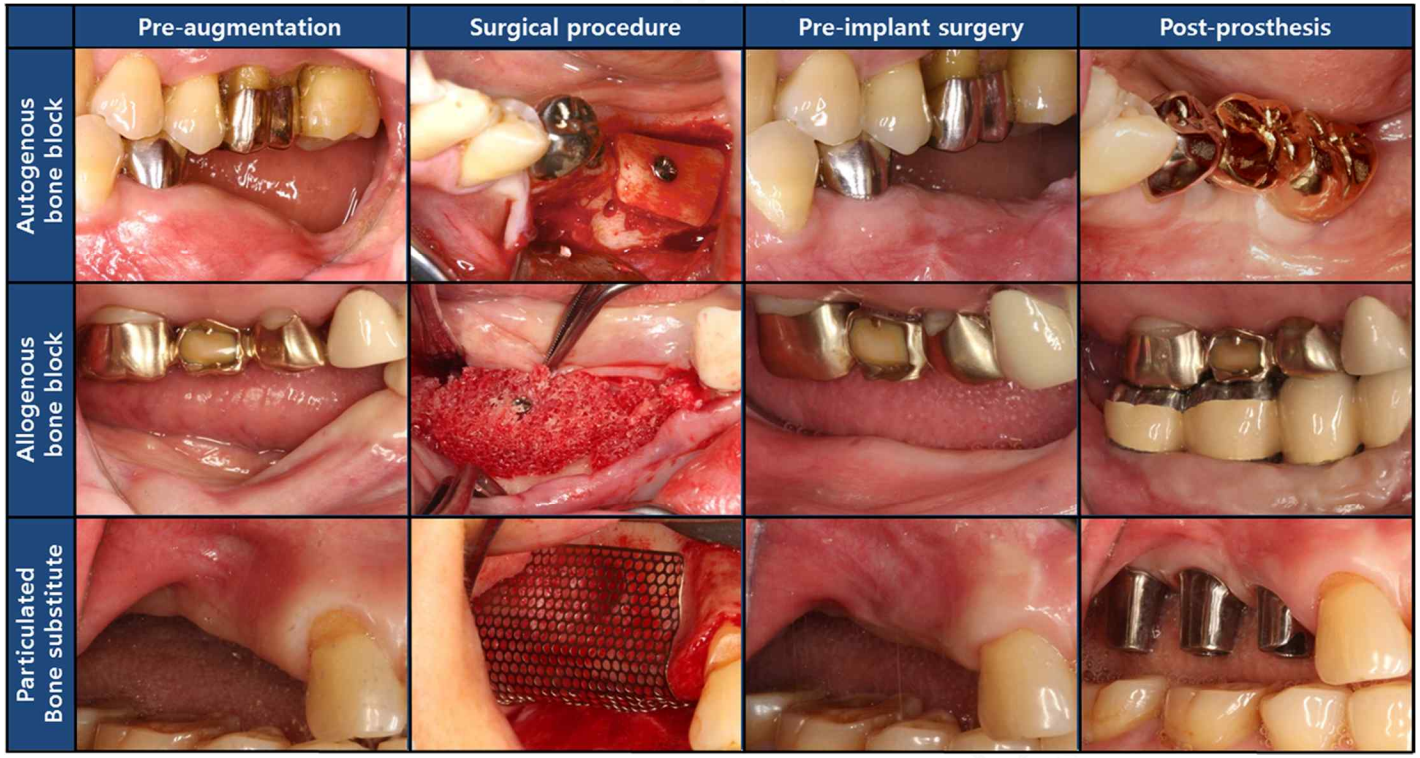


**Figure 1**

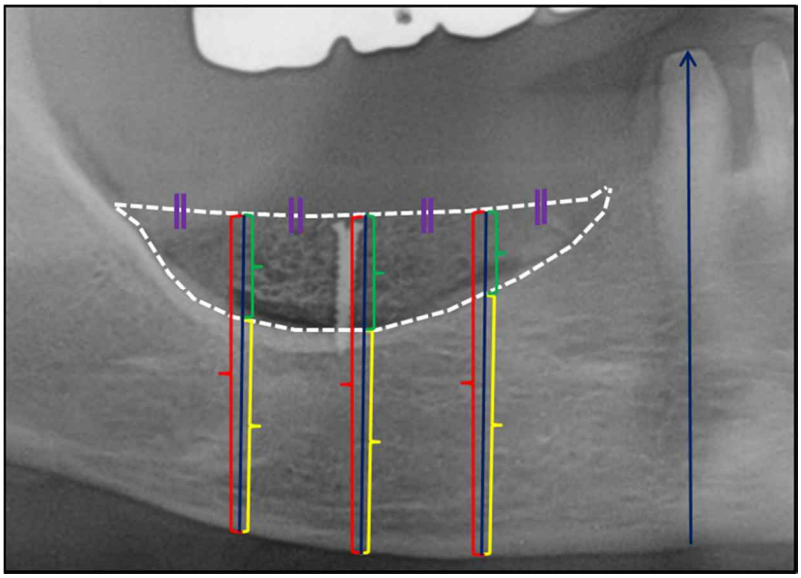

**Figure 2**

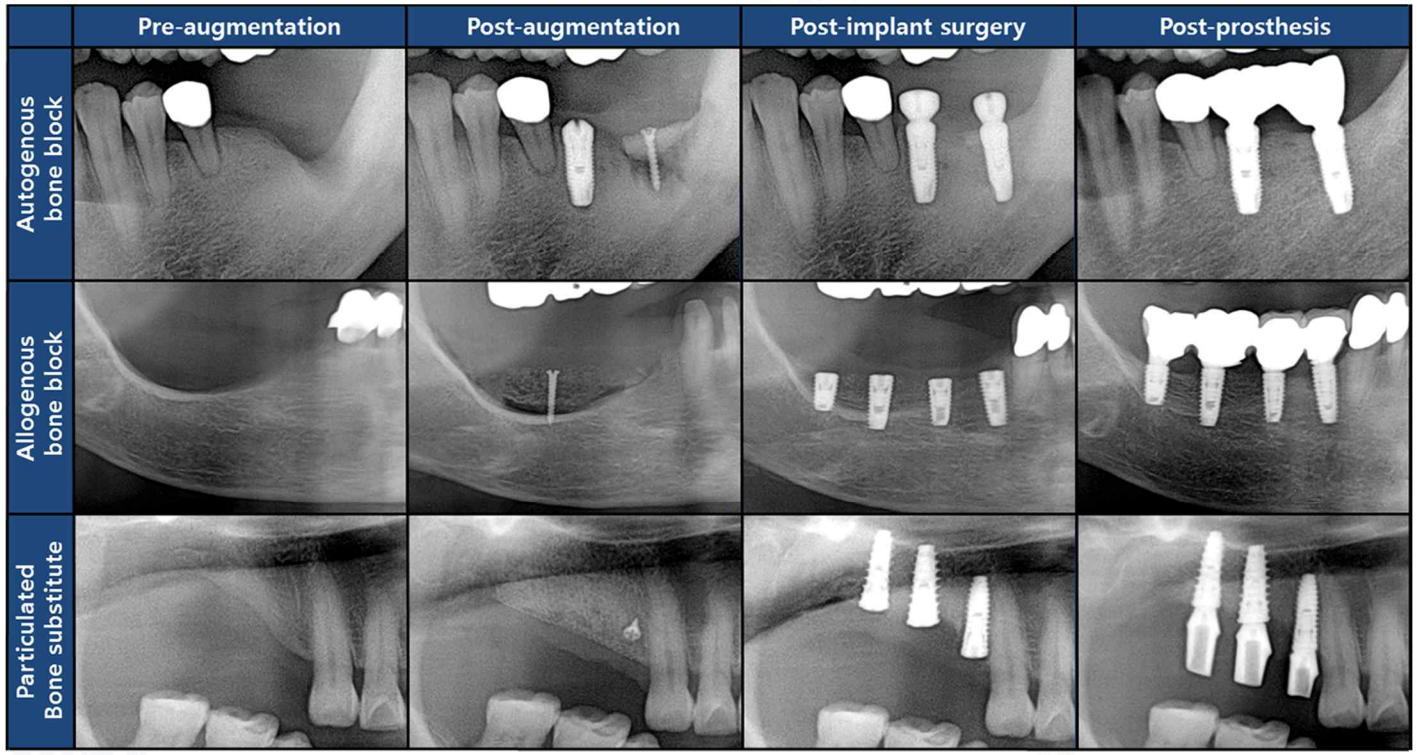


**Figure 3**

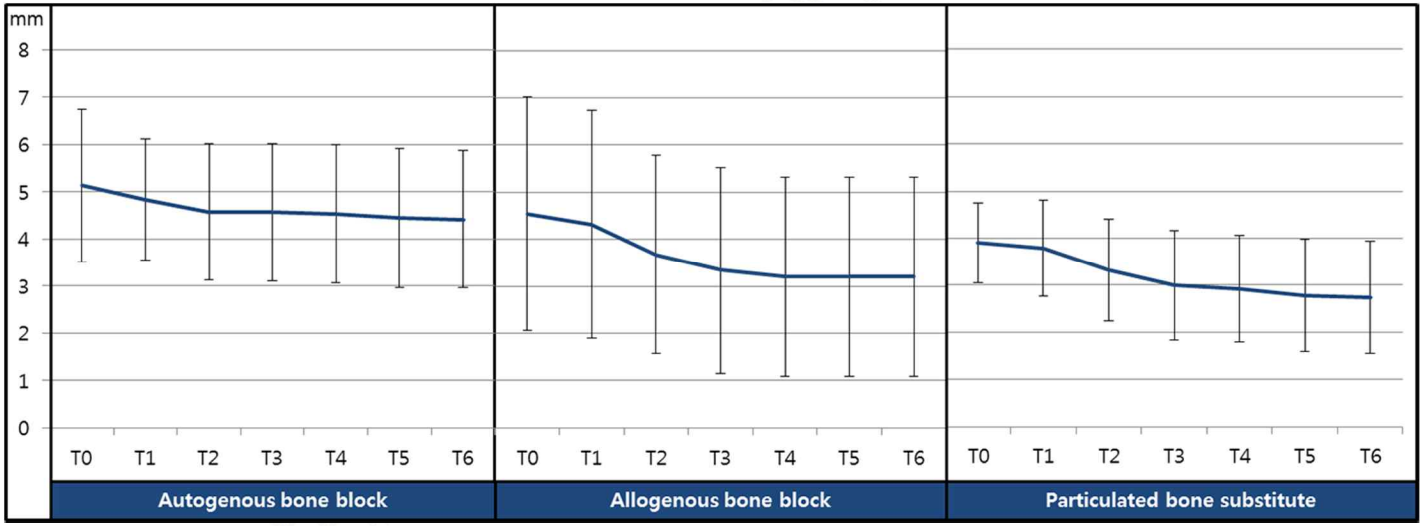


**Figure 4**

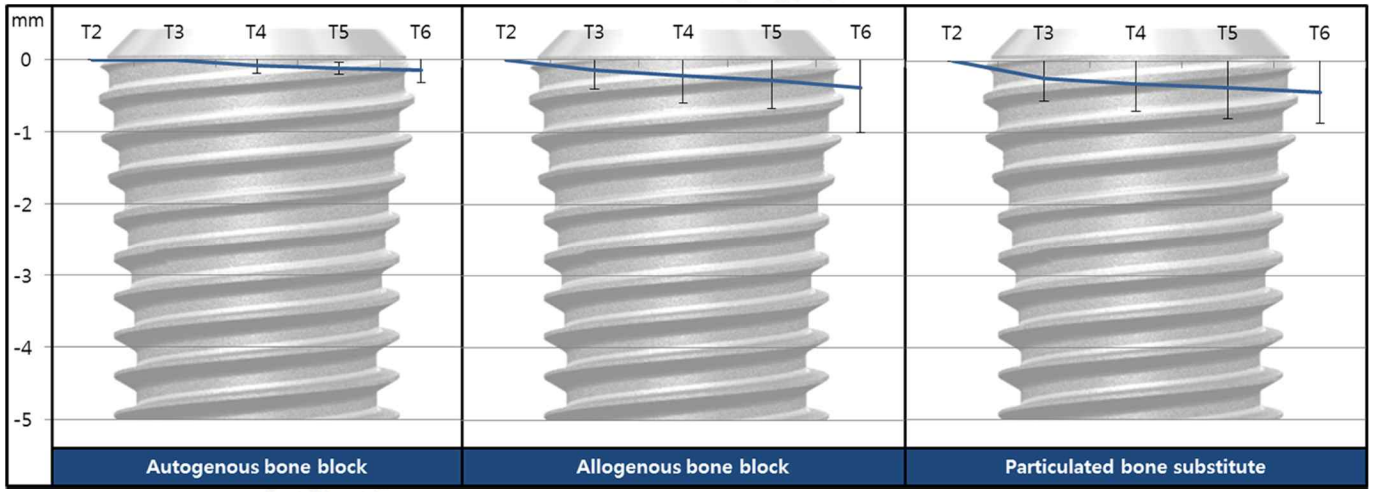


**Figure 5**

국문요약

# 세가지 골이식재 및 콜라겐 차폐막을 사용한 수직골 증강술 후 부피 변화 양상에 대한 후향적 연구

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**박 윤 호**

임플란트 치과학에서 임플란트의 적절한 식립을 위한 여러 가지 골이식술이 소개되어왔으며, 이 중 수직골 증강술은 임플란트 식립 시 해부학적 구조에 대한 침범 예방, 적절한 길이의 임플란트 식립, 구강 위생관리의 용이성 등을 위하여 시행된다.

수직골 증강술에서 가장 많이 사용되는 재료는 자가골 블록이나, 이는 환자의 공여부에 대한 손상 및 제한적인 골량, 추가적인 합병증 발생 등의 문제점들을 가지고 있다. 이에, 여러 가지 생체 재료가 수직골 증강술을 위하여 소개되고 있으며, 이는 자가골 이식술을 대체하기 위한 재료 및 방법으로써 사용된다.

본 후향적 연구는 세가지 골이식재와 콜라겐 차폐막을 이용하여 수직골 증강술을 한 경우들에 대하여, 방사선학적으로 그 부피 변화를 평가한 것이다. 3가지 골 이식재는 자가골 블록, 동종골 블록, 그리고 입자형 골대체재이다.

전자 의무 기록을 통하여 검색을 실시하였고, 위의 세가지 골이식재와 콜라겐 차폐막을 이용한 수직골 증강술로 치료받은 총 32명의 환자를 대상으로 하였다. 재료로 군을 분류하여, 자가골 블록은 9명, 동종골 블록은 12명, 그리고 입자형 골대체재는 11명이었다. 이들의 방사선 사진 기록을 토대로 하여 수직골 증강량, 골 흡수의 진행, 임플란트 변연골 소실 등이 계측되었다. 모든 환자는 3년간 추적 관찰되었다. 3년의 기간은 T0부터 T6까지 6개월의 간격으로 나누어졌고, 각 시기별로 방사선 사진 상에서 골 증강부위의 높이가 계측되었다. T0시점은 수직골 증강술 시행, T1시점은 임플란트 식립, T2시점은 임플란트 보철물 장착이며, T3부터, T6까지는 해당 임플란트 부위에 대한 정기검진이 이루어졌다.

각 군에서 임상적으로 임플란트의 실패나 특기할만한 합병증은 일어나지 않았고, 일부 환자에서 창상의 열개가 관찰되었으나, 2주 이내에 치유되었다. 치조제의 수직골 증강량(T0)은 자가골 블록에 대하여 5.13±1.61mm, 동종골 블록에 대하여 4.54±2.48mm, 그리고 입자형 골대체재에 대하여 3.90±0.85mm로 나타났다 (평균±표준편차). 치조골의 흡수 진행양상을 보면, 자가골 블록으로 증강된 치조제는 방사선학적으로 초기 1년간(T0~T2) 흡수되는

양상을 보였으나, 그 후 안정화되었다. 그리고 동종골 블록과 입자형 골대체재로 이식된 경우에는 술 후 1.5년 동안(T0~T3) 증강된 부피의 감소를 보였고, 그 후 안정화되었다. 그러나, 임플란트 변연골 소실에 관하여는 모든 군에서 관찰된 기간동안 1mm를 넘지 않는, 제한적인 흡수를 보였다.

이러한 결과는 동종골 블록 또는 입자형 골대체재를 사용하여 수직골 증강술을 사용한 경우에서도 임상적으로 용인할만한 결과를 보이는 것으로 판단된다. 그러나, 이러한 골대체재들은 자가골 블록에 비하여 그 부피 안정성을 유지하는데 있어 더 긴 치유기간을 필요로 하는 것으로 보인다.

**핵심되는 말 :** 치조골 개조, 골 증강술, 자가골 이식, 동종골 이식, 골유도 재생술