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The "International Journal of Ultrasonic Piezoelectric Bone Surgery" (Int J Ultrason Piezoelectr Bone Surg; IJUPS) is an international journal and publishes from Korea. The aim of IJUPS is to promote the international exchange of ideas and experience among clinical researchers worldwide through publishing original research and academically peer reviewed articles with highest quality on all aspects of the ultrasonic piezoelectric field. This journal includes scientific, basic and clinical researches in rapidly developing field of ultrasonic piezoelectric surgery.
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Original Article

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Comparative study of the effects of different bone particle sizes on bone regeneration in dog peri-implant defects

Sung-Moon Baek[1], Su-Gwan Kim[1], Ji-Su Oh[1], Wang-Shik Yang[1], Jin-Sung Park[1], Dong-Kook Seo[1], Jeong-Eun Yang[1], Sung-Chul Lim[2], Mi-Ae Jeong[3]

[1]Department of Oral and Maxillofacial Surgery, School of Dentistry, [2]Department of Pathology, School of Medicine, Chosun University, Gwangju, [3]Department of Dental Hygiene, Kangwon National University, Samcheok, Korea

Purpose: The aim of this study was to compare the efficacy of small particle-sized Tutoplast® (particle size: 0.25-1 mm) with that of large particle-sized Tutoplast® (particle size: 1-2 mm) for regeneration of bone defects adjacent to titanium dental implants.

Materials and Methods: In 6 mongrel dogs, 36 screw-shaped titanium dental implants were inserted into osteotomy sites in the dogs' iliac. Before implantation, a standardized gap (2.15 mm) was created between the implant surface and the surrounding bony walls using a trephine bur (8 mm in diameter). The control group received no bone grafts after implant placement. Gaps were observed in the experimental group after implant (Dentis®, 3.7 mm in diameter, 10 mm in length) placement. The animals were divided into 2 groups, which were sacrificed at 2 different time points (4 and 8 weeks) for histomorphometric analysis.

Results: New immature bone was observed at 4 and 8 weeks in the control and experimental groups, respectively. In addition, lamellated new bone was observed in the 8-week groups. In the histomorphometric studies, a statistically significant difference in bone formation was observed between the 2 groups (group 1 and group 2) at 4 weeks; however, no statistically significant difference in bone formation was observed between the 2 groups (group 1 and group 2) at 8 weeks.

Conclusions: Findings of this study showed that small bone particle size accelerates bone formation and osseointegration during the early bone formation stage (4 weeks). However, no statistically significant differences in bone formation or osseointegration were observed at 8 weeks.

Keywords: Allografts; Alveolar Bone grafting; Bone regeneration

INTRODUCTION

The success rate of implants is high, and their long-term prognoses are good.[1] Nonetheless, in previous years, implants were placed only in healthy alveolar bone. Thus, it is difficult to evaluate atrophic alveolar bone based on past data. In such conditions, implant placement becomes more difficult, and the shape, quality and quantity of bone are poor. Therefore, various pertinent data and procedures that allow for the placement of implants, even in poor alveolar bone, have been introduced. For cases that require bone augmentation or bone filling in association with implants,

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Correspondence to: Su-Gwan Kim
Department of Oral and Maxillofacial Surgery, College of Dentistry, Chosun University, 303 Pilmun-daero, Dong-gu, Gwangju 501-825, Korea
Phone: +82-62-220-3815, Fax: +82-62-228-7316, E-mail: sgckim@chosun.ac.kr

the success rate of methods that use autologous bones is high. Nonetheless,[2] the shortcomings are that the volume of harvestable bone is limited, additional surgery for the donor site is required, and unexpected delayed resorption can occur.[3]

The currently used bone graft materials are allogeneic bones,[4] xenogeneic bones,[5] and synthetic bones.[6] The success of a bone graft is dependent on various factors, for example, the types of graft materials and their treatment methods,[2,4-6] the composition factors of the defect areas,[7] whether blocking membranes are used, the size of the graft materials, and several other variables. Dahlin et al.[7] reported on a clinical study conducted that attempted bone regeneration in dehiscent defects around implants. It was observed that the size of the space required for regeneration determined the volume of bone regeneration and limited the regeneration range. In addition, numerous studies have been conducted on blocking membranes. It has been reported that the use of autologous bones and blocking membranes together is more effective than the use of bone graft materials alone.[8,9] This finding may be due to conditions in which the bone graft materials could not prevent the influx of soft tissues, causing the blocking membranes to block soft tissues, and thus, sufficient space was not maintained.

Recently, it has been reported that the particle size of graft materials for bone grafts that are performed simultaneously with implant procedures plays an important role in osteoconduction activity and that it also exerts effects on the quality of the newly formed ossein.[10-12] The ideal size of demineralized bone matrix (DBM) and bioactive glass to use in maxillary sinus lifts had been investigated. Nonetheless, the ideal particle size is not clear, and it is a subject of great controversy.

Therefore, in this study, a factitious injury of a critical size defect[13] was created, a bone graft was performed using two different sizes of a single commercial graft material, and the effectiveness of the material as an osteoinductive material, according to the size of the graft material, was evaluated histomorphometrically.

MATERIALS AND METHODS

1. Experimental materials

1) Experimental animals

The experimental animals were 6 mongrel dogs that were 10-12 months old and weighed approximately 15 kg each. All of the animals were maintained under identical conditions and were used regardless of their sex. All were healthy.

2) Implants

Thirty-six implants, 3.7 mm in diameter, 10 mm in length, and with an Resorbable Blast Media (RBM) surface (Dentis®, Daegu, Korea), were used. In each animal, 6 implants were placed.

2. Methods

1) Anesthesia

For general anesthesia, 2 mL xylazine (Rumpun®; Bayer Vetchem-Korea Co., Seoul, Korea) and ketamine (Ketalar®; Yoohan Co., Seoul, Korea) were injected intramuscularly into the femoral area. Subsequently, to prevent hemorrhage in the implant placement area and to suppress pain, infiltration anesthesia was performed with 2% lidocaine (containing 1:100,000 epinephrine; Yoohan Co.).

2) Classification of experimental groups

The experimental group was divided to two groups according to the size of the bone graft materials transplanted into the area around the placed implants. In other words, they were divided into groups based on the following treatments: the control group, in which bone grafts were not performed in the bone defect area around the implants (n=6); experimental group 1, in which the size of the graft materials was 0.25-1 mm (n=6); experimental group 2, in which the size of graft materials was 1-2 mm (n=6); and the 4-week group (A) and the 8-week group (B). For each group, 6 implants were used, and a total of 36 implants were placed.

3) The formation of bone defect areas, implant placement, and the transplant of bone graft materials

For the surgical procedures, anesthesia was performed by the above-described methods; the experimental animals were placed in the prone position, hair on both iliac crests and the vicinity were removed, and the area was sterilized with povidone-iodide and was covered with fabric. Along the iliac crest, an approximately 5-cm incisions was made in the skin and the periosteum, and the iliac crest was exposed by subperiosteal dissection. To assess the osteogenic capacity of the bone graft materials, using an 8-mm trephine drill, bone defect areas, three on the right side and three on the left side, 8 mm in diameter and 8 mm in depth, were formed. From the area 1 cm behind the anterior superior iliac spine along the iliac crest, implants (Dentis®) were placed at 2 cm intervals. During the implant placement procedure, saline was sprayed, and drilling was performed according to the instructions of the manufacturer. First, the implants

were placed in the bone defect areas, three on each side, in the adult dogs in the 8-week group, and after 4 weeks, implants were placed in the 4-week group of adult dogs. After implant placement, either graft materials with the particle size 0.25-1 mm (experiment group 1) or graft materials with the particle size 1-2 mm (experiment group 2) were transplanted into the bone defect areas that were prepared in advance. For the control group, the implants were placed without bone grafts. During implant placement, efforts were made to place the implants in the center of the defect area. Implants that deviated from the center during placement were placed in the precise position while transplanting the bone graft materials. In the control group, the lower parts of the implants were placed in the spongiosa; hence, the early stability of the implants was poor. Thus, the periosteum was covered carefully to preserve the positions of the implants. For the experimental group, while filling the vicinity of the implants with bone graft materials, efforts were made to minimize the movement of the implants. After bone grafting, the periosteum was sutured with 4-0 Vicryl, and the skin was sutured with layer-to-layer sutures, also using 4-0 Vicryl. To prevent infection in the surgery areas, for 5 days after surgery, 2 mL gentamicin (Gunil Pharmaceuticals Co., Seoul, Korea) was injected intramuscularly twice a day.

4) Sacrifice of experimental animals

Four weeks and 8 weeks after implant placement, the animals were sacrificed with an overdose injection of ketamine (Ketalar®), and the tissues containing the implants placed in the iliac area and the adjacent bone defect area were harvested.

3. Histopathological tests

The adult dogs were sacrificed at 4 weeks and 8 weeks after implant placement. The ilium was removed by dissection and fixed immediately in 10% formalin solution. Samples containing one implant were prepared. Afterward, the samples were fixed in 70% alcohol for 6 days and were washed under running water for 24 hours at room temperature. After dehydration by alcohol washing, the samples were embedded in glycometacrylate resin (Spurr's Low-viscosity Embedding medium; Polyscience, Warrington, PA, USA). The polymerized samples were sectioned using a high-precision diamond disc (low-speed diamond wheel saw 650; South Bay Technology Inc., San Clemente, CA, USA) approximately 200 μm in thickness along the long axes of the implants. Finally, the samples were polished to 30 μm in thickness using a lapping and polishing machine (OMNILAP 2000; South Bay Technology Inc.), and one slide per implant was prepared. A basic staining process was performed using Villaneuva osteochrome bone stain (South Bay Technology Inc.), which stains the osteoid and the calcified bone distinctly and allows assessment of the fluorescence level of the bone markers, and the samples were examined under a light microscope (Olympus BX50; Olympus, Tokyo, Japan).

1) Quantitative analysis

To evaluate the bone recovery level of the bone grafts, images were obtained using a digital camera attached to a microscope, and they were evaluated. The bone recovery level was evaluated by examination of the area of newly formed bones. The boundaries between the defect areas and normal bones were assessed first, and considering the entire defect area as 100, the area of the newly formed bone tissue was calculated as a percentage. In addition, because the bone was formed from the outer margin of the defect area, if the formation rate of new bones was assessed, the size of the bone graft materials at the time of the bone graft would help in evaluating the early stability of the implants. Therefore, the rate of formation of new bones within the implant screws was compared and evaluated as follows. For statistical analysis, the Mann-Whitney test was performed using SPSS software (for Windows, version 16.0; SPSS Inc., Chicago, IL, USA). p-values less than 0.05 were considered statistically significant.

Evaluation of new bones formed in defect areas

The rate of the filling of new bones within a defect area

= (the new bone area within a defect area/the entire bone defect area)×100

Evaluation of the rate of new bone formation within the implant screws

The rate of the filling of new bones within the screws

= (the new bone area within the implant screws/the entire bone defect area)×100

RESULTS

1. Examination using light microscopy

1) Histological findings after 4 weeks

(1) Control group (without bone grafts)

Regarding the new bones formed in the bone defect areas, bones were partially formed, primarily in the boundaries of the defect areas. Additionally, the spongiosa pattern was

maintained, and except for some areas in which loose connective tissue was present, most areas were formed by empty spaces (Fig. 1).

(2) Experimental group 1

New bones expanded to the root areas and covered most of the areas around the implants that had been exposed previously. Similarly, the new bones within the defect areas maintained dense bone patterns, which in most cases were centered on the boundaries of the defect areas. In the areas around the centers of the implants, the spongiosa patterns showed slightly denser patterns than in experimental group 2. The new bones within the implant screws maintained distinct spongiosa patterns in some areas (Fig. 2).

(3) Experimental group 2

At the centers of the defect area boundaries, the new bones within the bone defect areas maintained dense bone patterns in most areas. The areas around the centers of the implants showed spongiosa patterns, and slightly loose arrangements were observed. The new bones within the implant screws maintained distinct spongiosa patterns in some areas (Fig. 3).

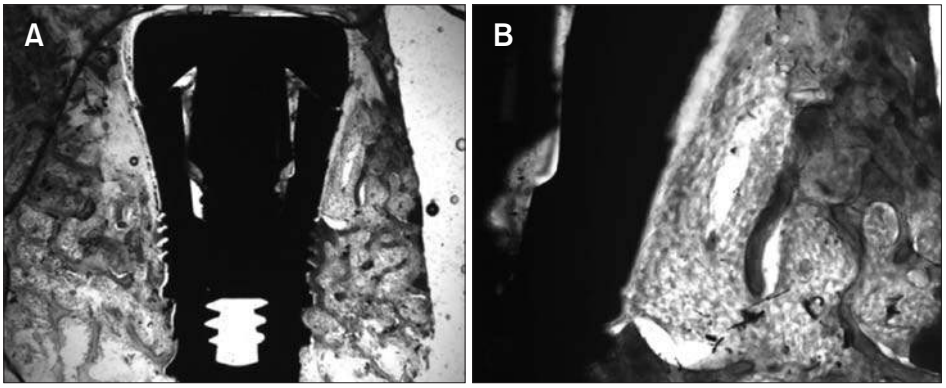

Fig. 1. A few immature new bones were observed in the peri-implant defects (4 weeks, Villanueva osteochrome bone stain). (A) Control group (×15). (B) Control group (×40).

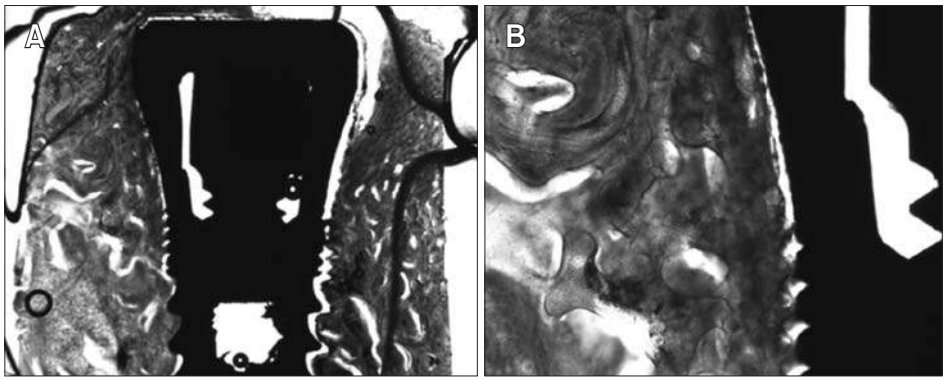

Fig. 2. Immature new bones were observed in the peri-implant defects using the 0.25-1 mm particle size (4 weeks, Villanueva osteochrome bone stain). (A) Experimental group 1 (×15). (B) Experimental group 1 (×40).

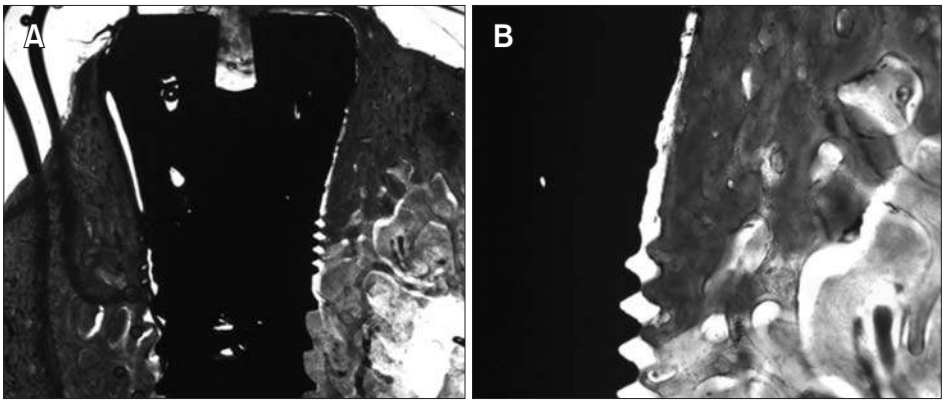

Fig. 3. Immature new bones were observed in the peri-implant defects using the 1-2 mm particle size (4 weeks, Villanueva osteochrome bone stain). (A) Experimental group 2 (×15). (B) Experimental group 2 (×40).

2) Histological findings after 8 weeks

(1) Control group (without bone grafts)

The new bones in the bone defect areas formed primarily in the boundaries of the defect areas, and afferent new bone formation was observed. The new bones maintained spongiosa patterns, and loose connective tissue was arranged among them. The new bones within the implant screws were insufficiently formed. Except for some areas consisting of loose connective tissue, most of the areas were empty spaces (Fig. 4).

(2) Experimental group 1

Histologically, experimental group 1 was not substantially different from experimental group 2. Although the contact areas of the implants with new bones showed diverse patterns, generally, the formation of new bones around implants was slightly better than in experimental group 2 (Fig. 5).

(3) Experimental group 2

The new bones within the bone defect areas maintained dense bone patterns, not only in the boundaries of the defect areas but also at the center areas around the implants. The

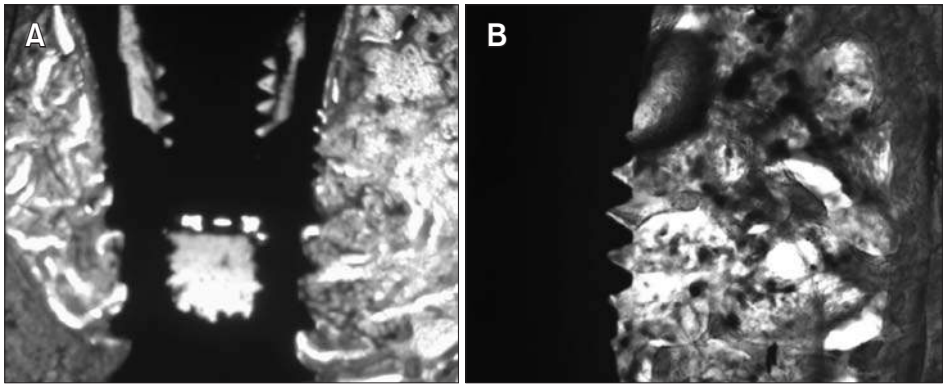

Fig. 4. A few immature new bones were observed in the peri-implant defects (8 weeks, Villanueva osteochrome bone stain). (A) Control group (×15). (B) Control group (×40).

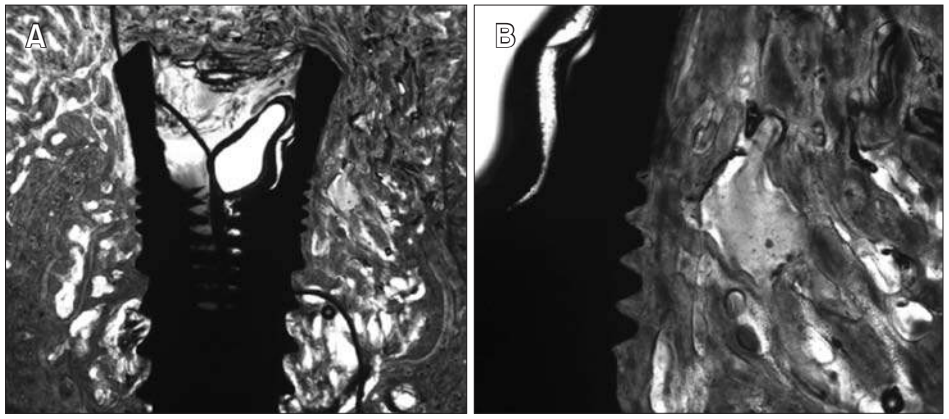

Fig. 5. New bones were observed in the peri-implant defects using the 0.25-1 mm particle size, and there was new bone formation on the implant threads defects (8 weeks, Villanueva osteochrome bone stain). (A) Experimental group 1 (×15). (B) Experimental group 1 (×40).

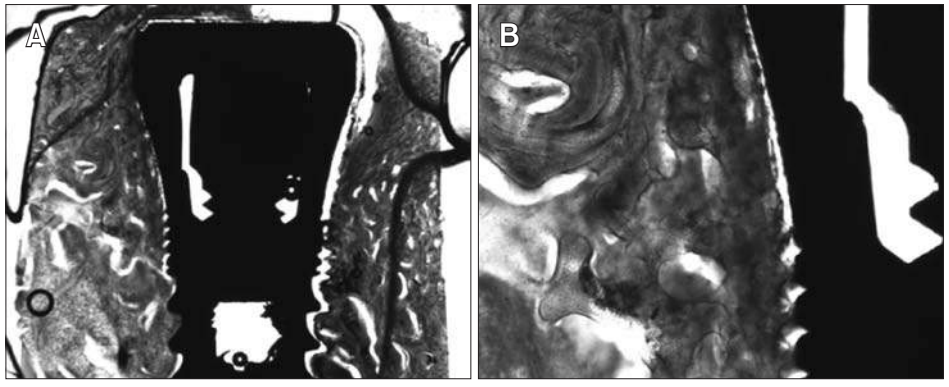

Fig. 6. New bones were observed in the peri-implant defects using the 1-2 mm particle size, and there was new mature bone formation on the implant threads (8 weeks, Villanueva osteochrome bone stain). (A) Experimental group 2 (×15). (B) Experimental group 2 (×40).

Table 1. Total volume of newly formed bone after 4 and 8 weeks (%)

Time period (wk)	Control	Experimental group 1	Experimental group 2
4	13.4500±3.3429	95.2167±2.4169[a,b]	86.3167±2.9335[a]
8	29.8500±1.6979	95.5833±1.6412[a,b]	90.0667±1.9012[a]

Values are presented as mean±standard deviation.
[a]Statistically significant difference relative to control ($p<0.05$).
[b]Statistically significant difference relative to group 2 ($p<0.05$).

Table 2. Mean bone area in the implant threads and new bone formation rates in the 3 groups at 4 and 8 weeks after placement (%)

Time period (wk)	Control	Experimental group 1	Experimental group 2
4	4.0500±1.1432	91.8167±3.8778[a,b]	78.6667±3.5357[a]
8	14.8333±2.9513	97.7000±1.5205[a,b]	94.3833±2.7043[a]

Values are presented as mean±standard deviation.
[a]Statistically significant difference relative to control ($p<0.05$).
[b]Statistically significant difference relative to group 2 ($p<0.05$).

new bones within the implant screws were also dense bones in most areas, except for the spongiosa partially filling the spaces between the screws (Fig. 6).

2. Statistical analysis

The results of the statistical analysis showed that in the 8-week group as well as the 4-week group, more mature bones were observed in the group with transplanted small particles. Nevertheless, in the experimental group, statistical significance was not observed when comparing the 4-week group to the 8-week group. In the comparisons of the subgroups of the 4-week and 8-week groups, all differences were statistically significant (Table 1).

In the statistical analysis, in both the 4-week group and the 8-week group in experimental group 1, the rate of formation of new bones within the implant screws was higher than group 2. The rate of formation of new bones within the implant screws of experimental group 1, with transplanted small graft materials, was significantly higher than that of experimental group 2, with transplanted large graft materials (Table 2).

DISCUSSION

Numerous studies have reported the importance of healthy alveolar bone for successful implant procedures. Nonetheless, in clinics, bone perforation, dehiscence, circular bone defects and other problems are commonly encountered during implant placement. Therefore, in situations in which the alveolar bone is in poor condition, for stable implant placement, bone grafts for the augmentation of the alveolar bone and appropriate bone graft materials are required. Hence, many types of graft materials have been developed to recover the bone defect areas around implants into normal bones.[14]

Bone grafts are successfully achieved by three independent processes: osteogenesis, osteoinduction, and osteoconduction. First, osteogenesis is the process that directly forms and raises the bone. Graft materials for osteogenesis originate from tissues pertinent to bone growth and healing, or they contain such tissues as their components. Osteoblasts induce osteogenesis in soft tissues or accelerate the rate of bone growth within bone tissues. Second, osteoinduction is the process that accelerates osteogenesis. Graft materials for osteoinduction accelerate osteogenesis and allow the bone to grow, even into areas in which the bone is not normally present. Third, osteoconduction provides an appropriate matrix or scaffold prior to the deposition of new bones. Graft materials for osteoconduction facilitate the deposition of new bone on existing bones and the growth of bones. Nonetheless, osteoconduction alone lacks the capacity for osteogenesis. Transplanted graft materials play the role of scaffold for vascularization of the inside of the transplanted area. Afterward, the resorption of graft materials and the deposition of new bones occur repeatedly. Such phenomena are referred to as creeping substitution. If osteoconduction graft materials are used to achieve better bone growth, existing bones or differentiated mesenchymal cells should be present in the vicinity of the implant. All bone graft materials have at least two of the above three characteristics. Bone tissues formed by such bone graft materials have dynamic characteristics, and their regeneration capacity is high. In addition, depending on the endogenous or exogenous in-

dividual condition, the remodeling process and the wound healing process are ongoing continuously. Such regeneration ability is essential for the maintenance of the volume, strength, and morphology of bone tissues. In adults, bone volume and strength are maintained by the bone-remodeling phenomenon. The bone-modeling process goes on continuously by the precise control of two opposite processes: bone resorption by osteoclasts and subsequent bone formation by osteoblasts.

Until now, there has been agreement that autologous bones are the best bone graft materials. Nevertheless, allogeneic bones and xenogeneic bone graft materials have excellent tissue compatibility with human hard tissues. In addition, allogeneic bones and xenogeneic bone graft materials have shown good results in histological as well as histomorphometric studies.[15] Furthermore, although many graft materials are identical from the aspect of their improving bone reactions by altering graft materials through various methods, we conducted this study to investigate the reaction of bone tissues according to the particle size of the graft materials. In several previous studies, diverse types of experiments have been performed in humans and animals to examine whether bone healing capacity differs according to the size of the graft materials.[10-12] However, in those studies, it was difficult to determine the size of bone graft that exerts the most beneficial effects on bone healing ability in bone defect areas around implants.

In our study, the experiments were initiated based on the hypothesis that the rate of bone formation of small-particle bone graft materials would be higher than that of large-particle bone graft materials. Particle graft materials are supplied in diverse sizes, and thus, the size of the particles can be selected according to the purpose of their application. Two sizes of Tutoplast® (Zimmer Dental, Carlsbad, CA, USA) are sold in Korea, 0.25-1 mm and 1-2 mm, and both were used in these experiments. The Tutoplast Spongiosa Microchip used in our experiments is a mineralized cancellous bone allograft, which is a type of allogeneic graft material, and its antigenicity and the possibility of virus cross-infection are reduced by special treatment processes. In both animal experiments and human experiments, the bone formation capacity and regeneration capacity of the materials have been shown to be good.[16,17] Tutoplast® has been used as a graft material in periodontal surgery (infra-bone defect), oral surgical procedures (extraction socket), implant procedures (bone-width augmentation) and other diverse intraoral surgeries. Furthermore, to remove water, the materials utilize solvent preservation methods, not freeze-drying methods. Hence, the phenomenon during the freeze-drying process, by which a liquid is converted into a solid, the volume expands, and subsequently minerals are denatured, does not occur. Thus, it has been reported that mineral matrix would be preserved.[18] Therefore, even if it is rehydrated, its crystal pattern does not change readily, and thus, the purpose of the experimental variables of alteration of the size of the graft materials could be reduced. Of course, although the two sizes of graft materials used in the current experiments do not represent all of the previous studies, considering that it is a commercialized bone graft material and that the study discussed the sizes of graft materials that could be obtained readily by clinicians, the this study should be considered meaningful. In our study, experimental group 1, in which small-particle bone graft materials (0.25-1.0 mm) were used, showed better outcomes of bone formation than experimental group 2, in which large-particle bone graft materials (1.0-2.0 mm) were used. The reasons for obtaining such results were assessed. Referring to previous studies, it is thought that when the particle size of the bone graft material is small, the surface of the particle is wider than in larger particles. This allows growth factors can be released easily and that new blood vessels are formed more readily. In addition, particle size has mediating effects on the ability to promote bone formation during the resorption period. In other words, if the particle size is small, the surface area becomes larger and thus accelerates the differentiation of undifferentiated mesenchymal cells into osteoblasts, which helps the bone formation process.

In such matters, particle size is important because it exerts effects on the ability to promote bone formation and on the resorption period. With regard to such a possibility, previous investigators have suggested their own opinions on the appropriate size of graft materials for bone grafts. Several previous studies reported that small particles promoted bone formation than large particles. Robinson et al.[19] reported that if small bone particles were produced by osseous coagulum techniques, in comparison with large bone particles, more rapid resorption and substitution were observed. In addition, the use of small bone particles promotes bone formation. Isaksson et al.[11] reported that bone defects were intentionally generated in rabbit crania, and very small powder type bone graft materials were compared with bone graft materials 0.5-1.0 mm^3 in size. After 4 weeks, in the area transplanted with 0.5-1.0 mm^3 bone graft materials, significant bone healing was observed. Nevertheless, after 8 weeks, significant differences were not observed.

Rivault et al.[20] reported that autologous bone particles 100

μm in size, which are rather than large particles, facilitated the activation of osteoblasts. Jonck[21] reported that 12-25 μm micro-bone particles augmented ossification during implant placement. Shapoff et al.[22] reported that the appropriate size of bone particles is the range of 100 to 300 μm. Pallesen et al.[23] reported that in bone grafts, the rate of bone remodeling is rapid, and thus, 0.5-2 mm^3 particles are preferable to 10 mm^3 particles. Xu et al.[24] reported that in an experiment that compared new bone formation using small-particle allogeneic graft materials (300-500 μm) with using large particles (800-1,000 μm), small particles showed better osteoconduction. In contrast to these reports, Hall et al.[25] reported that particle size was not important. Urist et al.[26] reported that in experiments in rabbits in which demineralized freeze-dried bone was used, 250-420 μm bone particles impeded the formation of cartilage and ossification and that 1,000-2,000 μm large particles were more effective. In contrast, Fucini et al.[27] also reported that significant differences between 250-500 μm small graft materials and 850-1,000 μm large graft materials were not observed. Regarding such matters, while numerous studies on the sizes of bone graft materials have been conducted, it may be difficult to conclude that, depending on size, the level of bone formation improved noticeably. Nonetheless, generally, when graft materials were smaller, better results have been reported. Previous investigators have examined the effects according to size by comparing of diverse sizes of graft materials. In our study, two sizes of a single graft material that is sold in Korea were examined to assess the size that exerts better bone regeneration effects. The results showed that the smaller the size of the graft materials, the better the bone formation, both quantitatively and qualitatively.

In this study, the effects according to the size of the graft materials were examined after short healing periods (4 and 8 weeks). According to the results of our study, during the initial 4 weeks, the rate of bone formation in experimental group 1, transplanted with 0.25-1 mm graft materials, was better than in experimental group 2, transplanted with 1-2 mm graft materials. Nevertheless, by 8 weeks, large differences were not seen. It could be considered that, similar to the study reported by Isaksson et al.,[11] small particles showed better outcomes in the initial period, with sizes in the range of the particle size that was preferred by Pallesen et al.[23] for bone grafts.

With the development of better bone graft materials, the improvement of the shape of the graft materials and treatment methods, the use of shorter experimental periods and diverse sizes and shapes of graft materials, the aspects of bone formation that remain unclear, according to the size of the graft materials, should be assessed.

In the ilia of adult dogs, bone defects 8 mm in diameter and 8 mm in depth were made bilaterally, implants were placed, and two different sizes of bone graft materials were transplanted. The experimental animals were sacrificed after 4 weeks or 8 weeks, and the formation of bones in the bone defect areas and at the interfaces of the implants were examined by light microscopy. The following results were obtained.

1. After 4 weeks and 8 weeks, the rates of formation of new bones in the bone defect areas around the implants were compared. After 4 weeks and 8 weeks, the formation of new bones was shown to be higher in experimental group 1, transplanted with small-size bone graft materials.

2. In both the 4-week group and the 8-week group, the rate of formation of new bones within the implant screws in the experimental group was higher. The rates of formation of new bones within the implant screws of the 4-week group and the 8-week group were compared. The rate of formation of new bones within the implant screws in experimental group 1, transplanted with small graft materials, was significantly higher than that of experimental group 2, transplanted with large graft materials.

Based on the results, it was found in our study that as the size of the graft materials decreased, the material exerted better effects on bone formation. It should be considered in the future that in using diverse sizes of graft materials, further studies on the effect of the size of particles on bone formation are required.

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골이식을 시행하지 않은 상악동 거상술의 장기 추적 임상 연구

문지원, 손동석

대구가톨릭대학교병원 치과 구강악안면외과학교실

Long term follow-up clinical study of maxillary sinus lift without bone graft

Jee-Won Moon, Dong-Seok Sohn

Department of Dentistry and Oral and Maxillofacial Surgery, Daegu Catholic University Medical Center, Daegu, Korea

Purpose: The purpose of the current study was to evaluate the predictability of bone formation in the maxillary sinus using only peripheral venous blood as a graft material.

Materials and Methods: Thirteen sinus floor elevation and placement of implants were performed on 10 patients. The sinuses were augmented with elevation of membrane. A total of 24 implants were immediately inserted into the sinuses. Three to 6 months afterwards, implants were loaded. The mean follow-up period was 680.8 months (range, 43.5-106.1 months).

Results: The implant success rate was 100%. No clinical or radiographic differences were found between perforation and non-perforation cases. Sinus floor level gain was 7.2 mm.

Conclusions: The results showed that sinus floor elevation without graft materials can be predictable for sinus augmentation.

Keywords: Sinus floor augmentation; Bone regeneration; Dental implants

서 론

상실된 치아의 대체로서 임플란트를 이용한 치료는 임상가에 의해 널리 사용되고 있다. 그러나 상악 구치부 무치악에서 임플란트 식립 시 광범위한 치조골 흡수, 상악동의 함기화, 잔존골의 불량한 골질과 같은 해부학적 한계에 부딪히는 경우가 많다. 많은 연구에서 상악 구치부의 불량한 골질과 불충분한 골량으로 인한 임플란트 실패를 보고하였다.[1,2]

이러한 해부학적 한계를 극복하기 위한 치료방법으로 상악동 거상술(maxillary sinus augmentation)은 충분한 골높이를 획득할 수 있는 예지성 있는 골증강술이다.[3,4] 1960년대에 Boyne[5]이 보철적인 목적으로 골조직을 증가시키기 위해 상악동에 골이식술을 시행할 것을 처음으로 제안한 이래 많은 임상가에 의해 변형, 발전되어 왔다. 현재 상악동의 측방 접근을 통한 상악동 거상술은 상악 구치부에서 5 mm 이하의 잔존 치조골 높이를 갖는 증례에서 임플란트의 초기고정을 제공할 수 있는 치료방법으로

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Correspondence to: Jee-Won Moon
Department of Oral and Maxillofacial Surgery, Daegu Catholic University Medical Center, 33 Duryugongwon-ro 17-gil, Nam-gu, Daegu 705-718, Korea
Phone: +82-53-650-4291, Fax: +82-53-622-7067, E-mail: jeewon@cu.ac.kr

보편적으로 사용되고 있다.[6] 상악동 거상술은 상악동 막의 거상 후, 그 하방에 신생골 재생을 위한 공간을 확보하기 위하여 다양한 종류의 골이식재를 이식하는 술식으로 상악동 내 이식된 이식골의 종류와 양, 자가골의 양의 여부 등이 상악동 거상술과 동시에 식립된 임플란트 주변 신생골의 형성에 영향을 미친다고 알려져 있다.[5,7,8]

다양한 골이식재를 이용한 상악동 골이식술은 40년 이상 임상에 보편적으로 적용되어 왔지만 근래에 Lundgren 등[9,10]과 Cricchio 등[11]은 상악동 내에 골이식을 하지않고 임플란트를 식립하여 성공적인 방사선학적, 조직학적 결과를 보고한 바 있다. 하지만 이는 환자의 방사선학적 소견과 동물 실험모델에서 얻어진 조직학적 결과로, Sohn 등[11,12]은 골이식을 하지 않고 상악동막의 거상 후 임플란트를 식립한 증례에서 방사선학적 소견과 더불어 인체에서 상악동 내 신생골의 조직학적 소견을 통해 골이식재를 사용하지 않고도 상악동 내부에서 신생골이 형성됨을 증명한 바 있다.

이번 연구에서는 상악동막 하방에 골이식재를 사용하지 않고 상악동 내의 신생골이 형성된 저자들의 이전의 연구들[12-14]에 기반하여 생성된 신생골의 장기적인 추적을 통하여 이들 술식의 예지성을 평가하기 위해 시행하였고, 또한 식립된 임플란트의 예후를 평가하여 이에 대해 보고하고자 한다.

대상 및 방법

1. 연구 대상

이번 연구는 2006년 6월부터 2010년 2월까지 상악 무치악 구치부에 임플란트 식립을 위해 내원한 환자 중 임플란트 식립과 동시에 측방 상악동 거상술을 시행하고 임플란트를 실패없이 사용하고 있는 환자 10명을 대상으로 하였다. 총 13개의 상악동에(편측 상악동 증대술 8명, 양측 상악동 증대술 2명) 임플란트를 식립하였고, 환자 18명의 좌, 우측 상악동에서 제2소구치, 제1대구치, 제2대구치의 모두 108 부위의 영상을 얻었다. 남자가 8명, 여자가 2명으로 평균 나이는 52.8세(±12.4, 35-75세)였다. 술 전 과거 병력을 조사하였으며 흡연과 비조절성 전신질환을 가진 환자는 없었다.

2. 연구 방법

1) 방사선사진의 평가 방법 및 내용

술 전에 수술 부위의 잔존골의 높이와 상악동 내부의 점막 병변을 알아보기 위해 파노라마 및 cone-beam computed tomography (CBCT, Combi®; Pointnix, Seoul, Korea)를 촬영하였다. 이에 연동된 컴퓨터 프로그램(Realscan 2.0; Pointnix)상의 축 평면영상(axial view)에 cross-sectional guide curve를 설정하고, 이를 통해 파노라마 영상(panoramic view)을 획득하였다.

상악동저와 상악구치부 치조정 사이의 잔존골 높이는 약 1.57.2 mm (평균 4.7 mm)로 측정되었으며, 상악동 내 병소는 관찰되지 않았다. 상악동 거상술 직후, 그리고 2차수술 직전 혹은 직후에 동일한 방사선 사진을 촬영하여 상악동 내부의 신생골 형성 정도를 확인하였다. 프로그램의 'measure tool'의 ruler로 구조물 간의 거리 및 길이를 측정하였다.

추적관찰 기간에 임플란트 주변 골높이 및 상악동저의 높이는 치근단 방사선 사진의 평행촬영법을 통해 관찰되었다. 이들 방사선 사진의 600 dpi 해상도의 TIFF 포맷으로 전환하여 측정되었고, 식립된 임플란트의 길이를 이용하여 골높이를 계산하였다.

2) 수술 과정 및 골창 형성 방법

예방적 항생제로 수술 하루 전에 cefditoren pivoxil (Meiact; Boryung Parm., Seoul, Korea) 300 mg을 하루 3번 복용하고 수술 이후 총 7일간 복용하였다. 수술 부위에 1:100,000 epinephrine을 포함한 2% lidocaine으로 침윤 마취 후 점막을 거상하고 상악동 외측벽으로 접근하여 상악동 거상술을 시행하였다. 얇은 piezoelectric saw insert (S-Saw; Bukboo Dental Co., Daegu, Korea)를 초음파 수술 기구(Surgybone; Silfradent srl, Sofia, Italy)에 연결하여 상악동 외측벽에 골창을 형성하였다. 골창은 상악동의 전방 경계선의 2-3 mm 후방에서 상악동 내측으로 경사지게 saw tip을 기울인 후 약 10 mm 높이의 수직 골삭제선을 형성하였고, 상악동 하연의 2-3 mm 상방에 동일하게 약 20 mm 길이로 골 삭제선을 형성하였다. 형성한 골편을 떼어내고 상악동막을 골창의 상층과 평행해질 때까지 거상하였다. 이는 상악동 내측벽을 노출하여 이로부터 혈류 공급을 받아 신생골 형성을 유도하기 위함이다.

임플란트 식립 후 연조직이 상악동 내부로 자라 들어가는 것을 막고 상악동 내 혈병을 유지시키며 치유 후에는 환자의 상악동 외측벽이 그대로 유지되도록 골편을 재위치시켰다.

봉합은 Cytoplast® PTFE suture (Osteogenic Biomedical, Lubbock, TX, USA)를 사용하였고 수술 직후 panorama 사진과 CBCT를 촬영하였다. 수술 후 주의 사항을 설명하고 수술 하루 후 환부의 소독을 시행하였으며, 발사는 술 후 2주째 시행하였다. 평균 6개월 후, 파노라마와 CBCT scan를 촬영하여 신생골 형성 정도를 확인하였고 2차 수술을 시행하였다. 임시 보철물 사용기간을 포함하여 평균 680.8개월 간 임플란트의 하중이 주어졌다.

Table 1. Patient characteristics and clinical findings

Patient No.	Gender	Age (yr)	Site	Residual bone height (mm)	Implant length (mm)	Achieved bone height (mm)	Loading period (day)	Membrane perforation
1	M	41	R max first molar	2.0	13.0	11.0	3,183	Y
			R max second molar	2.0	13.0	11.0	3,183	Y
2	M	52	L max first molar	7.5	13.0	5.5	1,394	Y
3	M	45	L max first molar	8.5	13.0	8.5	1,330	N
			L max second molar	6.5	13.0	6.5	1,330	N
4	F	45	R max first molar	4.5	13.0	8.5	2,132	N
			R max second molar	5.5	13.0	7.5	2,132	N
5	M	56	L max first molar	3.0	13.0	13.0	1,646	N
			L max second molar	2.0	11.5	10.0	1,646	N
6	M	53	L max first molar	3.0	13.0	10.0	1,793	N
			L max second molar	4.0	13.0	10.0	1,793	N
7	M	64	L max first molar	2.0	13.0	11.0	2,084	Y
			L max first molar	7.0	13.0	6.0	2,084	Y
8	F	57	R max first molar	1.5	9.0	7.5	1,240	N
			R max second molar	0.5	9.0	8.5	1,240	N
			L max first molar	3.0	9.0	6.0	1,240	N
			L max second molar	2.0	9.0	7.0	1,240	N
9	F	56	R max first molar	2.0	12.0	10.0	1,306	N
			R max second molar	1.0	12.0	11.0	1,306	N
10	F	41	R max second premolar	2.0	14.0	12.0	1,633	N
			L max first molar	4.0	14.0	10.0	1,633	N
			L max second molar	3.0	14.0	8.0	1,633	N

M, male; F, female; R, right; L, left; Y, yes; N, no.

결 과

상악동 거상술 후 치유기간 및 추적기간에 술 후 합병증은 관찰되지 않았다. 잔존골의 높이는 0.5 mm에서 8.5 mm 사이(평균 3.30 mm)였다. 평균 6개월의 치유기간 후 찍은 방사선학적으로 모든 증례에서 원래의 상악동저 피질골이 관찰되지 않으면서 동시에 거상된 상악동막 하방에 신생골이 형성된 것을 확인할 수 있었다. 평균 680.8개월간의 추적기간을 통하여 방사선 사진에서 상악동의 함기화 양상으로 임플란트를 둘러싸며 상악동저가 유지되었다(Table 1).

상악동막의 천공은 2명의 환자에서 나타났다. 2명의 환자 모두에서 상악동 치조정 접근법으로 상악동막의 거상 시 천공이 일어나 측방법으로 접근한 경우였으며, 2 mm 이하의 천공이 관찰되었다. 천공이 일어난 경우 콜라겐 테이프를 사용하여 천공부를 폐쇄하였으며, 천공이 되지 않은 환자와 비교시 방사선학적 차이점은 관찰되지 않았고 신생골 형성 및 보철물의 사용기간 동안 별다른 합병증은 관찰되지 않았다.

Table 2. Clinical parameters of the study

Parameter	Data
Patient (n)	10
Average age (yr)	52.15±11.37[a]
Sinus graft (n)	12
Average bone height (mm)	3.3
Implant (n)	22
Average vertical bone gain (mm)	8.68
Average loading period (wk)	2,917.71

[a]Mean±standard deviation.

고 찰

상악동 거상술은 상악 구치부의 임플란트 식립 시 부족한 골량을 증대시킬 수 있는 비교적 안전하고 예지력 있는 술식으로 알려져 있다.[3-8] 이번 연구에서는 상악동 거상술 시 골이식재를 사용하지 않고 거상된 상악동막 하방에 임플란트만을 식립하여 신생골 형성을 유도하였다. 상악동저의 높이를 관찰하기 위하여 임상적으로 잘 사용되고 있는 임플란트 및 상악동을 3-8년간 추적하여 상악동 내 생성된 신생골의 장기 안정성을 관찰하기 위해 연구가 진행되었다.

상악동 거상술 후 시간이 경과함에 따라 상악동막과 상악동저가 상당량 함기화된 소견을 보였다. 이는 상악동 거상술 시 골이식을 시행할 경우 골이식재가 충전재로 작용하여 추후의 골기질을 형성하는 데 충분한 공간을 제공하지만, 이번 연구에서는 상악동 거상술 후 식립한 임플란트가 상악동막에 대한 텐트의 기둥 역할을 하여 상악동막이 임플란트 근단 하부로 함기화되는 것을 방지하여 임플란트 주위로 신생골이 형성되고 유지됨을 시사한다.

골이식을 시행하지 않는 상악동 거상술의 성공에 영향을 미치는 중요한 요소는 상악동막의 천공을 최소화면서 충분히 거상시켜 상악동 내측 골면을 충분히 노출시키는 것이다[15]. 이는 기존의 골이식재를 이용한 상악동 골재건술에서도 필요한 동일한 술식이다[16]. Gruber 등[17]은 상악동 점막은 골생성 세포를 생성할 수 있는 mesenchymal cell을 함유하여 상악동 거상술 후 골생성 세포의 중요한 source가 될 수 있다고 보고하였고, Palma 등[18]은 동물 실험을 통해 상악동막 거상 후 자가골을 이식한 경우와 그렇지 않은 경우 상악동 내 생성된 골조직을 6개월의 치유기간 후에 비교했을 때 차이가 없었고 혈병이 모인 부위에서 상악동 점막에 접촉되어 신생골이 침착되는 것이 관찰되어 상악동 점막의 골형성 유도(osteoinduction)에 대한 잠재적인 능력을 보여준다고 하였다. 이러한 상악동 점막의 연속성은 상악동의 정상적인 기능을 유지하는 데 중요하다. 골이식을 하지 않은 상악동 거상술에서 상악동막의 천공이 발생하여 적절한 처치가 이루어지지 못하면 혈병의 유지와 안정을 저해할 수 있어 술식의 실패를 야기할 수 있다.

이번 연구에서는 골창을 형성하는 동안 상악동막의 천공을 최소화하기 위하여 초음파 수술기를 사용하여 상악동막의 천공 가능성을 줄이려 하였다. 골창 형성 시의 초음파 수술기를 사용하면 미세진동을 이용하여 골을 삭제하기 때문에, 골조직와 같은 경조직에서만 힘이 작용하고 상악동막과 같은 연조직에서는 힘이 작용되지 않아 골창을 형성하는 동안 상악동막의 천공을 최소화한다.[19-26] 그러나 불가피하게 상악동막의 천공이 발생한 경우에는 충분히 상악동막을 거상하여 막의 천공된 부위를 중첩시키고, 최종적으로 흡수성 젤라틴으로 상악동 점막의 천공을 폐쇄하여 막의 연속성을 유지함으로써 상악동 내부에 새롭게 모인 혈종을 보존할 수 있다[27].

충분한 상악동 점막의 거상은 숙주골이 새로운 골을 형성하는 데 도움을 줄 수 있는 부가적인 골벽을 제공한다. Misch7는 상악동 거상술 시행 후의 신생골 형성이 상악동막이 거상된 곳의 상악동 주위골로부터 자라온다고 보고하였는데, 이는 골생성이 발치와와 유사하게 주위의 골벽으로부터 유래한다는 것으로, 골을 형성하는 가장 마지막 부분은 일반적으로 외측 접근창의 중심부와 새로이 형성한 거상된 상악동점막 하방의 상악동저 부위이다.

이번 연구에서는 측방 상악동저 거상술과 임플란트 식립을 동시에 시행한 환자 총 10명의 환자의 방사선 사진 및 전산화단층촬영 영상을 장기추적한 결과를 식립된 임플란트 부위에서 관찰하여 다음과 같은 결론을 얻었다.

1. 총 22개의 상악동 절단면 영상에서 2차수술 시 임플란트 기저부까지 생성된 신생골을 관찰할 수 있었고, 이후 시간이 경과함에 따라 더욱 상악동의 함기화된 양상을 관찰할 수 있었다.

2. 2개의 증례에서 상악동막의 천공이 발생하였으며, 천공부의 적절한 처치를 통하여 별다른 합병증없이 잘 기능할 수 있었다.

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Case Report

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외상으로 흡수된 하악전치부에 대한 interpositional bone graft를 이용한 수직적 치조골 증대술 및 vestibuloplasty: 6.5년 관찰 증례보고

정창화, 이우열, 양성원, 조진용, 류재영, 김현민

가천대학교 길병원 치과센터 구강악안면외과

Vertical alveolar bone augmentation of traumatic resorpted anterior mandible using interpositional bone graft and vestibuloplasty: A 6.5 years follow up case report

Chang-Hwa Jeong, Woo-Yul Lee, Sung-Won Yang, Jin-Yong Cho, Jae-Young Ryu, Hyeon-Min Kim

Department of Oral and Maxillofacial Surgery, Dental Center, Gachon University Gil Medical Center, Incheon, Korea

Vertical alveolar bone resorption can occur as a result of periodontic, endodontic, or traumatic problems, etc. Several surgical procedures such as guided bone regeneration, block bone graft, distraction osteogenesis, and interpositional bone graft have been advocated for vertical alveolar bone augmentation of the atrophic mandible for dental implant placement. Advantages of the interpositional bone graft compared with the onlay type technique include ensuring a better blood supply to the positioned bony segment and maintaining vascularization in the bone ridge. Therefore, we report on a patient with deficient alveolar ridge in the anterior mandible, which was caused by trauma, who was treated with interpositional bone graft for vertical alveolar bone augmentation using a piezoelectric device to create selective cutting and vestibuloplasty for a stable soft tissue environment with a review of the literature.

Keywords: Interpositional bone graft; Vestibuloplasty; Osteotomy

서 론

치조골 흡수는 치수염, 치주염, 외상 등 여러 원인에 의해 발생될 수 있다.[1,2] 이로 인해 발생된 광범위 치조골 흡수는 임플란트 식립 등을 포함한 보철 치료에 있어서 치조골 증강술을 필요로 하게 된다. 특히 수직적인 치조골 증강술을 위해서 입자골(particulated bone)을 이용한 골유도재생술(guided bone regeneration, GBR), 블록골 이식술(block bone graft), 골신장술

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Correspondence to: Hyeon-Min Kim
Department of Oral and Maxillofacial Surgery, Dental Center, Gachon University Gil Medical Center, 21 Namdong-daero 774beon-gil, Namdong-gu, Incheon 405-760, Korea
Phone: +82-32-460-3373 , Fax: +82-32-460-3101, E-mail: jumincw@gilhospital.com

(distraction osteogenesis, DO), interpositional bone grafts 등 많은 방법과 재료들이 소개되어 있다.[2-7] 이들 술식 중, interpositional bone graft (sandwich technique)을 이용한 골증대술은 1976년 Schettler와 Holtermann[8]이 보고한 이후 변형된 술식 등과 더불어 지속적으로 발표되고 있다.[8-10] 이는 설측 또는 구개측 판막을 보존하면서 거상하여 위치시킴으로써 상방 부위에 혈류를 공급하여 기존의 block bone graft의 문제점인 상방골 흡수 및 열개의 비율을 낮추고, GBR 수술과 같은 많은 판막 거상을 필요로 하지 않으며, DO와 같은 장치의 이물감이 없어 수직적 골 증대술에 유용하게 이용되고 있다.[11-15] 골이식술 후 얕아진 구강 전정부(vestibule)에 대해 구강 전정성형술 (vestibuloplasty)를 시행하게 되는데, 이는 근육 부착부 위치를 낮추어 주고 치조골 융선을 회복시키며 충분한 구강 전정부의 깊이를 가져와 임플란트 주변 치은의 안정성과 장기간 예후를 향상시키기 위해 적용되고 있다.[16,17]

이에 본 보고에서는 외상으로 흡수된 하악 전치부에 대해 설측 판막 손상을 최소화하기 위해 piezoelectric surgery를 사용하고 interpositional bone graft를 통한 수직적 골재건술 및 구강 전정성형술을 시행한 후 6.5년간 관찰한 환자의 예후에 대해 문헌 고찰과 함께 보고하고자 한다.

증 례

44세 여성환자가 작업 도중 외상으로 타병원 수술 후 본원으로 전원되었다. 내원 당시 하악골 정중부 골절, Le-Fort II 및 III 골절, 비사골 골절, 안와저 골절에 대한 관혈적 정복술 및 재골내고정술 시행하였으며 이후 하악골 비유합이 발생하여 고정판 위치변경 및 괴사골 제거술 등을 시행하였다(Fig. 1). 수술 후 하악 전치부 치아 상실을 동반한 치조골의 수직적 흡수 및 구강 전정의 상실, 턱끝 근육(mentalis muscle)등의 협착을 동반한 개구제한소견을 보였다(Fig. 2A). 약 6개월 후 고정판 제거술 및 흡수된 하악 전치부 치조골 골대를 위해 interpositional bone graft를 계획하고 전신 마취하에 골절단술을 시행하였다(Fig. 2B). 먼저 전정부 절개(vestibular incision)를 시행하고 치조정 부위 판

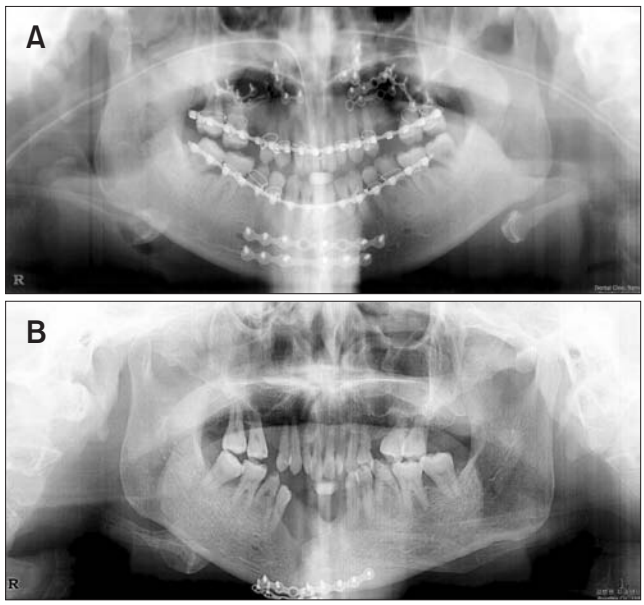

Fig. 1. A 44-year-old woman with a facial trauma. (A) Panoramic radiograph at the first visit. (B) Panoramic radiograph of the severely resorbed anterior mandible at 6 months after the re-operation of fractures.

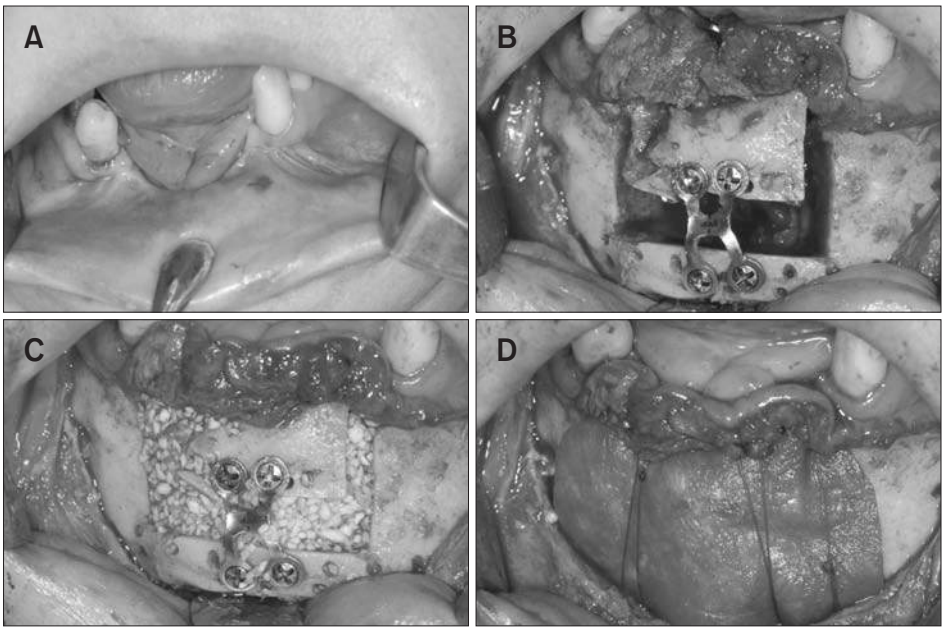

Fig. 2. Clinical photographs during sandwich osteotomy using piezoelectric surgery. (A) Clinical intraoral photo with the shallow anterior vestibule. (B) Elevation and fixation of the upper segment with a titanium plate and screws. (C) The interpositional bone graft with allograft. (D) A absorbable collagen membrane for preventing labial bony resorption.

막이 손상되지 않도록 박리한 후 상부 분절골의 주 혈류공급이 되는 설측 판막의 손상을 최소화하기 위해 piezoelectric surgery (Surgistar®; Dmetec Co., Bucheon, Korea) saw를 이용하여 골절단을 시행하였다. 인접치아에서 약 2 mm 떨어진 2개의 수직 골절단과 기존 screw 구멍을 이용하고자 치조정에서 약 8 mm 떨어진 곳에 수평골절단을 시행한 후 골절단부를 서로 연결하였다. 절단된 골의 상방 이동을 시행하고 수술 후 회귀현상을 방지하기 위해 티타늄 microplate 및 microscrews (Le Forte®; Jeil Co., Seoul, Korea)를 이용하여 상방분절골을 고정하였다(Fig. 2C). 이후 형성된 빈 공간에 동종골이식 (Sure-Oss™; HansBiomed Corp, Seoul, Korea)을 시행하였으며(Fig. 2C), 골이식 순측 부위에 이식골의 이동과 순측 연조직 침입을 방지하기 위해 흡수성 콜라겐 차폐막(Bio-Arm™; Purgo Co., Seongnam, Korea)으로 피개 후 봉합 고정하였다(Fig. 2D). 이후 층별 봉합을 시행하

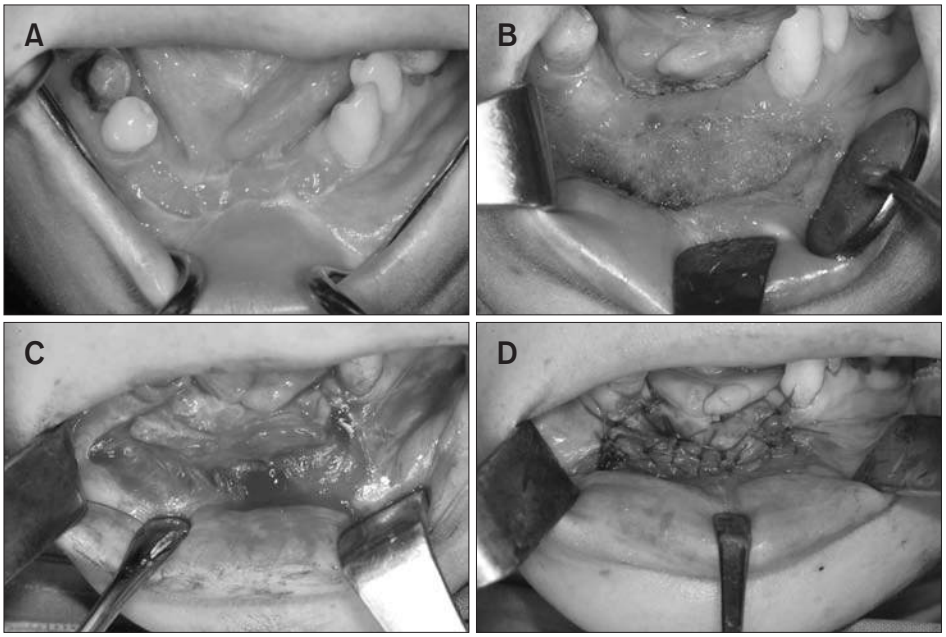

Fig. 3. Clinical photographs during vestibuloplasty for deepening of the vestibule and ensuring the stable soft tissue. (A) A pre-operation intraoral photo with the lower anterior vestibule. (B) After vestibuloplasty with CO_2 laser. (C) Picture of the submucosally raised labial flap towards top of the alveolar process. (D) Picture after the Kazanjian's operation.

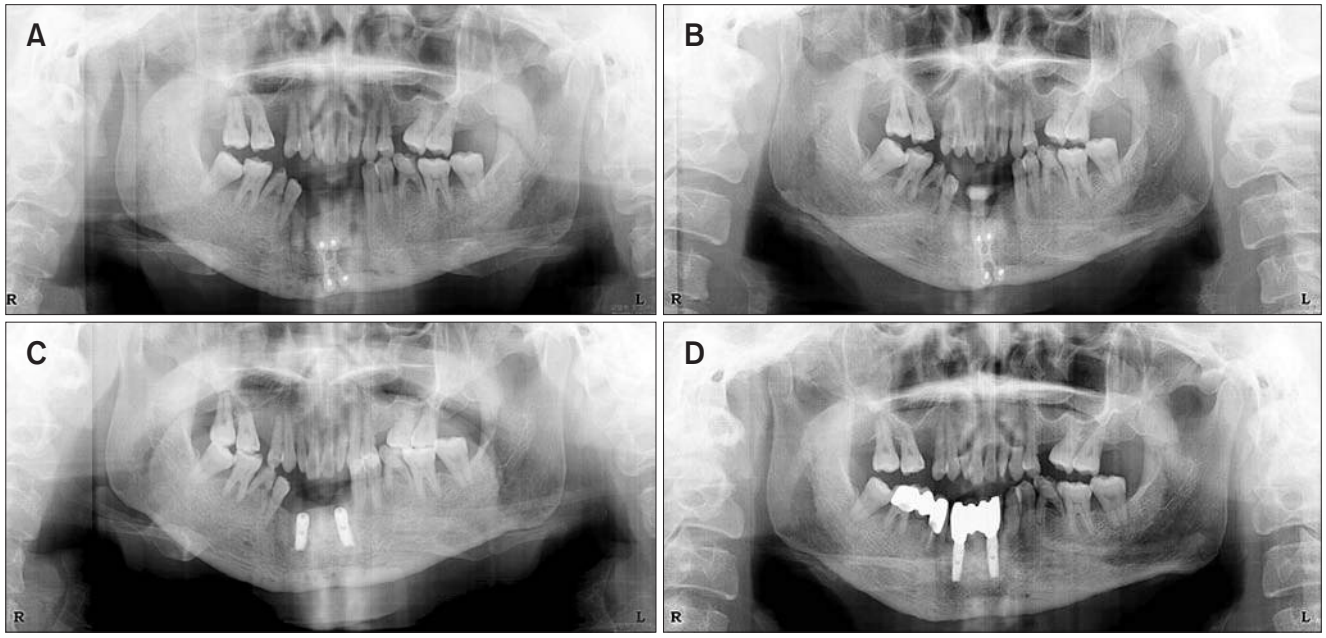

Fig. 4. Panoramic radiographs from interpositional bone graft to final implant supported restoration. (A) Panoramic view after the interpositional bone graft. (B) Five months after vertical augmentation. (C) Implants were placed after about one year. (D) Two years after the final implant supported restoration.

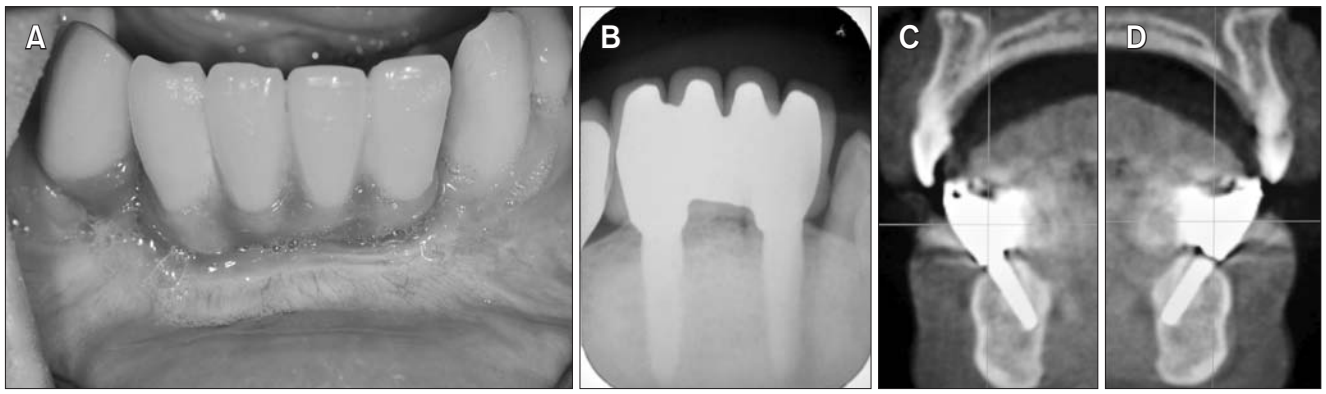

Fig. 5. Pictures at 6.5 years after interpositional bone graft. (A) A clinical photograph with stable vestibule. (B) Periapical radiograph with stable crestal bone. (C, D) Computed tomography scans show the favorable quality of alveolar bone.

였으며 봉합사는 1주일 후 부분 제거 및 약 2주 경과 후 완전히 제거하였다. 약 5개월 뒤 하순부 전정부위 깊이를 증가시키고, 입술 움직임을 향상시키기 위해 국소마취하에 CO_2 레이저(DS-40U(B), Daeshin Enterprise Co., Seoul, Korea)를 이용하여 구강전정성형술을 시행하였다(Fig. 3A, B). 이 후 전정 깊이의 추가적인 증가를 위한 변형된 Kazajian씨 구강전정성형술과 임플란트 식립이 동시에 시행되었다(Fig. 3C, D). 거상된 치조제와 골이식 부위는 안정적인 상태로 유지되어 있었고 지름 4.0 mm, 길이 13 mm 임플란트(GSIII®, Osstem Implant Co., Seoul, Korea) 2개를 식립하였다(Fig. 4C). 식립 후 3개월 경에 임플란트 이차수술을 시행하였고 1개월 후 최종 보철물을 장착하였다(Fig. 4). 이후 주기적 검사를 시행하고 약 6.5년 경과 관찰시 안정적인 골 및 연조직 상태를 유지하고 있었다(Fig. 5).

고 찰

다양한 수직적 골재건 방법 중 interpositional bone graft를 이용한 sandwich technique은 상하악 전치부 구치부 모두에 적용 가능한 술식으로 보고되고 있다.[6-13] Bormann 등[11]은 이 술식이 치조정 절개가 아닌 협, 순측 절개가 시행되고 가동성 점막의 탄력성으로 부가적인 감장 절개(release incision) 없이 긴장 없는(tension free) 봉합이 가능하여 다른 술식보다 열개(dehiscence)가 적으며, 상방 골 높이가 2-3 mm라도 괴사없이 하악 구치부에 적용시 수평 및 수직적 골증대를 가져 왔다고 보고하였다. 또한 상방 위치된 골 부위로의 치조점막이 유지되어 양호한 혈류공급을 기대할 수 있어 다른 onlay 형태 술식보다 골 흡수가 적고 치조정 부위 혈류화(vasculization)가 유지된다고 보고하였다.[13-15] 이와 같은 장점을 유지하기 위해서는 설측 연조직의 손상 없이 혈류공급을 보존하는 것이 중요하다. 여러 골절단 장비 중 piezoelectric surgery는 혈관, 상악동막, 신경과 같은 연조직 손상을 최소화하면서 골에 대한 선택적 절단이 가능하고 미세진동에 의한 섬세한 골절단이 가능하며, cavitation 효과로 시야 확보가 용이하다는 장점들이 있다. 상기 환자에 있어서도 상방 골의 혈류화에 중요한 요소인 설측 연조직 손상을 피하기 위해 piezoelectric surgery를 이용하였으며 설측 판막의 손상을 피하며 수직 증가를 가져올 수 있었다.[18-20] Sohn 등[12]은 piezoelectric 수직 골증강술 후 interpositional bone graft 재료로 mineral 동종골을 사용하여 5개월 뒤 조직검사에서 염증 반응없이 양호한 신생골 형성을 보였다고 하였다. 상기 증례의 경우에 있어서도 동종골 사용 후 안정적인 결과를 보였으며 순측에 흡수성 차폐막을 적용하여 순측 입자골의 흡수를 최소화할 수 있었다.

한편 구강전정성형술은 틀니(denture)의 유지력과 안정성을 증가시키고 GBR 후 얇은 구강 전정의 깊이를 회복시키며, 임플란트 주위 환경을 안정적으로 유지시키기 위한 목적으로 다양한 술식이 보고되고 있는데,[16-17] 본 증례의 경우 외상성 치조골 흡수로 구강 전정소실 및 턱끝 근육의 압박을 동반한 개구제한 증상을 CO_2 레이저 및 Kazanjian 순측 구강 전정성형술을 시행하여 임플란트 주변 및 구강전정의 안정성을 확보할 수 있었다.

본 증례를 통해 외상성 흡수로 발생된 하악 전방부 치조골에 대해 piezoelectric surgery를 이용한 sandwich osteotomy 및 구강전정성형술을 통해 수직적 골증대 및 주변 연조직 안정성을 경험하였기에 문헌고찰과 함께 보고하는 바이다.

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Case Report

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Piezosurgery sinus lift via crestal approach and without bone graft: A case report with cone-beam computed tomography 40 months follow-up

Giuseppe Sepe, Giorgio Dagnino, Rosario Sentineri, Calogero Bugea
Private Practices, Italy

Atrophy of posterior maxilla is a common clinical situation limiting standard implant surgery due to pneumathyzation of maxillary sinus and lack of sufficient bone height. Many procedures have been suggested in recent years, such as sinus lift by lateral access, sinus lift with crestal approach until the use of short implants to avoid sinus bone graft. The use of piezoelectric devices in recent decades enabled bypassing the major problem of classic technique of sinus lift by crestal approach as the use of a mallet, due to the possibility of identifying the sinus bone floor during ultrasonic implant site preparation and then directly reaching the membrane by means of a specific diamond-coated tip without cutting edges. In this case, a sinus lift procedure was performed via crestal approach with the aid of piezo-electric bone surgery and a 40-month cone-beam computed tomography follow-up with implant apex fully embedded in newly formed bone. The authors emphasize the importance of use of a piezo-electric device to reach sinus membrane without risk of lesion and to improve implant site preparation in terms of optimal implant primary stability and faster osseo-integration.

Keywords: Piezosurgery; Sinus lift; Crestal approach; Minimally invasive surgical procedure

INTRODUCTION

Implant supported dental prostheses have became a predictable treatment option in last 20 years in a continuous increasing number of patients worldwide. The need of oral implants rehabilitations, especially for advanced aged people presents many problems related to atrophy of jaws and lack of sufficient amount and/or quality of bone to insertion and stabilization of fixtures. The atrophy of posterior maxilla is a common clinical situation limiting standard implant surgery due to pneumathyzation of maxillary sinus and lack of sufficient bone height.

Many procedures were suggested in the past years as sinus lift by lateral access, sinus lift with crestal approach, the use of short implants until to all-on-six or all-on-four protocols with tilted distal implants, to avoid maxillary sinus and the need of bone graft. If the tilted implants technique has demonstrated an high predictability in the treatment of fully edentulous patients, the management of single or 2-3 implants rehabilitations in posterior maxilla is more difficult and often requires sinus lift aimed to gain 10 or plus millimeters bone height to standard implants installation.

Nowadays the principal question discussed into vary consensus conferences is a cut line in terms of residual bone

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Correspondence to: Giuseppe Sepe
Via 24 maggio, 9 Fondi, LT 04022, Italy
Phone: +39-771-523795, Fax: +39-771-523795, E-mail: giuseppesepe@tiscali.it

height to choice of lateral or crestal approach to sinus graft in order to offer a better and minimally invasive surgery as possible to the patient. According several authors the most involved factors in this choice are the possibility of implant insertion and its primary stability, the opportunity of single surgery, the need of brief healing periods due to work, social and psychological motivations.[1,2] The minimal bone height requested to avoid lateral access to sinus is reported be 4-5 mm in order to prepare implant site until to sinus bone floor and then lift Schneiderian membrane to accomplish standard implant of 10 mm or plus length.

Several techniques of crestal approach to sinus lift was described in last years, from osteotomes Summer's approach and further modified techniques[3], balloon technique, until to the advent of piezoelectric bone surgery as Intralift, hydrodynamic piezoelectric internal sinus elevation (HPISE) of physiolift in studies of Sohn et al.[4], Kim et al.[5] and Sentineri and Dagnino.[6] All these procedures are focused about implant primary stability reaching and preservation of sinus membrane integrity without perforation and dislocation of graft into a blind field as sinus antro.

The use of piezoelectric devices in last decades allowed to bypass major problem of classic technique as the use of mallet due to the possibility of identify during ultrasonic implant site preparation (UISP) the sinus bone floor and then

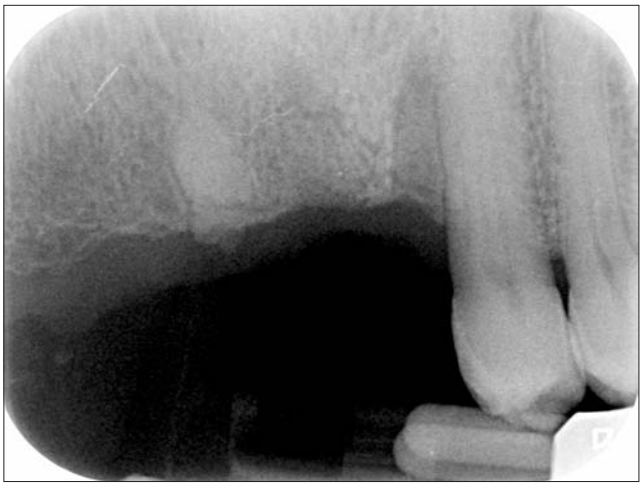

Fig. 1. Pre-operative radiogram with residual root and approximatively sufficient bone quantity to implant insertion.

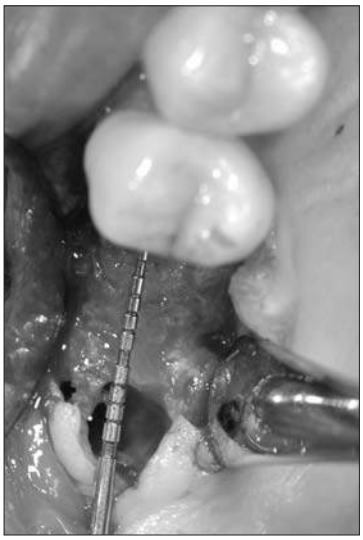

Fig. 3. Confirmation of mesio-distal space and crestal width by periodontal probe.

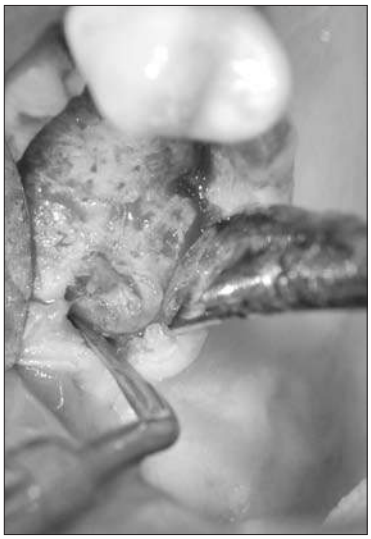

Fig. 2. Piezosurgery osteotomy and root plasty with EX1 tip to extract residual root .

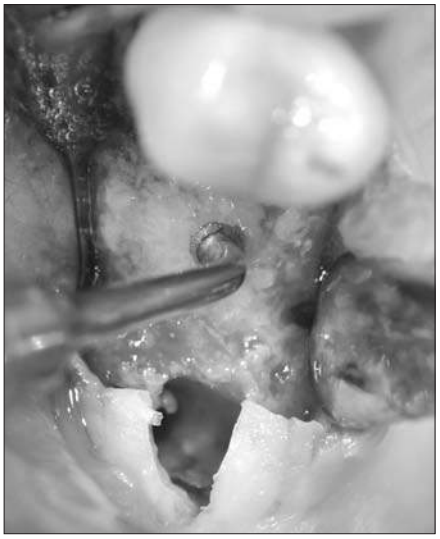

Fig. 4. Piezosurgery IM1 conical 0.5-2 mm tip to determining precise position and axis of implant pilot osteotomy.

to directly reach the membrane by mea n of a specific non cutting tip.

In fact, the selective cut on mineralized tissues of piezosurgery diamond-coated tips, designed without intrinsically cutting edges, preserve the integrity of sinus membrane during its contact and lift it by effect of saline flow and ultrasonic cavitation.

Moreover from the implant site preparation point of view, several studies have demonstrated many advantages of piezosurgery cut rather than drills in terms of more rapid and better bone healing with absence of inflammation,[7] faster secondary stability,[8,9] high radiologic bone response with increasing of cortical bone aronud implant threads.[10] The pool of this data emerged from piezosurgery studies suggest a better bone healing and regeneration, named by Vercellotti et al.[9] as "ultra-osseointegration" and explained by microsurgical selective cut with bone micronization and subsequent high surface cleanness of implant bone site as effect of ultrasonic cavitation of double saline irrigation of piezoelectric tips.

The present case-report shows the management of single-implant in insufficient bone height site by mean piezosurgery device to perform implant osteotomy and lift sinus membrane without graft of bone substitutes. After 40 months cone-beam computed tomography (CBCT) follow-up to confirm the success of technique with implant fully embedded In new

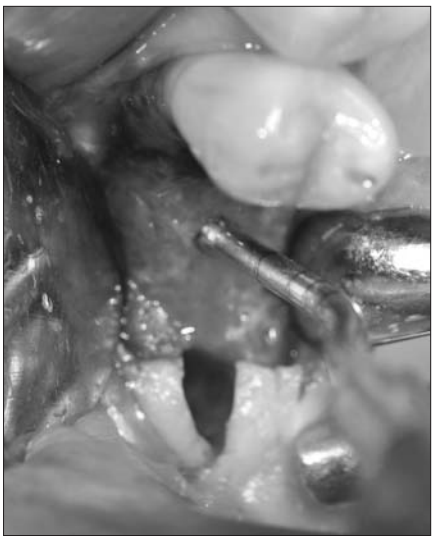

Fig. 5. Cylindrical osteotomy of 2 mm diameter performed with IM2A tip; the microsurgical cutting action allows the tip stop against sinus bone floor.

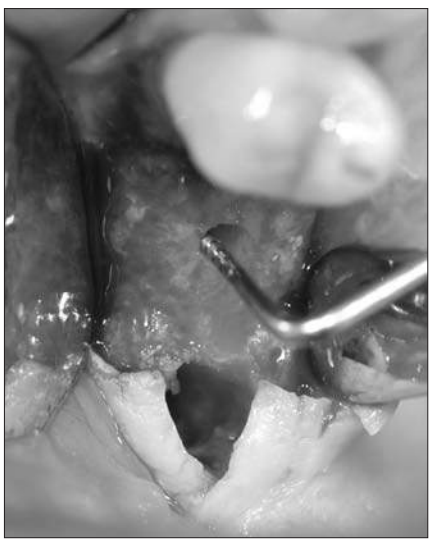

Fig. 6. Confirmation of depth of 7 mm until sinus bone floor with periodontal probe.

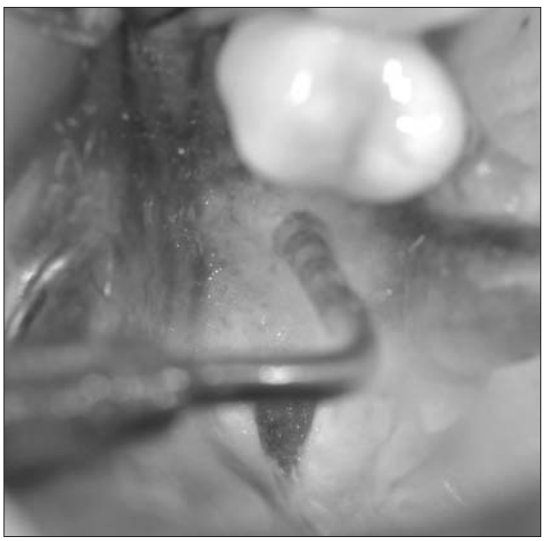

Fig. 7. Piezoelectric erosion of sinus bone floor by osteoplastic action of diamond-coated OT4 tip. The macro and micro geometry of tip without cutting edges allows a safe procedure.

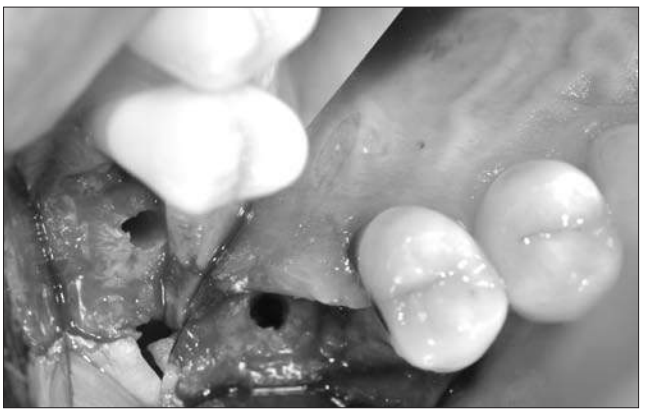

Fig. 8. Implant site after osteoplasty of sinus bone floor.

formed bone, several advantages of piezosurgery technique are discussed in comparison with others clinical procedures.

CASE

A male patient aged 60 years old, no smoker and risk class ASA grade 1, requested implant replacement of right upper first molar extracted 6 months ago due to prosthetic and endodontic failure.

According a baseline endoral radiography (Fig. 1) in which a sufficient bone height was approximatively expected and a residual root was noticed, a standard implant procedure was planned for wide diameter 10 mm length fixture, with UISP technique by mean of Mectron Piezosurgery II device (Mectron Company, Carasco, Italy).

After soft tissues raising to access to surgical site, the residual disto-buccal root was extracted after piezoelectric osteotomy by EX1 tip and the ridge bone width was measured with a periodontal probe to asses mesio-distal and bucco-lingual space (Figs. 2, 3).

Implant site preparation was started with IM1 tip (Fig. 4) and its position and axis were defined respect to limiting second bicuspid.

The second tip (IM2) (Fig. 5), used according Vercellotti

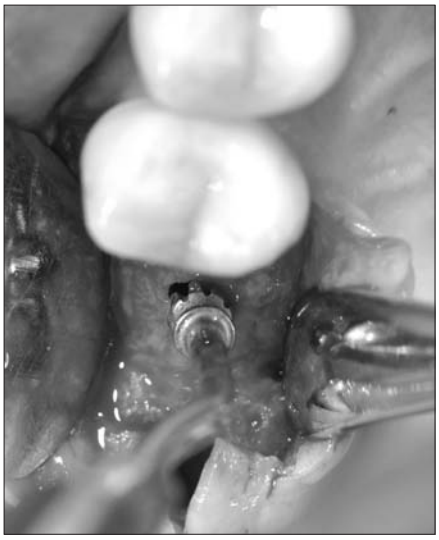

Fig. 9. Enlargement of implant bed to 3 mm diameter with IM3 tip.

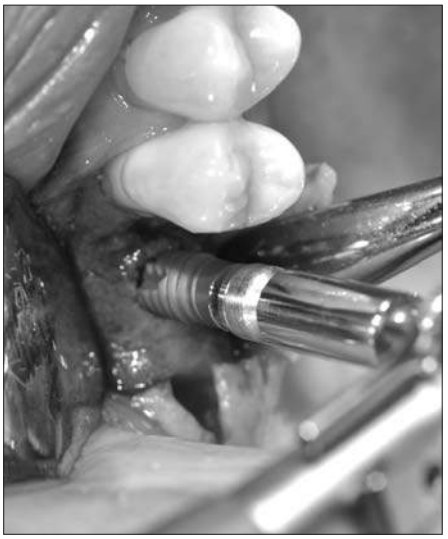

Fig. 11. Insertion of transmucosal 4.8 mm diameter and 10 mm length implant (Sharp; Impladent, Formia, Italy) after lifting sinus membrane by means of fibrin sponges.

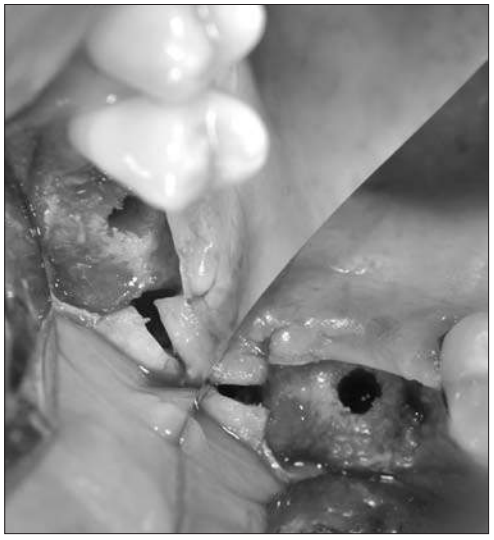

Fig. 10. Control of membrane integration preservation.

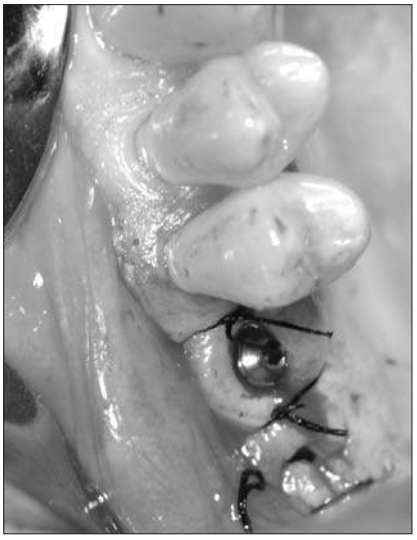

Fig. 12. Single 3.0 silk interrupted suture to primary closure of soft tissues.

et al.'s protocol[9], stopped is action at 7 mm depth (Fig. 6) due to sudden increasing of bone resistance and so allowed to identify the sinus bone floor "as it was an apex locator". This unespected even induced the surgeon to decide for sinus lift via implant site to accomplish a 10 mm implant.

By means of the same IM2 tip and by control under magnification of depth lines on the tip, anothers 0.5-1.0 mm in the width of sinus bone floor were consumed, then a diamond coated OT4 tip (Fig. 7) without intrinse cutting edges was gently pushed until to direct contact with Schneiderian membrane without lacerate it.

The OT4 tip with interposition of some sponges of fibrin lifted sinus membrane and implant site was completed with IM3 and IM4 tips (Figs. 8-10). A 4.8 mm diameter and 10 mm length implant (Complete Implant; Impladent, Formia, Italy) was inserted at over 50 N/cm torque and sinus membrane was lifted near of 5 mm height (Figs. 11, 12). The post-operative endoral X-ray confirmed optimal implant position with sinus lift (Fig. 13A) and fibrin sponges secured under the membrane.

After 6 months uneventful radiological healing (Fig. 13B) and second surgery the implant was connected and finalized with metal-ceramic cemented crown (Figs. 14, 15). The follow up seriated X-rays showed the optimal function of implant and the stability of hard tissues (Fig. 16). After 40 months the patient underwent CBCT scan for endodontic

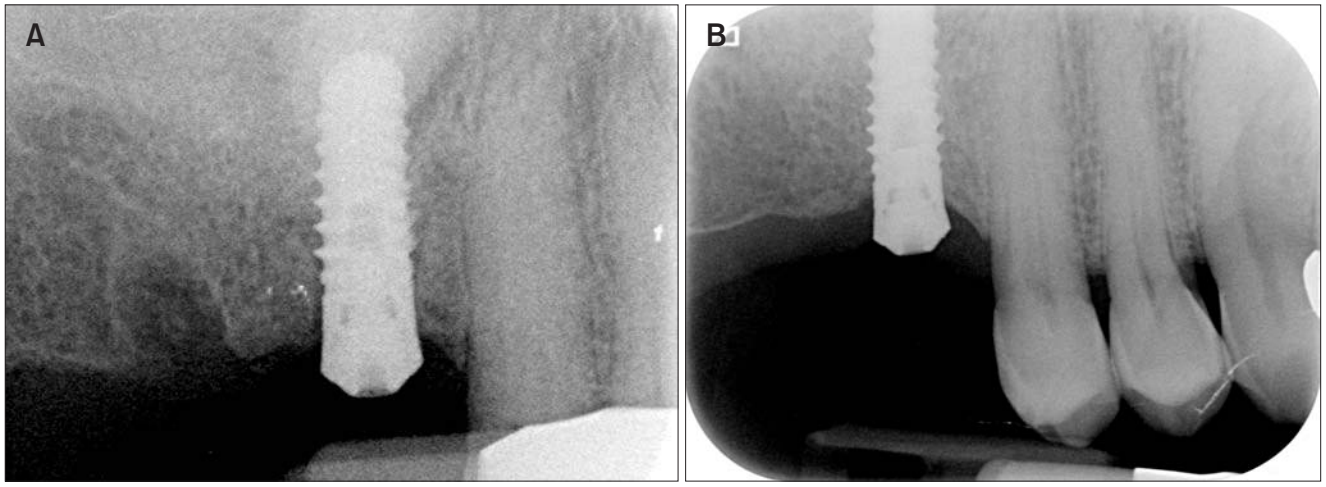

Fig. 13. (A) Post-operative radiogram showing the correct implant position and the fibrin sponges over the fixture apex. (B) Radiologic check-up after 6 months with evidence of peri-implant bone healing.

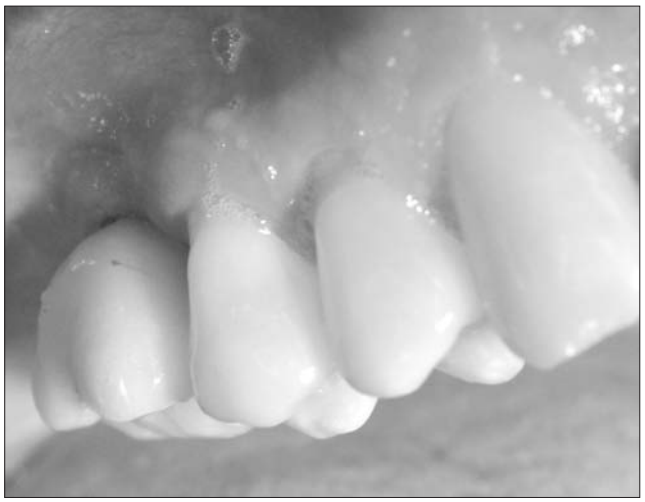

Fig. 14. Prosthetic management of implant with metal-ceramic crown cemented to standard titanium abutment.

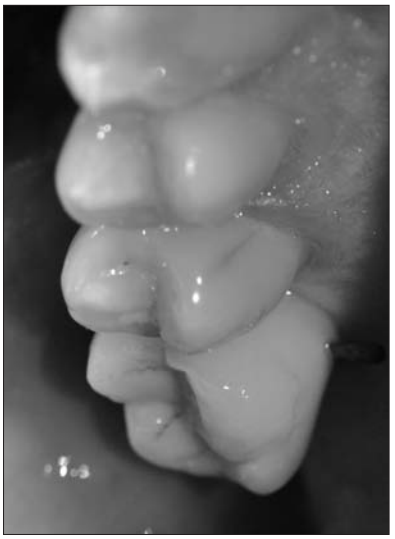

Fig. 15. Prosthetic management of implant with metal-ceramic crown cemented to standard titanium abutment.

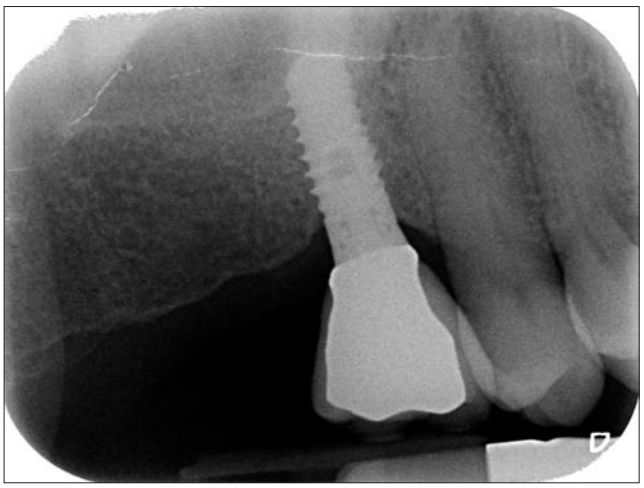

Fig. 16. Radiogram after 1-year loading showing bone stability around the implant and at the site of sinus lift.

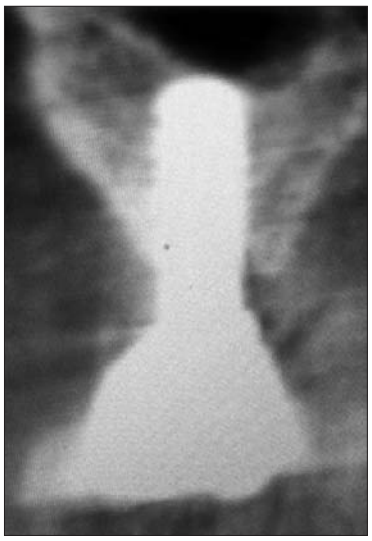

Fig. 18. Cone-beam computed tomography images after 40 months of loading, planned for other reasons, with implant apex fully embedded into bone and stability of peri-implant bone.

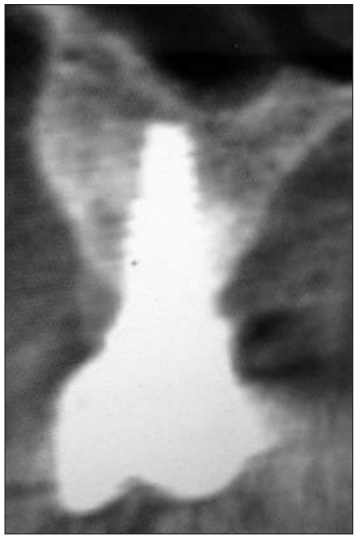

Fig. 17. Cone-beam computed tomography images after 40 months of loading, planned for other reasons, with implant apex fully embedded into bone and stability of peri-implant bone.

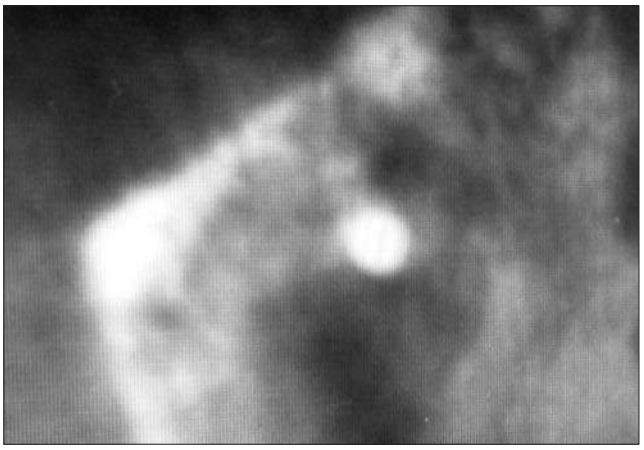

Fig. 19. Cone-beam computed tomography images after 40 months of loading, planned for other reasons, with implant apex fully embedded into bone and stability of peri-implant bone.

reasons and it was possible to evidence a fully embedded in bone implant, a real bone regeneration under lifted membrane (Figs. 17-19), the stability of regenerated hard tissues without any graft of bone substitutes.

DISCUSSION

The crestal via to sinus lift when bone height and amount are insufficient to ensure implant primary stability allows a minimally invasive surgical management of atrophy of posterior maxilla without need and risks of lateral access and the dilatation of healing period.[11]

The original technique of Summer[12] showed an high success percentage but was affected by principal disadvantage of use of the mallet to obtain the progression of osteotomes used to expand implant site and finally to lift sinus bone floor.

The mallet not ever is well accepted by patients and can provoke such complications as parossistic vertigo, direct membrane perforation, profuse bone bleeding and hematomas.

In order to avoid the use of mallet specific drills eroding sinus bone floor were proposed[11] together with devices to atraumatically lift sinus membrane as rubber balloons and

similar.

The development of piezosurgery devices and techniques has revolutioned the management of sinus lift with low membrane perforation rates in the lateral access[12] or via crestal approach.[4-6] Piezoelectric bone surgery techniques as Intralift or HPISE are based on ultrasonic erosion of sinus bone floor by mean of specific tips until to reach the Schneiderian membrane and then they lift sinus membrane by saline flow out of the tip edge providing the space to accomplish the bone graft, when necessary, and the implant.

Sentineri and Dagnino's[6] physiolift technique, instead, after gentle consumption of sinus bone floor with round ball diamond coated piezosurgery tips (OT9 or OT5), requests sinus lift according the concept of hydrostatic pressure of saline water forced into a syringe connected via a plastic tube with a bone expander previously screwed into implant site osteotomy. The amount of sinus lift available with this technique varies from 3-4 mm to over 10 mm as reported by authors, furthermore it can be more time consuming procedure and requests a deep learning curve. Moreover even this technique is based on graft of bone substitutes according a blind field approach without direct control of membrane integrity and with the risk of dislocation of the graft into the sinus.

Sohn's[4,5] HPISE technique, instead, after piezoelectric cut of sinus bone floor, lifts the sinus membrane by bone graft or, more recently, only with the use of fibrin-rich blocks with concentrated growth factors membrane, with a consistent gain of bone height.

Many authors have reported high success percentages in terms of implant success and bone height increasing with classic osteotomes techniques and without use of bone graft and explained these results with the creation of a self regenerative space between implant apex and sinus membrane rather the use of bone substitutes.

Piezosurgery sinus lift via crestal approach and without bone substitutes has not yet documented in literature, and the result of present case-report can be explained by surgical and biologic effects of ultrasonic cut respect the microdamage of implant site by the action of drills or osteotomes. These last ones was demonstrated to enlarge the osteotomy size by fracturing bone trabeculas and so to be characterized by high failure percentage.

The surgical effect of UISP is the achievement of implant bed with high surface cleanness rate, without necrotic bone debris, with preservation of bone microarchitecture in the cortical and marrow spaces, with the maintenance of intact micro-vessels and osteocytic lacunas.[7,14]

From the biologic point of view the study of Preti et al.[7] has emphasized the increase of bone morphogenetic protein and transforming growth factor factors after piezosurgery implant site preparation in *in vivo* animal models, respectively 16 to 4 times than drill techniques, and this fact can induce us to suppose that piezosurgery bone cut can improve the genetically pre-determined regenerative processes. These results find a clinical confirmation in studies about implant site preparation with piezo-electric device versus twist drills; the evidence of better and faster appearance of secondary stability in immediately loaded implants was by Stacchi et al.[8] on piezosurgery group as, in analogue manner, Di Alberti et al.[10] described in a radiologic study a dramatically increased bone density for fixtures inserted after UISP rather those screwed after drill preparation.

A recent multicentre study conducted by Vercellotti et al.'s[9] group on 3,579 implants inserted after UISP and with a 1-3 years follow-up documented an overall implant survival rate of 97.74% (96.99% maxilla, 98.75% mandible) showing as this technique could be a reliable alternative to traditional protocols. The importance of these results can direct the choice of the surgeon on the UISP especially in cases of poor bone quantity or quality and of difficult anatomy due to evident advantages of piezosurgery cut as preservation of noble soft tissues (nerves, vessels, Schneiderian membrane) respect those mineralized and extreme precision of microsurgical cut on reduced bone, avoiding peri-implant dehiscences and the need of regenerative procedures.

The sinus lift via crestal approach and without bone substitute graft can become a viable and safe technique, without risks of membrane perforation and dislocation of heterogenic materials in the antro. In adjunct UISP allows a minimally invasive surgery with the achievement of better primary implant stability and stimulation of self bone regeneration in the closed space between implant apex and sinus membrane pushed up by the fibrin as space maintainer.

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Case Report

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Removal of displaced foreign body from the maxillary sinus, followed by simultaneous sinus augmentation: A case report

Dong-Seok Sohn
Department of Dentistry and Oral and Maxillofacial Surgery, Daegu Catholic University Medical Center, Daegu, Korea

Implant displacement to the maxillary sinus is a common complication in sinus augmentation. Numerous surgical techniques for removal of implants from maxillary sinuses have been reported. This case report demonstrates an innovative surgical technique for removal of displaced implants concomitant with sinus by utilization of a replaceable bony window.

Keywords: Dental implant; Piezosurgery; Sinus floor augmentation

INTRODUCTION

Dental implants can be displaced into the maxillary sinus due to poor bone density and poor surgical technique in the atrophic posterior maxilla.[1] Migrated implants in the sinus can cause significant complications such as inflammatory reactions, sinusitis, and fungal infections,[2,3] and the dental implant can be displaced into the sphenoidal sinus.[4] To remove displaced implant from the sinus, the Caldwell-Luc approach or the lateral window approach, combined with endoscopic surgery have been reported.[5-8] However, when the Caldwell-Luc or lateral window approach is performed without a sinus graft, the access window is not be replaced by a new bony wall in the lateral wall of the sinus.[9] The utilization of endoscopy is definitely effective, but this procedure requires specific training and expensive equipment.[10] The aim of this report is to present a simple procedure to remove displaced implant using replaceable bony window to save lateral wall of sinus cavity, followed by sinus augmentation with simultaneous implant placement.

CASE

A fifty years old woman was referred, by her family dentist, to the Department of Oral and Maxillofacial Surgery in Daegu Catholic Medical Center, for the removal of displaced implant into the maxillary sinus during crestal approached sinus augmentation. Initial stability of implant was very poor improper osteotomy (Fig. 1). Prophylactic Flomoxef sodium

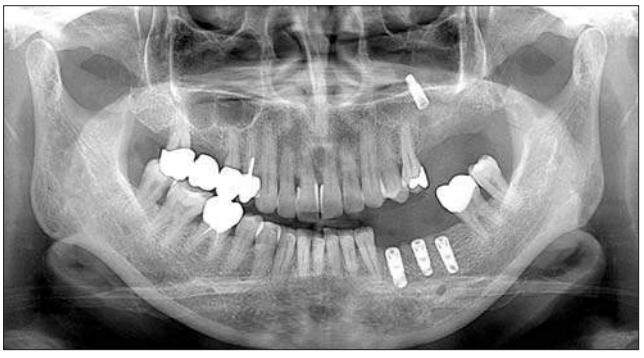

Fig. 1. Radiogram showing displace implant in the left maxillary sinus.

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Correspondence to: Dong-Seok Sohn
Department of Oral and Maxillofacial Surgery, Daegu Catholic University Medical Center, 33 Duryugongwon-ro 17-gil, Nam-gu, Daegu 42472, Korea
Phone: +82-53-650-4291, Fax: +82-53-622-7067, E-mail: dssohn@cu.ac.kr

(Flumarin®, 500 mg intravenous; Ildong Pharmacentical Co., Seoul, Korea,) was administered one hour before surgery. After the administration of a local anesthetic solution (2% lidocaine with 1:100,000 epinephrine), a full thickness mucoperiosteal flap was elevated to expose the lateral wall of the maxillary sinus. A saw insert with a thin blade (S-Saw; S-Dental Co., Daegu, Korea), connected to an ultrasonic piezoelectric device (Surgybone®; Silfradent Srl, Sofia, Italy), was used to make the replaceable bony window. The inferior osteotomy was made 2-3 mm above the sinus floor and the anterior vertical osteotomy was made 2 mm distal to the anterior vertical wall of the maxillary sinus. Both osteotomies were created perpendicularly to the inside of the maxillary sinus lateral wall in order to facilitate the precise replacement of the bony window after removal of the foreign body from the sinus. The distal osteotomy was made approximately 15 mm away from the anterior vertical osteotomy. The height of the vertical osteotomy was approximately 10 mm (Fig. 2). The bony window was detached to expose the sinus membrane. An approximately 1 cm long incision was made through the sinus membrane. The suction apparatus was

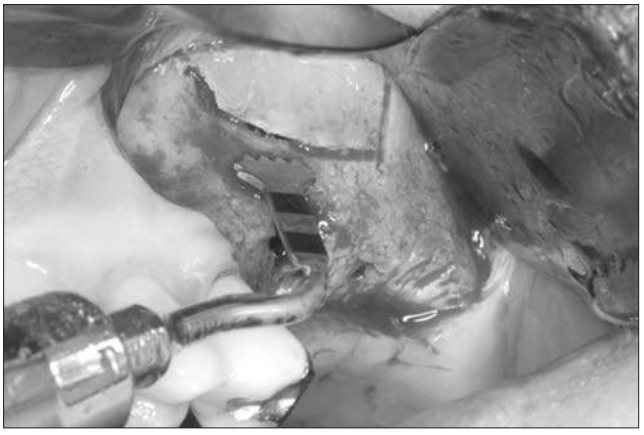

Fig. 2. Piezoelectric saw insert was utilized to make a replaceable bony window. Tilted osteotomy was performed to facilitate replacement of bony window.

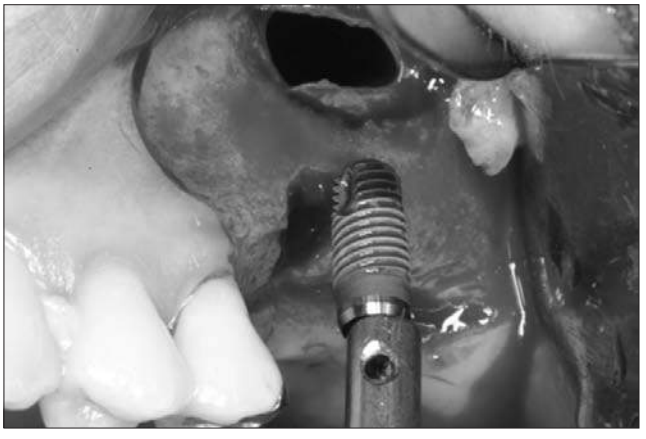

Fig. 3. The implant was suctioned with a saline flow by an aspirator.

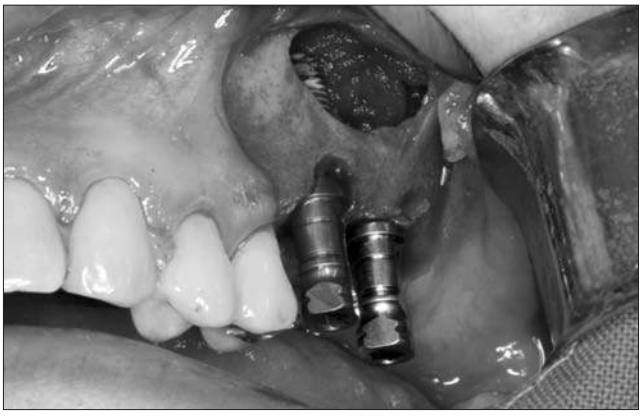

Fig. 4. Implants were placed at the same time after placing absorbable gelatin sponge in the new compartment under the elevated sinus mucosa.

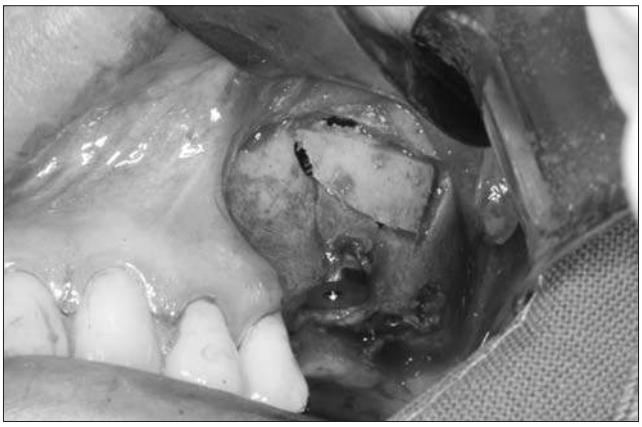

Fig. 5. Replacement of bony window.

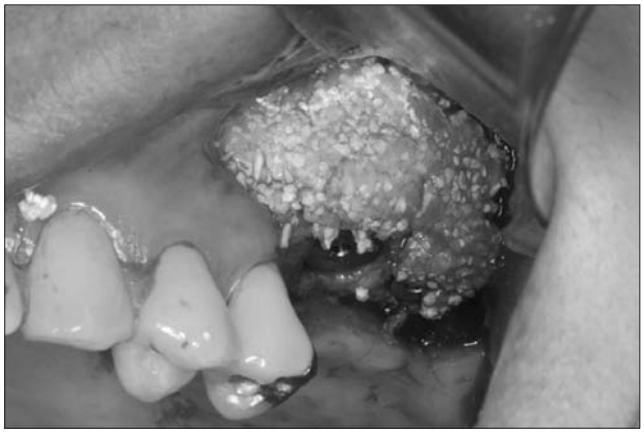

Fig. 6. Ridge augmentation using gel conditioned bone collagen membrane was performed.

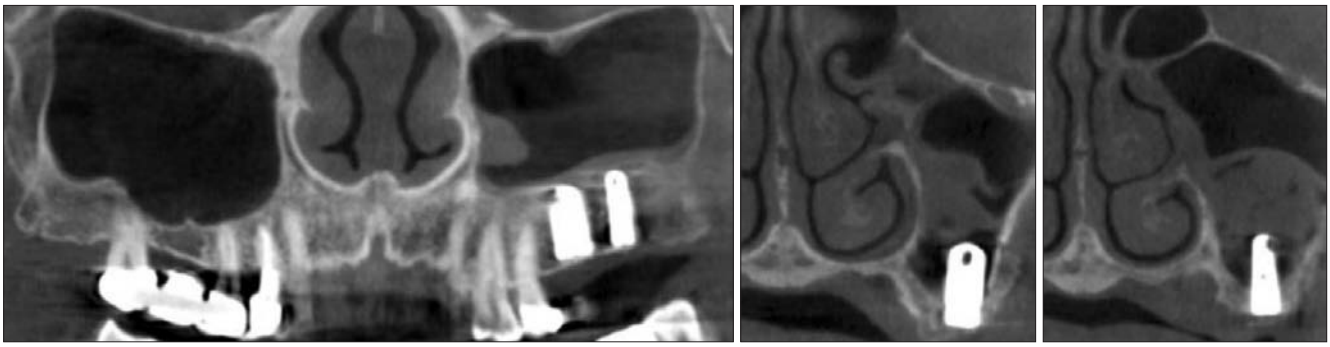

Fig. 7. Postoperative cone-beam computed tomotraphy showing sinus elevation.

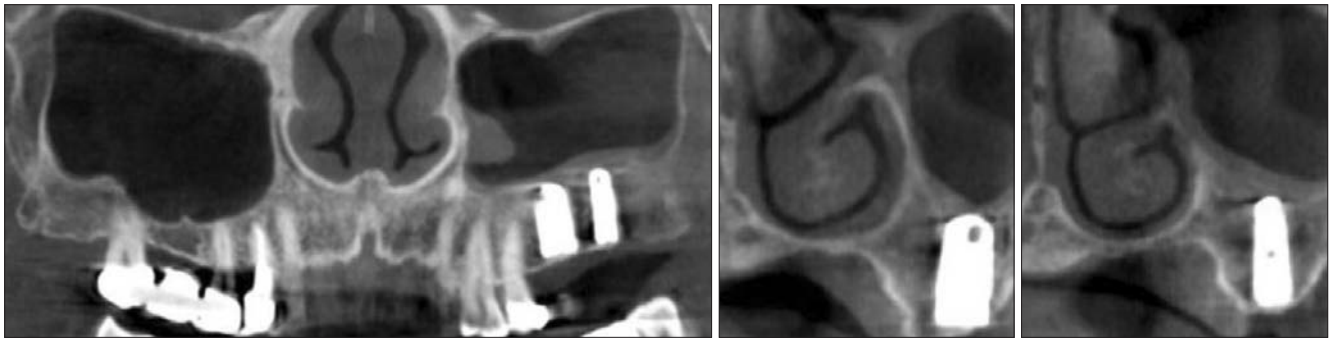

Fig. 8. Cone-beam computed tomotraphy showing new bone formation in the sinus after 9 month healing.

intruded into the sinus, and normal saline was injected into the sinus cavity at the same time. The implant, floating in the saline flow, was removed by suction apparatus (Fig. 3). After the removal of the implant, elevation of sinus mucosae was continued as same as procedure of conventional sinus augmentation. Absorbable gelatin sponge (Cutanplast®; Mascia Brunelli Spa., Milano, Italy) was placed in the sinus to seal membrane perforation and stabilize blood clot. Implants were placed at the site corresponding to the first and second molar simultaneously without further osteotomy (Fig. 4). Bony window was repositioned and ridge augmentation using gel conditioned bone (Orthoblast II®; Integra, Irvine, CA, USA) and collagen membrane was performed. Flaps were sutured using PTFE sutures (Cytoplast®; Osteogenic Biomedical, Lubbock, TX, USA) to achieve passive primary closure (Fig. 5, 6). Postoperative cefditoren pivoxil (Meiact®; Boryung Parm., Seoul, Korea) 300 mg was used for seven days three times a day and the sutures were removed 10 days postoperatively. Postoperative cone-beam computed tomographic (CBCT) scans revealed the sinus is filled with blood clots and voids under the elevated sinus membrane (Fig. 7). The patient came back to our department after 9 months healing. CBCT revealed new bone formation in the sinus and favorable healing of repositioned bony window and ridge augmentation (Fig. 8, 9).

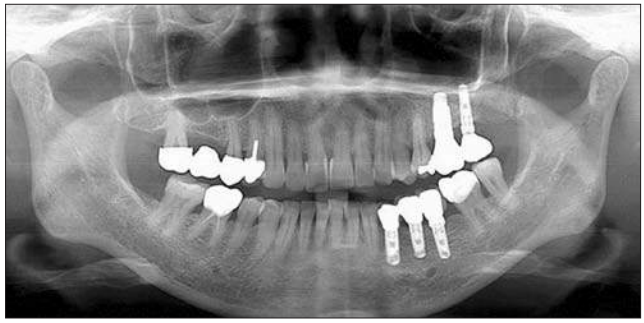

Fig. 9. Radiogram after 6 months loading. Note well maintained new bone in the sinus.

DISCUSSION

The displacement of a dental implant into sinuses is one of a common complication in implant dentistry. Displacement of implant or foreign body can cause serious complications if not removed from the sinus.[2,3,8] Numerous surgical methods for the removal of foreign bodies in the sinus have been reported.[2,3,9-11]

Endoscopic transantral/transnasal surgery are commonly

used procedures for the retrieval of migrated foreign material in the sinus. However this technique requires special training on endoscopy, special equipment and high surgical cost.[10] In addition, when the dental office doesn't have this device, a patient should be referred to another clinic which have endoscopy, so this complication can't be solved at the same place. Therefor surgical cost and number of surgery are increased.

The Caldwell-Luc approach using the lateral window provides easy access to sinus cavity and visualization of displaced implant but has some disadvantages such as postoperative numbness, paresthesia, facial asymmetry and dental problems.[12] In addition, sinus bone graft is not performed simultaneously, lateral wall of sinus cavity is not regenerated.[13] According to some studies, sinus bone grafting procedure causes high risk of sinusitis and implant failure when large perforated sinus membranes is existed.[14,15]

After detachment of replaceable bony window, saline irrigation through a small incision site of sinus mucosa into the sinus cavity mobilizes displaced foreign bodies in the sinus, and a surgical suction apparatus aspirates the saline and foreign body at the same time. This technique is a simple and quick method to retrieve a foreign body out of the sinus, and does not require special instruments, as endoscopy does.[11]

The replaceable bony window not only maintains the integrity of the lateral wall of the sinus after the removal of the foreign body but also accelerates bone regeneration in the sinus.[16,17]

A piezoelectric saw insert-assisted osteotomy has some advantages such as speed, precision, and minimal bone loss.[18] The lateral bony window made by the piezoelectric saw insert with a thin blade is precisely repositioned, whether bone grafting in the sinus was performed or not, because of the tilted osteotomy into the sinus and the minimal bone loss during osteotomy.

Several studies confirmed that bone graft is not an essential condition for sinus augmentation.[19-21] Bone graft is not recommended when sinus mucosa is severely damaged to prevent postoperative sinusitis. Large perforation of sinus mucosa is always made when retrieving of displaced implant from sinus cavity. Therefore, as an alternative to bone substitute for sinus augmentation, patient's blood, gelatin sponges, platelet-rich plasma, and platelet-rich fibrin blocks with concentrated growth factors grafted in the new compartment under the elevated sinus membrane are strongly suggested to prevent sinusitis.[19]

Lateral approach using replaceable osteoinductive bony window could be an innovative technique for the removal of displaced implant and simultaneous sinus augmentation.

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