Chapter 16

Healing Mechanism and Clinical Application of Autogenous Tooth Bone Graft Material

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Additional information is available at the end of the chapter

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1. Introduction

Autogenous bone, allogenic bone, xenogenic bone, and alloplastic materials are bone graft materials that are presently used in dental clinics. According to bone healing mechanism, they can be categorized into materials that induce osteogenesis, osteoinduction, and osteoconduction. Among the many different types of bone graft materials, autogenous bone is the most ideal since it is capable of osteogenesis, osteoinduction, and osteoconduction. Its advantage is the rapid healing time without immune rejection. As its biggest shortcomings, however, the harvest amount is limited, bone resorption after graft is unavoidable, and second defect is generated in the donor area. Therefore, to overcome such shortcomings, allogenic bone and synthetic bone were developed and used in clinics, and efforts have been made to develop more ideal bone substitution materials [1]. Lately, researchers and clinicians have become interested in the use of human dentin from extracted teeth in the context of autogenous bone grafts [2,3]. Dentin has inorganic and organic components that are very similar to those of human bone. In dentin, the inorganic content is 70 ~ 75%, whereas the organic content is about 20%. In alveolar bone, the inorganic content is 65%, and the organic content is 25%. At least 90% of organic content of dentin is type I collagen, which plays an important role in bone formation and mineralization. Dentin also contains bone morphogenetic proteins (BMP), which promote the differentiation of mesenchymal stem cells into chondrocytes and consequently enhance bone formation. In addition, both alveolar bone and teeth are derived from neural crest cells [4-6]. Thus, studies have been done to use fresh tooth in the form of demineralized dentin matrix (DDM) as a biocompatible autogenous bone graft material in alveolar bone repair. Butler, et al [7] and Conover and Urist, et al [8] successfully extracted bone BMP

from rabbit DDM, and Bessho, et al [9] secured new bone formation *in situ* by BMP from human DDM. Furthermore, Ike and Urist [10] used dentin root matrix as a carrier of recombinant human bone morphogenetic protein (rhBMP). Starting in 1993, we developed bone graft materials using human teeth with which we conducted experimental studies [11-22]. In 2008, we developed an autogenous tooth bone graft material (AutoBT; Korea Tooth Bank Co., Seoul, Korea) from extracted teeth prepared as powder and grafted it to the donor patient himself. The mineral components of autogenous tooth bone graft materials have 4 stages (types) of calcium phosphate (HA, TCP, OCP, and ACP). Under scanning electron microscopic examination, HA crystalline structures and collagen fibers around the dentinal tubules were detected. Short-term clinical studies reported that, even when wounds became dehiscent, the bone graft materials were not infected, and good secondary healing was achieved [3,23].

2. Osteoinduction of AutoBT

Many researchers have examined tooth dentin as a potential carrier for human proteins and as grafting material because its biological composition is very similar to that of alveolar bone [9, 24-28]. Both tooth and alveolar bone are derived from neural crest cells and are made up of the same Type I collagen. Furthermore, dentin contains BMPs, which induce bone formation and noncollagenous proteins such as osteocalcin, osteonectin, and dentin phosphoprotein [29, 30]. Since its investigation by Urist in 1965, BMP has been widely studied and used in clinical applications [31]. As a result, Yeoman and Urist, et al (1967) and Bang and Urist, et al (1967) showed the osteoinductivity of rabbit DDM by BMP [32, 33]. Bessho, et al extracted BMP from bone matrix, dentin matrix, and wound tissue after extracting teeth from rabbits. Each BMP was confirmed to have induced the formation of new bone when xenogenic implantation was performed [9]. Bessho, et al extracted human dentin matrix containing 4mol/L guanidine HC1 and refined it into liquid chromatography and found out based on SDS-PAGE and IEF that purified BMP is homogenous, inducing the formation of new bone within 3 weeks of implantation in muscle pouches in Wistar rats. Dentin matrix-derived BMP is not exactly same as bone matrix-derived BMP, but they are very similar. In other words, two types of BMP exhibit the same action in the body [34]. The organic component accounts for about 20% of dentin weight and mostly consists of type I collagen. Moreover, it was proven to have BMP promoting cartilage and bone formation, and differentiating undifferentiated mesenchymal stem cells into chondrocytes and osteogenic cells [30, 35-37]. Noncollagenous proteins of dentin such as osteocalcin, osteonectin, phosphoprotein, and sialoprotein are known to be involved in bone calcification [38,39].

Patterns of matrix protein in teeth must have osteoinductive potential even though it does not perfectly match the protein in alveolar bone. Moreover, the apatite in teeth has long been known to play the role of protecting proteins [40]. According to Boden, et al, LIM mineralization protein 1 (LMP-1) is an essential positive regulator of osteoblast differentiation and maturation and bone formation [41]. Wang, et al found that LIM-1 was expressed primarily in predentin, odontoblasts, and endothelial cells of the blood vessels of teeth [42].

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Many researchers have observed that alveolar bone formation occurs around bone graft materials as a result of experiments on animals [43-47]. Chung registered the patent for the technology of extracting proteins from teeth in 2002 and 2004; this carries an important, serving as evidence that teeth contain bone morphogenic protein [48,49]. Ike and Urist suggested that root dentin prepared from extracted teeth may be recycled for use as carrier of rhBMP-2 because it induces new bone formation in the periodontium [10]. Murata, et al reported that demineralized dentin matrix (DDM) does not inhibit BMP-2 activity but shows better release profile of BMP-2. Human recycled DDM is an unique, absorbable matrix with osteoinductivity, and DDM should be an effective graft material as a carrier of BMP-2 and a scaffold for bone-forming cells for bone engineering [2].

Lee [50] performed quantitative analysis of proliferation and differentiation of the MG-63 cell line on the bone grafting material using human tooth. This study demonstrated that the cellular adhesion and proliferation activity of the MG-63 cell on partially demineralized dentin matrix (PDDM) were comparable to control with enhanced osteogenic differentiation (Figure 1). Kim & Choi [51] reported a case on tooth autotransplantation with autogenous tooth bone graft. The extracted right mandibular third molar of a 37-year-old man was transplanted into the first molar area, and a bone graft procedure using autogenous tooth-bone graft material was performed for the space between the root and the alveolar socket. Reattachment was achieved (Figure 2). Therefore, the autogenous tooth bone graft material is considered reasonable for bone inducement and healing in the autotransplantation of teeth.

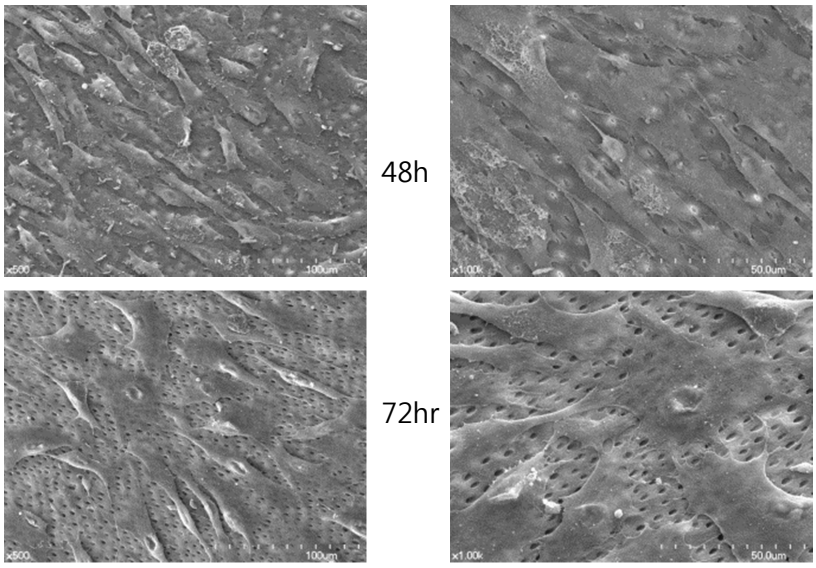

Figure 1. MG-63 cells adhered to PDDM, and they were spread out. This means excellent biocompatibility between cells and PDDM. (Lee H.J. Quantitative Analysis of Proliferation and Differentiation of MG-63 Cell Line on the Bone Grafting Material Using Human Tooth. PhD Thesis. School of Dentistry, Seoul National University, 2011.)

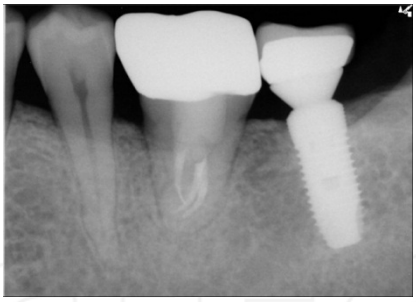

Figure 2. Periapical radiograph 2 years after autotransplantation.

Recently, we conducted a study to demonstrate the osteoinductivity of AutoBT when fabricated from bio-recycled dysfunctional teeth after patented processing. A total of 46 extracted dysfunctional teeth samples were collected from actual patients. *In vivo* study was done on 15 athymic mice by inserting AutoBT in dorsal subcutaneous muscular tissues. Samples were then biopsied in 2, 5, and 8 weeks. For additional analyses, Bradford assay, SDS-PAGE, and western blotting were performed *in vitro*. Histologic analyses *in vivo* showed new active bone formation as early as 2 weeks later (Figure 3,4,5). The Bradford assay indicated the existence of noncollagenous proteins in AutoBT. Nonetheless, rhBMP-2 was not extractable from AutoBT according to electrophoresis and immunoblotting analyses (Figure 6). In conclusion, this study provided an evidence of osteoinductivity of AutoBT th rough noncollagenous proteins.

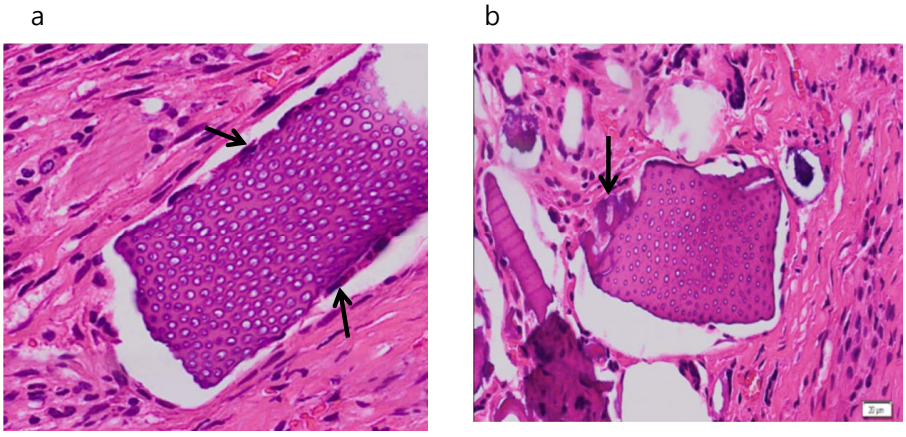

Figure 3. Histologic analyses of 2-week biopsy sample. a) The new cell lining and attachment to AutoBT powder and b) Newly deposited osteoid formations were observed. (H&E staining, X 200).

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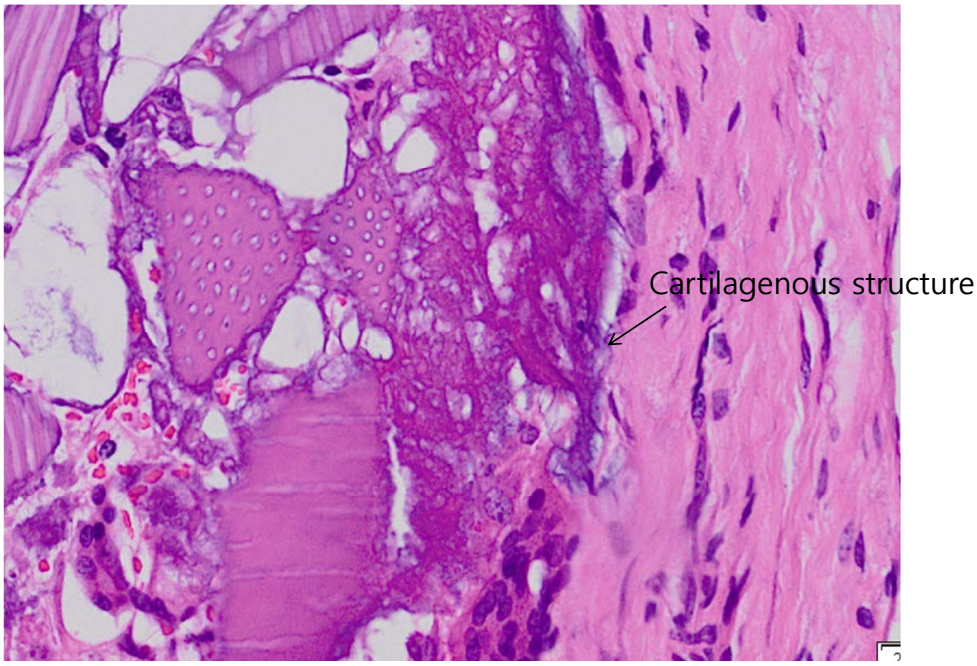

Figure 4. Cartilages were formed at the periphery of AutoBT in 5-week biopsy sample (H&E staining X 200).

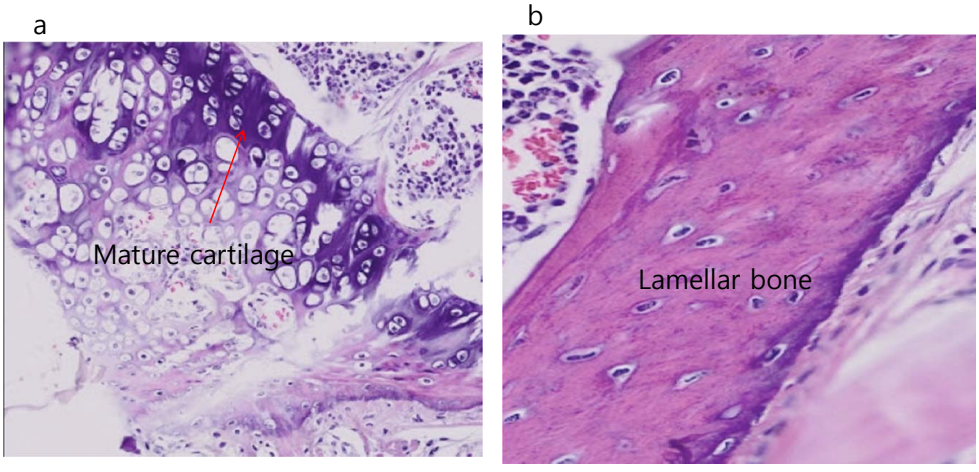

Figure 5. a) Endochondral ossification and b) lamellar bone formation were identified 8 weeks after the insertion of AutoBT powder in the intramuscular pouch of athymic mice (H&E, staining, X 200).

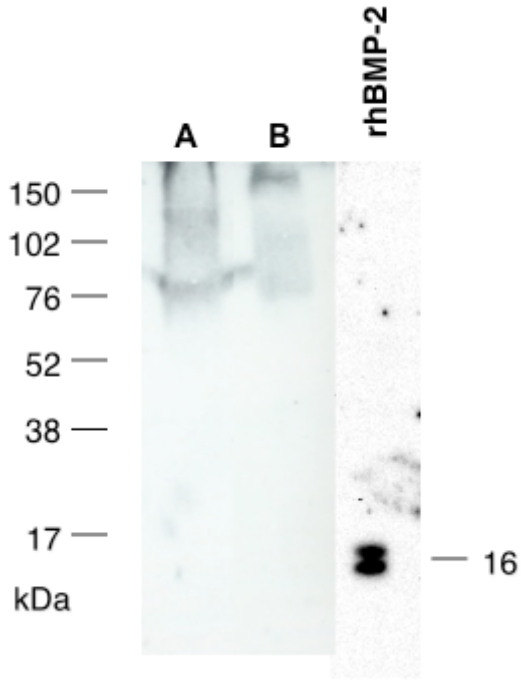

Figure 6. SDS-PAGE of purified fractions from AutoBT powder fabricated from a dried tooth in 25 ºC (A) and from wisdom tooth in fresh state (B).

3. Osteoconduction of AutoBT

The analytic results showed that AutoBT consisted of low-crystalline hydroxyapatite (HA) and possibly other calcium phosphate minerals (ß-tricalcium phosphate (ß-TCP), ACP, and OCP), similar to the minerals of human bone tissues. Note, however, that the level of HA crystallization and the amount of HA differed greatly depending on the area of the tooth. The XRD pattern was much stronger in the crown portion with enamel than in the root portion (Figure 7). Likewise, the dental crown portion consisted of high-crystalline calcium phosphate minerals (mainly HA) with higher Ca/P ratio, whereas the root portion was mainly made up of low-crystalline calcium phosphates with relatively low Ca/P ratio [3, 23]. Kim, et al [52] performed the study to evaluate the surface structures and physicochemical characteristics of a novel autogenous tooth bone graft material currently in clinical use. The material's surface structure was compared with a variety of other bone graft materials via scanning electron microscope (SEM). The crystalline structure of the autogenous tooth bone graft material from the crown (AutoBT crown) and root (AutoBT root), xenograft (BioOss), alloplastic material (MBCP), allograft (ICB), and autogenous mandibular cortical bone were compared using x-

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ray diffraction (XRD) analysis. The solubility of each material was measured with the Ca/P dissolution test. The result of the SEM analysis showed that the pattern associated with AutoBT was similar to that from autogenous cortical bone (Figure 8). In the XRD analysis, AutoBT root and allograft showed a low crystalline structure similar to that of autogenous cortical bone (Figure 9). In the CaP dissolution test, the amount of calcium and phosphorus dissolution in AutoBT was significant from the beginning, displaying a pattern similar to that of autogenous cortical bone (Tables 1, 2). In conclusion, autogenous tooth bone graft materials can be considered to have physicochemical characteristics similar to those of autogenous bone.

Day	MBCP	ICB	BioOss	AutoBT Crown	AutoBT Root	Auto Bone
3 d	54.2	97.7	35.5	230.7	280.0	246.8
7 d	48.6	71.7	33.6	162.7	255.2	189.2
14 d	62.7	97.6	35.1	144.5	180.6	180.6

m/z: mass-to-charge ratio

Table 1. Ca (m/z; 42.959) ion dissolution (Kim Y.K., et al. Autogenous teeth used for bone grafting: a comparison to traditional grafting materials. Oral Surg. Oral Med. Oral Pathol. Oral Radiol., 2013, in press)

Day	MBCP	ICB	BioOss	AutoBT Crown	AutoBT Root	Auto Bone
3 d	301.7	217.8	174.0	269.8	269.4	260.5
7 d	311.4	191.2	151.7	282.8	230.2	282.8
14 d	302.5	165.4	148.7	253.8	229.0	245.3

m/z: mass-to-charge ratio

Table 2. P (m/z; 30.994) ion dissolution (Kim Y.K., et al. Autogenous teeth used for bone grafting: a comparison to traditional grafting materials. Oral Surg. Oral Med. Oral Pathol. Oral Radiol., 2013, in press)

In an in vitro dissolution test, AutoBT showed excellent biodegradability, whereas apatite re-precipitation was actively visible immediately after transplantation. We conjecture that this material plays an effective role in inducing bone regrowth [52]. Priya, et al [53] reported that the extensive dissolution of calcium phosphate composites, which release calcium and phosphorus ions, induces the re-precipitation of the apatite onto the surfaces. According to them, the combination of dissolution and re-precipitation was the mechanism behind apatite formation. Apatite layer formation was expected to encourage the osseointegration of bioceramic composites.

Both the organic and inorganic compositions differ between the crown and root of autogenous tooth bone graft materials. Thus, when the material is grafted, crown and root show different healing mechanisms. Apatites present in bone tissues form a ceramic/high-molecular weight

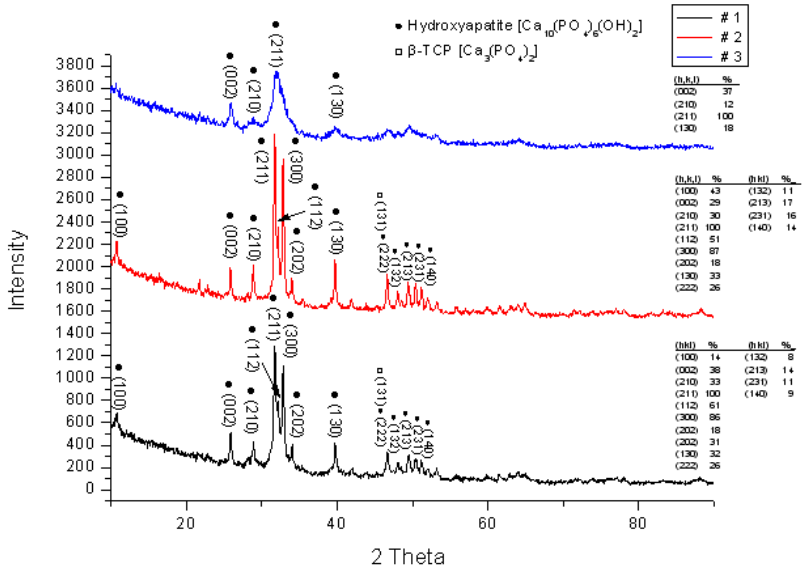

Figure 7. X-ray diffraction patterns of human tooth. (#1: root portion, #2: crown portion, 3: whole tooth) (Kim Y.K., et al. Development of a novel bone grafting material using autogenous teeth. Oral Surg. Oral Med. Oral Pathol. Oral Radiol. Endod., 2010.)

nanocomplex pattern [54]. In particular, apatites present in human bone tissues have low crystallinity and crystal size that are several tens of nanometers. On the other hand, hydroxyapatites prepared via the sintering process at high temperatures have high crystallinity. Grain growth occurs during the sintering process, resulting in sizes that are at least ten times larger than those apatites present in bone tissues [55]. The biodegradation of large particles with high crystallinity is almost impossible. Their osteoconduction capacity is very low, and osteoclasts cannot degrade them. Low-crystalline carbonic apatites show the best osteoconduction effects [56,57].

Nampo, et al introduced alveolar bone repair using extracted teeth for the graft material. DSP is a dentin-specific noncollagenous protein involved in the calcification of dentin. Based on immunohistochemical staining with anti-DSP antibody, the positive reaction was localized to the dentin of the extracted tooth fragments; thus suggesting that dentin has high affinity for and marked osteoconductive effect on the jaw bone [58].

Kim, et al reported bone healing capacity of demineralized dentin matrix materials in a mini-pig cranium defect [59]. A defect was induced in the cranium of mini-pigs, and those without defect were used as control. In the experimental group, teeth extracted from the mini-pig were manufactured into autogenous tooth bone graft material and grafted to the defect. The mini-pigs were sacrificed at 4, 8, and 12 weeks to evaluate histologically the bone healing ability and observe the osteonectin gene expression pattern with RT-PCR. At 4 weeks, the inside of the bur hole showed fibrosis, and there was no sign of bone formation in the control group. On the other

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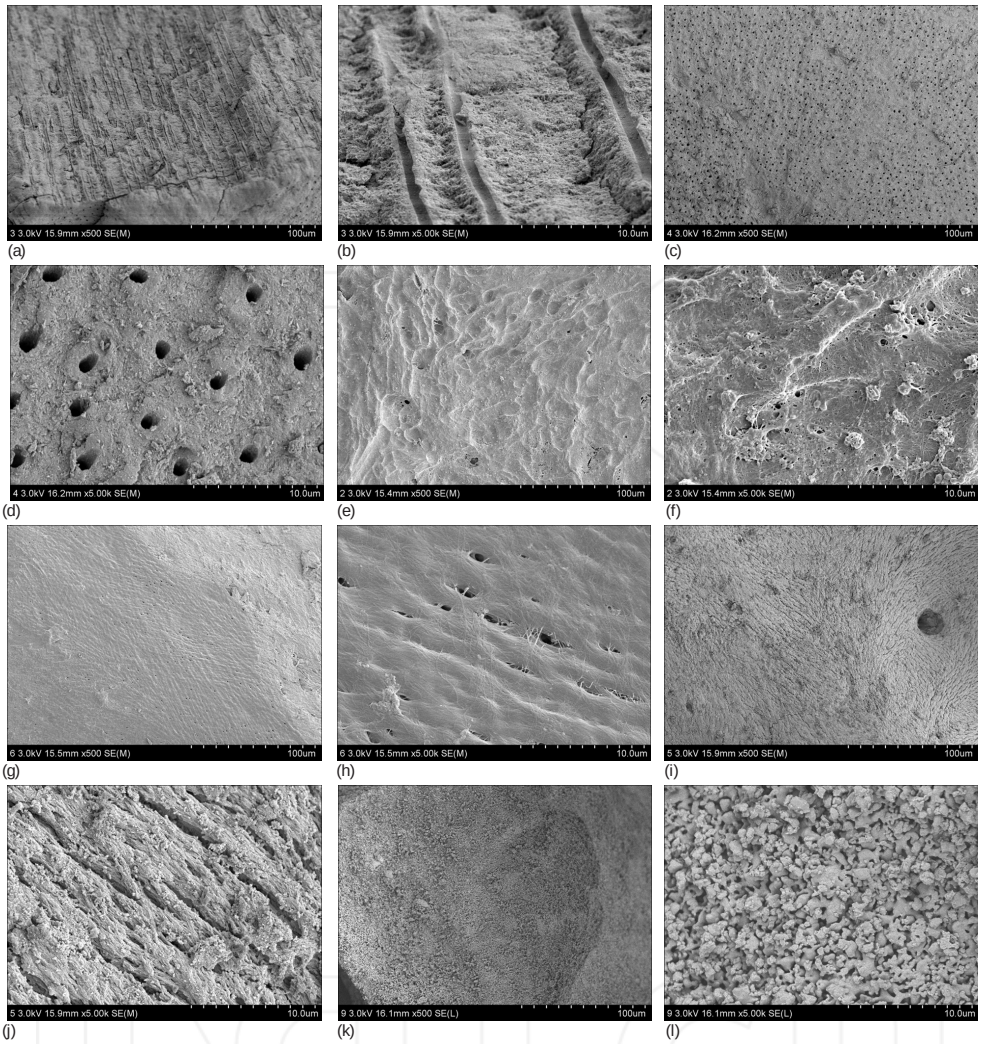

Figure 8. SEM views of the different types of bone graft materials. (Kim Y.K., et al. Autogenous teeth used for bone grafting: a comparison to traditional grafting materials. Oral Surg. Oral Med. Oral Pathol. Oral Radiol., 2013, in press) a): AutoBT crown (x500), b): AutoBT crown (x5,000), c): AutoBT root (x500), d): AutoBT root (x5,000), e): Autogenous cortical bone (x500), f): Autogenous cortical bone (x5,000), g): ICB (x500), h): ICB (x5,000), i): BioOss (x500), j): BioOss (x5,000), k): MBCP (x500), l): MBCP (x5,000)

hand, bone formation surrounding the tooth powder granule was observed at 4 weeks in the experimental group wherein the bur hole was filled with tooth powder. There was practically no osteonectin expression in the control group, whereas active osteonectin expression was observed from 4 to 12 weeks in the experimental group. In this study, excellent osteoconductive healing of autogenous tooth bone graft material was confirmed (Figure 10, 11).

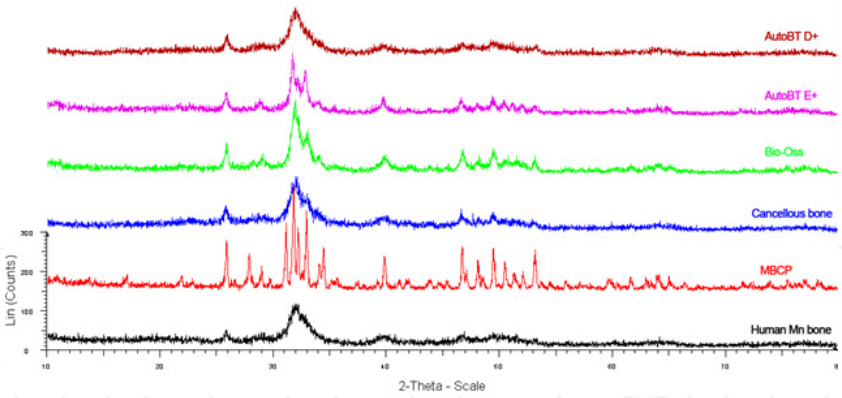

Figure 9. Results of the X-ray diffraction analysis. AutoBT D+: AutoBT root, AutoBT E+: AutoBT crown, Cancellous bone: ICB. (Kim Y.K., et al. Autogenous teeth used for bone grafting: a comparison to traditional grafting materials. Oral Surg. Oral Med. Oral Pathol. Oral Radiol., 2013, in press)

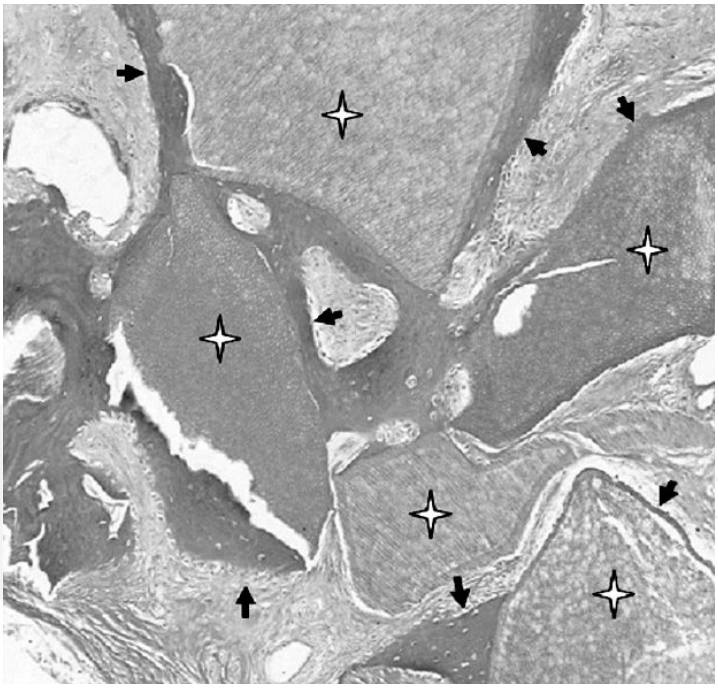

Figure 10. Experimental group of 8 weeks. New bone is actively formed around the tooth powder granules. Asterisks and arrows indicate graft tooth granule materials and new bone formation around the tooth granules, respectively. Hematoloxylin and eosin staining (×100). (Kim J.Y., et al. Bone healing capacity of demineralized dentin matrix materials in a mini-pig cranium defect. J. Korean Dent. Sci., 2012.)

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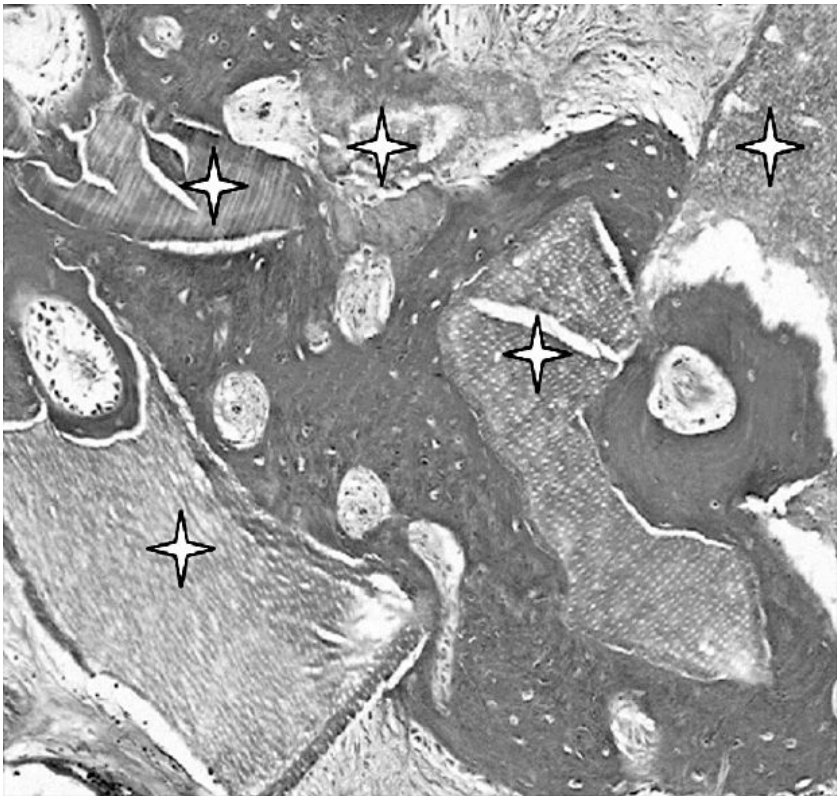

Figure 11. Experimental group of 12 weeks. Extensive new bone formation was noted around the bone powder granules in the bur hole. Asterisks indicate tooth powder materials. Hematoloxylin and eosin staining (×100). (Kim J.Y., et al. Bone healing capacity of demineralized dentin matrix materials in a mini-pig cranium defect. J. Korean Dent. Sci., 2012.)

4. Clinical application of AutoBT

Kim, et al developed a novel bone grafting material using autogenous teeth (AutoBT) in 2008 and provided the basis for its clinical application. Having organic and inorganic mineral components, AutoBT is prepared from autogenous grafting material; thus eliminating the risk of immune reaction that may lead to rejection. AutoBT was used at the time of implant placement -- simultaneously with guided bone regeneration -- and excellent bone healing by osteoinduction and osteoconduction was confirmed [3]. In a total of 6 patients, guided bone regeneration was performed simultaneously at the time of implant placement, and tissue samples were then harvested at the time of the second surgery with the patient's consent. In the histomorphometric analysis of the samples collected from 6 patients during the 3 ~ 6 months' healing period, new bone formation was detected in 46 ~ 87% of the area of interest,

and excellent bone remodeling was achieved (Table 3) (Figure 12). Clinically available AutoBT consists of powder, chips, and block (Figure 13).

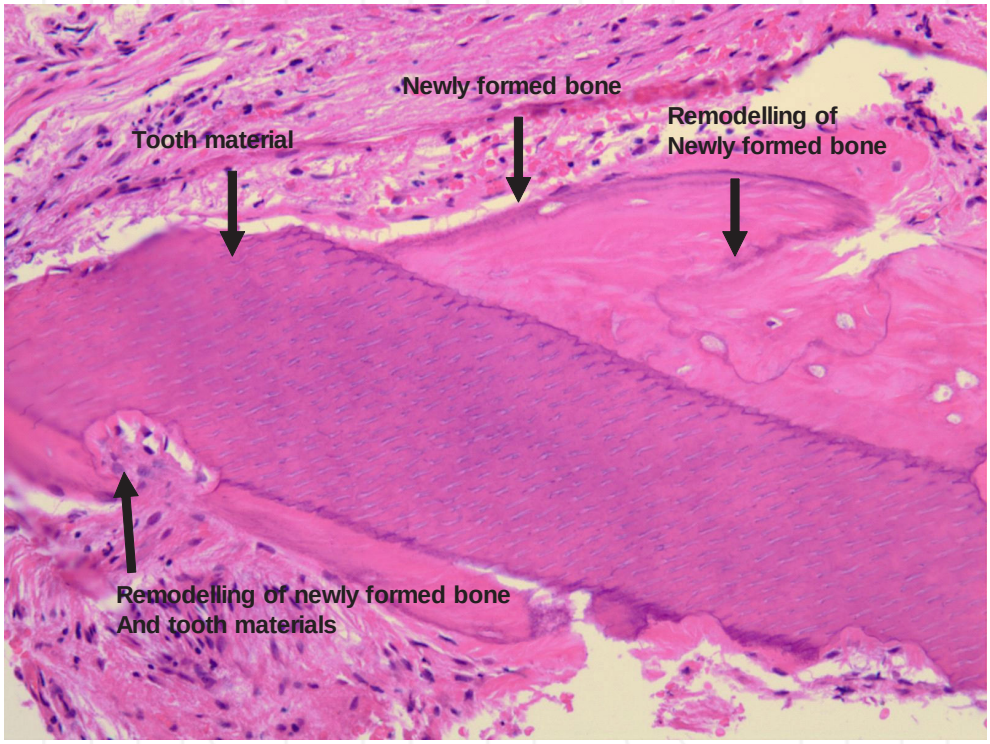

Figure 12. Newly formed bone and tooth materials showing remodeling were identified around the implant chip and at the periphery of the implant chip, respectively (H&E staining, X 100). (Kim Y.K., et al. Development of a novel bone grafting material using autogenous teeth. Oral Surg. Oral Med. Oral Pathol. Oral Radiol. Endod., 2010.)

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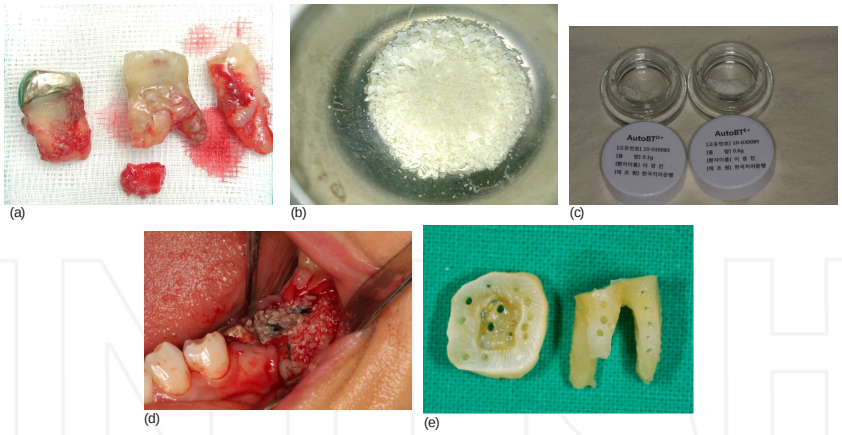

Figure 13. Three types of AutoBT can be fabricated from extracted teeth. a): Extracted teeth. Foreign body such as prosthetic crown, cements, calculus, and soft tissue are removed. AutoBT is then fabricated through pulverization, defatting, demineralization, and lyophilization. b): AutoBT one-powder. Crown and root portion are mixed. c): AutoBT crown and root powder. d): AutoBT chips. e): AutoBT block.

Case	Age/Sex	Site	Healing period	WB:LB:IM ratio	New bone-forming area (%)
1	**40/M**	#24	3	43:11:46	74
2	**28/F**	#17	4	85:14:1	87
3	**47/F**	#17	6	56:39:5	46
4	**50/M**	#24	5	84:12:4	73
5	**43/F**	#36	3	51:1:48	52
6	**61/M**	#25-27	6	65:0:35	68

WB: woven bone; LB: lamellar bone; IM: residual implant material

Table 3. Histomorphometric finding (Kim Y.K., et al. Development of a novel bone grafting material using autogenous teeth. Oral Surg. Oral Med. Oral Pathol. Oral Radiol. Endod., 2010.)

Lee and Kim [60]performed a retrospective study to evaluate the clinical efficacy of AutoBT. This study included 37 patients (54 implants) into which AutoBT was grafted between Oct. 2008 and Dec. 2009. The mean follow-up period was 31 months. Postoperative complications and marginal bone status around the implants were evaluated using medical records and dental radiography. Wound dehiscence and hematoma developed in 7 patients (8 implants). Osseointegration failure in 2 patients (4 implants) was recorded. These complications were well managed through conservative treatment and re-implantation. Mean peri-implant marginal bone loss 1 year after implant placement was 0.33±0.63mm. Autogenous tooth bone graft was confirmed to be a safe procedure, showing excellent bone healing through a 2-year retrospective study (Tables 4, 5, 6).

Type	Number of implants
GBR	29 (53.7%)
Sinus graft (lateral approach)	14 (25.9%)
Sinus lifting (crestal approach)	7 (13.0%)
Ridge augmentation	4 (7.4%)
Total	54 (100%)

Table 4. Types of surgery

Type	Number of patients
Powder	32 (86.5%)
Block	2 (5.4%)
Powder + Block	3 (8.1%)
Total	37 (100%)

Table 5. Types of AutoBT

Type	Number of implants
Wound dehiscence	7
Hematoma	1
Osseointegration failure	4
Total	12

Table 6. Types of complications

5. Sinus bone graft

If there is any material whose resorption speed is not too high and whose bone healing process approximates that of autogenous bone graft, it may be useful in maxillary sinus bone grafting. Likewise, more excellent clinical achievement may be expected when these materials are used in mixture with other bone substitutes with slow resorption properties [61,62,63]. With evidence presented in the foregoing paragraphs, AutoBT® developed by the author, et al was proven to exhibit bone healing ability through osteoinduction and osteoconduction, demonstrating a histological healing process similar to that of free bone grafting being resorbed over 3~6 months [3]. Accordingly, AutoBT® is regarded as a possible substitute when autogenous bone is needed for sinus bone graft, and it may wield a useful effect on increasing the volume of bone graft materials and minimizing repneumatization (Figure 14).

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A retrospective study on sinus bone graft was performed. One hundred implants in 51 patients were selected, with the patients receiving maxillary sinus augmentation and implant placement using autogenous tooth graft materials at Chosun University Dental Hospital and Seoul National University Bundang Hospital (SNUBH) between July 2009 and November 2010. In cases of using autogenous tooth bone graft alone or together with other graft material, the implant survival rate was 96.15%. Based on the histomorphologic examination, autogenous tooth bone graft materials showed gradual resorption and new bone formation through osteoconduction and osteoinduction. The results suggest that autogenous tooth bone graft materials are appropriate for use in maxillary sinus augmentation [64].

Lee, et al [65] conducted a study to evaluate histomorphometrically and compare the efficiency of various bone graft materials and autogenous tooth bone graft material used in the sinus bone graft procedure. The subjects were 24 patients who had been treated with sinus bone graft using the lateral approach from October 2007 to September 2009 at SNUBH. The average age was 52.51±11.86 years. All cases were taken after 4 months of procedure and divided into 3 groups according to bone graft material: Group 1 for autogenous tooth bone graft material (AutoBT), Group 2 for OrthoblastII (Integra Lifescience Corp., Irvine, US)+Biocera (Osscotec, Cheonan, Korea), and Group 3 for DBX (Synthes, West Chester, PA, USA), BioOss (Geistlich Pharm AG, Wolhusen, Switzerland). A total of 37 implant placement areas was included and evaluated (7 in group 1, 10 in group 2, 20 in group 3). The evaluation of new bone formation, ratio of woven bone to lamellar bone, and ratio of new bone to graft material was performed on each tissue section. The Kruskal-Wallis test was used for statistical analysis (SPSS Ver. 12.0, USA). New bone formation was 52.5±10.7 % in group 1, 52.0±23.4% in group 2, and 51.0±18.3% in group 3 (Table 7) (Figure 15-18). There were no statistically significant differences between groups, however. The ratio of woven bone to lamella bone was 82.8±15.3% in group 1, 36.7 ±59.3% in group 2, and 31.0±51.2% in group 3. The ratio of new bone to graft material was 81.3±10.4% in group 1, 72.5±28.8% in group 2, and 80.3±24.0% in group 3. After a 4-month healing period, all groups showed favorable new bone formation and around the graft material and implant. Within the limitation of our study, autogenous tooth bone graft material may be used as a novel bone graft material for sinus bone graft. Kim, et al and Lee, et al performed sinus bone graft and guided bone regeneration using autogenous tooth bone from humans and took the tissue specimen 2 months and 4 months later for histomorphometric analysis. They found favorable new bone formation as a result and suggested that autogenous tooth bone graft materials could be used in various bone grafts [65,66].

Group	New bone formation
I	52.5±10.7%
II	52.0±23.4%
III	51.0±18.3%

*Kruskal-Wallis test: P-value>0.05

Table 7. Histomorphometric data on new bone formation (Mean±SD)

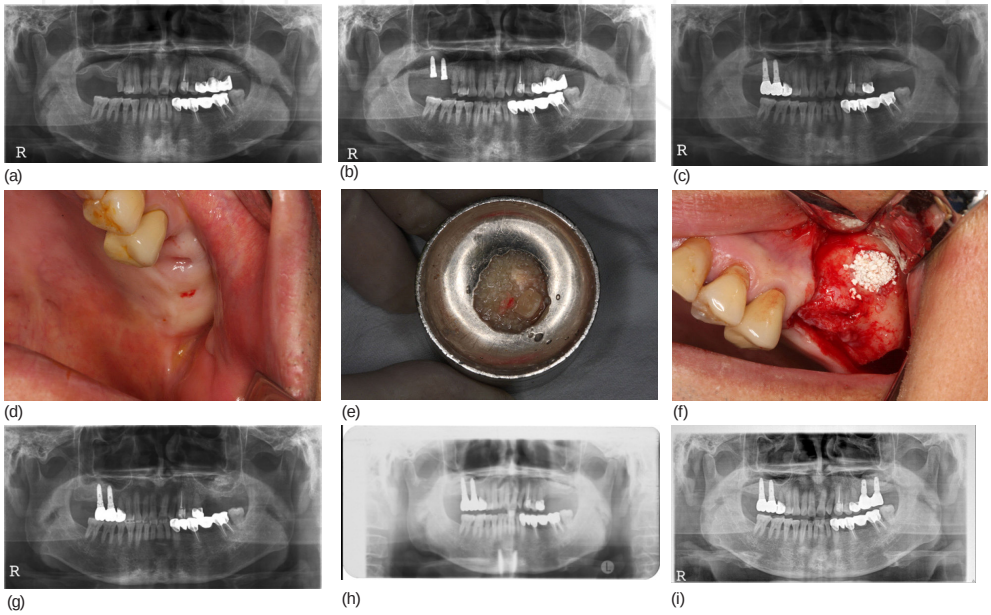

Figure 14. A case of sinus bone graft performed by the mixture of AutoBT, autogenous maxillary tuberosity bone and synthetic bone. a) Panoramic radiography of a 64-year-old man at the first examination. b) Radiography after placing implants simultaneously with the sinus bone graft on the right side. c) Panoramic radiography after 2 weeks of maxillary left 1st molar extraction. The prosthodontic therapy for the upper right maxillary bone was completed, and the extracted tooth was replaced with bone graft materials. d) Intraoral photography before operation. e) View of mixture of AutoBT and maxillary tuberosity bone. f) Grafted in the mixture with a synthetic bone, OSTEON (GENOSS, Suwon, Korea). g) Panoramic radiography after sinus bone graft. h) Panoramic radiography taken in a private dental clinic after 3 months of bone grafting. Performing implant placement in a private dental clinic was decided due to the medical costs. i) Panoramic radiography one year after final prosthetic delivery. The bone materials grafted on the maxillary sinus are maintained stably.

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Figure 15. Overview of biopsy of Group I (Auto BT®). New bone formation (arrows) was identified around the graft material (asterisks). (Hematoxylin & Eosin stain, x40. scale bar measures 500um)

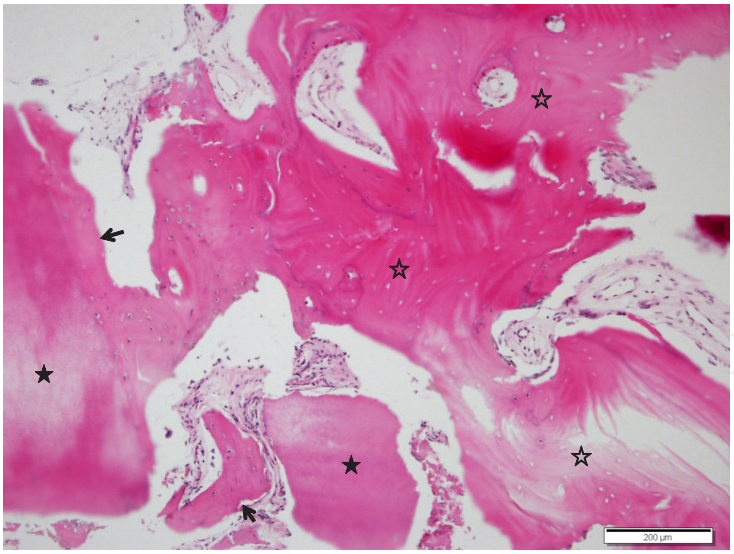

Figure 16. Histomorphometric image of Group I (Auto BT®). New bone formation (arrows) was identified around the graft material (asterisks). Confluent new bone formation was observed (open asterisk) (Hematoxylin & Eosin stain, x200. scale bar measures 200um)

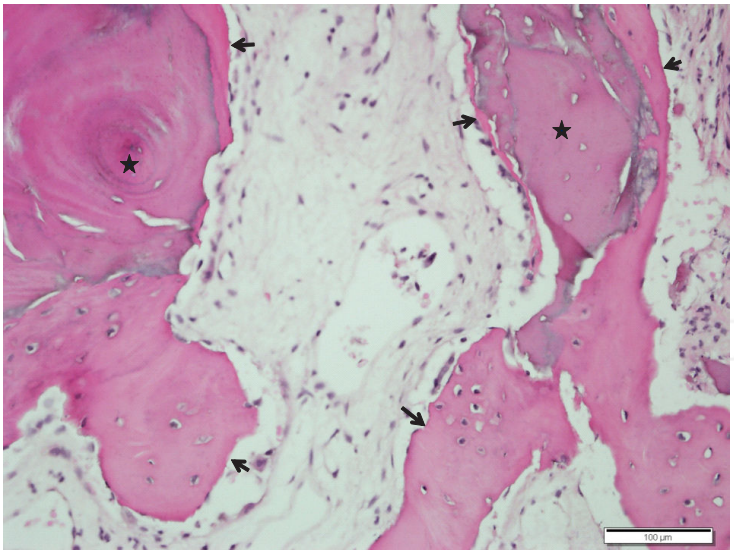

Figure 17. Microphotograph 4 months after Orthoblast/Biocera transplantation (Group II). Higher magnification demonstrated new bone formation (arrows) around the implant chips (asterisks). (Hematoxylin & Eosin stain, x200. scale bar measures 100um)

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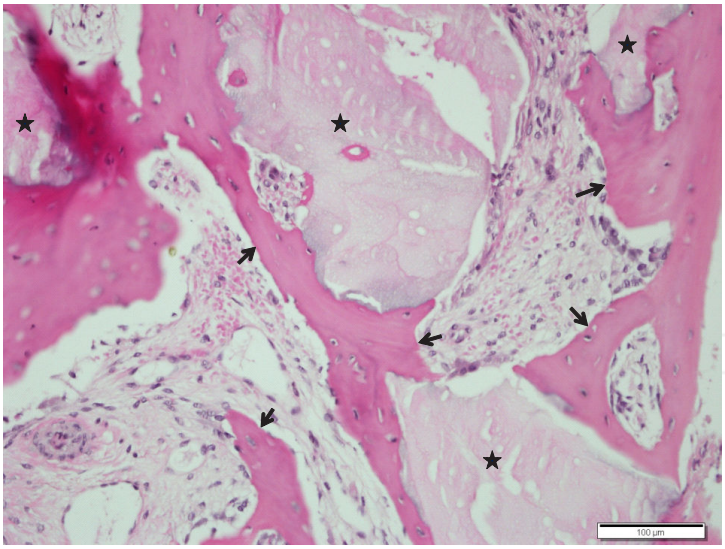

Figure 18. Microphotograph 4 months after DBX/BioOss transplantation (Group III). Higher magnification demonstrated new bone formation (arrows) around the implant chips (asterisks). (Hematoxylin & Eosin stain, x200. scale bar measures 100um)

6. Guided bone regeneration

Bone dehiscence or bone fenestration often develops after dental implant placement, and guided bone regeneration using bone graft materials has become a popular method. The most ideal material for guided bone regeneration is autogenous bone, but autogenous bone graft has limited sources and high risk of complications at the donor site and causes high resorption after bone graft. Therefore, alternative bone materials have been developed and used clinically, such as allogenic bone, xenogenic bone, and synthetic bone. Note, however, that they are often mixed with autogenous bone to maximize their advantages.

Autogenous teeth bone graft materials have very good osteoinductive and osteoconductive properties due to the organic and inorganic contents of the teeth, such as collagen, bone growth factors, and various forms of calcium phosphate. In our study, we achieved 46~74% new bone formation in 3~6 months compared with the results of Babbush [3,67]. Considering the histological healing of the sites where autogenous teeth bone graft materials were applied, bone graft materials were replaced with new bone following resorption, and new bone directly fused with the remaining autogenous teeth bone graft materials. A healing process associated with excellent osteoinduction and osteoconduction was observed in every sample, including abundant lamella bone; thus indicating that rapid bone reconduction was occurring [50,51,59,65,66]. Kim, et al [68] installed implants combined with guided bone regeneration using autogenous tooth bone graft material in 6 patients. In the 6 months' histological

examination after operation, excellent osteoconductive bone healing was noted. A clinically favorable outcome was obtained (Figure 19~21).

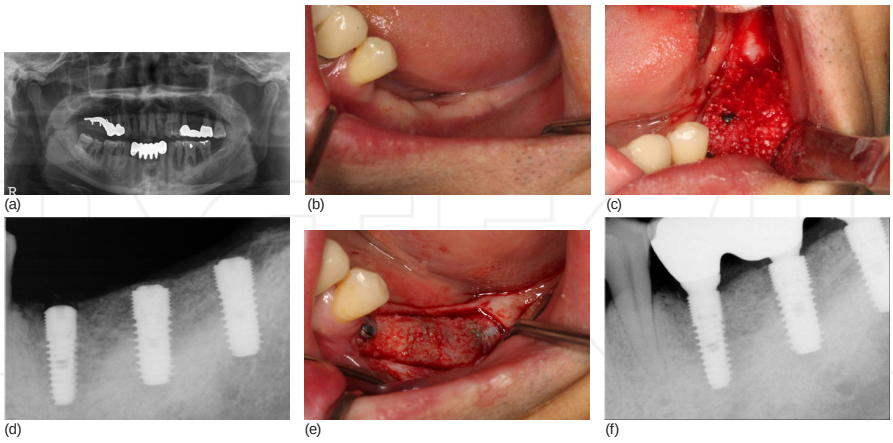

Figure 19. Guided bone regeneration using AutoBT powder (Kim Y.K., et al. Guided bone regeneration using autogenous teeth: case reports. J. Korean Assoc. Oral Maxillofac. Surg., 2011.) a): Initial panoramic radiography of a 44-year-old male patient. b): Preoperative intraoral view. Teeth were extracted 2 months ago. c): Implants were placed, and dehiscence defects were covered with autogenous tooth bone graft material. d): Periapical radiography 6 months after implant placement. e): Secondary surgery was performed, and flap was elevated. Excellent bone healing was observed. f): Periapical radiography 6 months after the final prosthetic delivery.

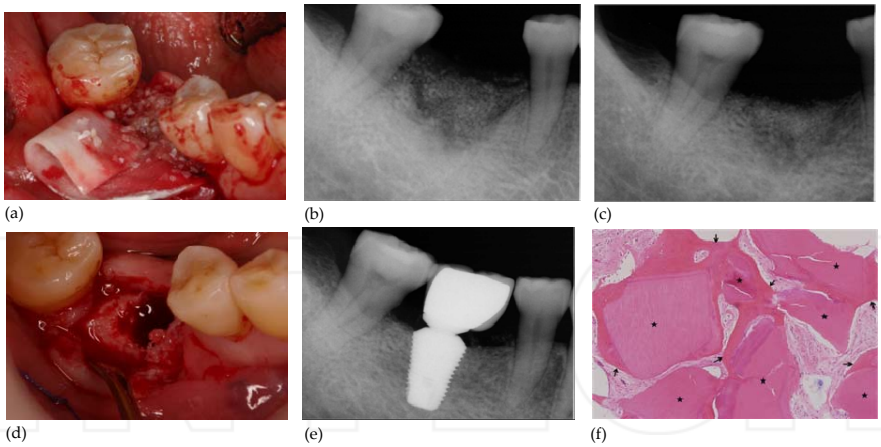

Figure 20. GBR was performed on the right mandibular 1st molar area of a 49-year-old female patient. (Kim Y.K., et al. Guided bone regeneration using autogenous teeth: case reports. J. Korean Assoc. Oral Maxillofac. Surg., 2011.) a): Autogenous tooth bone graft material and collagen membrane (BioGuide) were used. b): Periapical radiography 3 weeks after bone graft. c): Periapical radiography 6 months after bone graft. The alveolar crestal level was stable. d): Implant was installed 6 months after bone graft. Bone quality was type I. e): Periapical radiography after the final prosthetic delivery. f): Microphotograph 6 months after AutoBT transplantation. Higher magnification demonstrated new bone formation (arrows) around the implant chips (asterisks). Hematoxylin & Eosin stain, x100.

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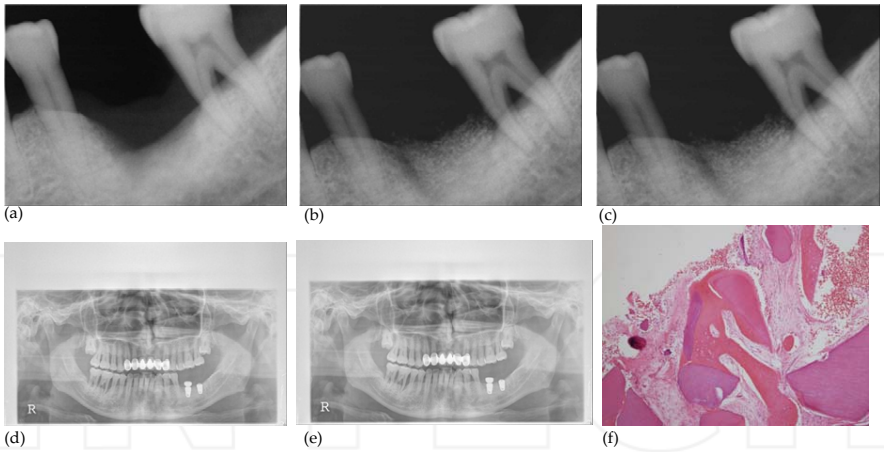
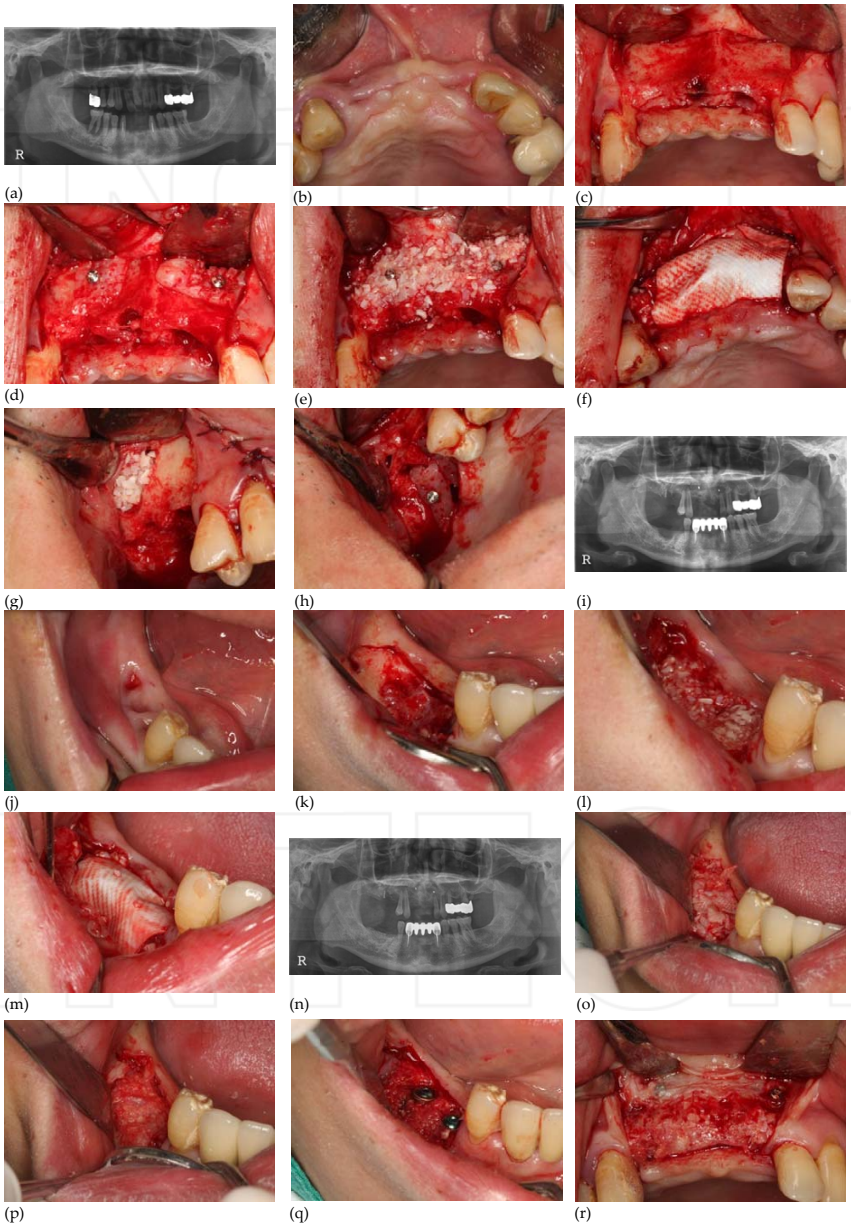


Figure 21. GBR was performed on the mandibular left 1st molar. (Kim Y.K., et al. Guided bone regeneration using autogenous teeth: case reports. J. Korean Assoc. Oral Maxillofac. Surg., 2011.) a): Periapical radiography of a 50-year-old male patient 2 months after the extraction of the mandibular left 1st molar. b): Periapical radiography 2 weeks after autogenous tooth bone graft. c): Periapical radiography 5 months after autogenous tooth bone graft. Alveolar crestal bone level was stable. d): Implant was placed 6 months after bone graft. The adjacent 2nd molar was extracted. e): Second surgery was performed at the #36 area. Additional implant was placed at the #37 area. f): Periapical radiography after the final prosthetic delivery. g): Microphotograph 6 months after AutoBT transplantation. Higher magnification demonstrated new bone formation around the implant chips. Hematoxylin & Eosin stain, x200

7. Ridge augmentation (Figure 22)

Autogenous bone grafting produces the best results in case a large volume of bone increase is required, as in the reconstruction of a site with lots of bone defects or ridge augmentation. The autograft may be taken from the endochondral bone such as ilium, rib, tibia, etc., and from the intramembranous bone such as calvaria, facial bone, etc. Alveolar ridge augmentation is a method of augmenting the height or width of the alveolar ridge by implementing bone grafting on the upper part or lateral part of the ridge in particulate or block type in case bone volume is insufficient vertically or horizontally; vertical and horizontal augmentation may be done simultaneously, but it may also be carried out individually. Since it is a kind of onlay graft, bone resorption occurs considerably after grafting, and dehiscence on the upper soft tissue easily arises [69]. Meanwhile, as for the autogenous bone graft, there may be some complications on the donor site, and doing the grafting takes time. Likewise, there are several problems such as limit to the volume of collection. Consequently, patients and clinical doctors are inclined to avoid it in many cases. As substitutes for autograft, bone graft materials such as allograft, xenograft, synthetic bone, etc., were developed, but the single use of each is not recommended in the method of augmenting bone tissue vertically or horizontally [69,70]. For the vertical or horizontal ridge augmentation, AutoBT may be a substitute method for autogenous bone graft and may be very useful in clinical practices when used in mixture with

other graft materials in case of insufficient volume. Kim, et al. [71,72] reported the successful case of alveolar ridge augmentation using various autogenous tooth bone graft materials.



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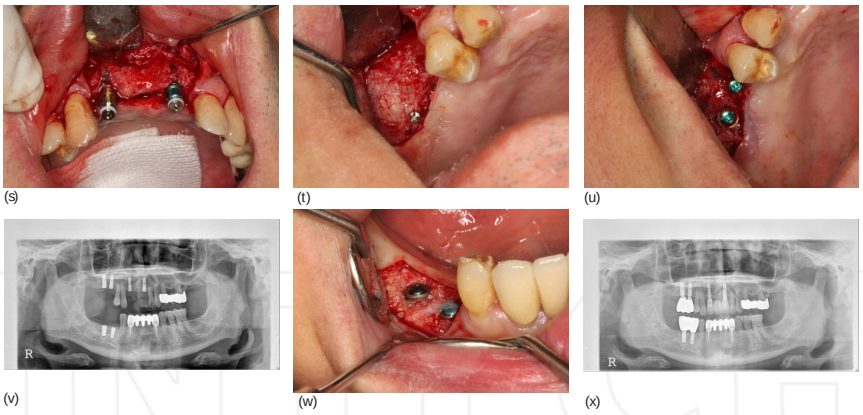

Figure 22. Placement of implants after the ridge augmentation of the maxillary anterior and maxillary/mandibular posterior area. a): Panoramic radiography at the first examination. Alveolar resorption was in considerable progress on the whole. b): Intraoral photograph taken just before the ridge augmentation of the maxillary anterior area. One month passed after extraction. c): View of the elevated mucoperiosteal flap. The labial side concavity is observed. d): View of fixation with titanium screws after applying the AutoBT block on the labial side. e): View of grafting the AutoBT powder additionally. f): Sutured after covering the resorbable collagen membrane (Ossix plus). g): View of the sinus bone graft on the right side using the AutoBT powder. h): View of fixation with titanium screws after vertical ridge augmentation with the AutoBT block. i): Panoramic radiography after grafting the bone on the maxillary anterior area and the right posterior area. j): Intraoral photograph prior to the right mandibular posterior bone grafting. One month passed after extraction. k): View of the elevated mucoperiosteal flap. The vertical bone defects on the ridge is observed. l): After applying the AutoBT block on the #45 area, the AutoBT powder was grafted on the surrounding sites. The AutoBT block was hydrated in saline solution for 15 ~ 30 minutes and operated. m): After covering the Ossix plus, the wound was closed. n): Panoramic radiography after bone graft. o): View of the elevated mucoperiosteal flap on the #45 and 46 sites after 2 months of ridge augmentation. Some Ossix plus that were not resorbed is observed. p): After removing Ossix plus, very excellent bone healing was observed. q): View of #45 and 46 implant placement. r):View of the elevated mucoperiosteal flap on the maxillary anterior area 4 months after bone grafting. Good bone healing is observed. There was not much bone resorption when the state of titanium screws was examined. s): After removing the titanium screws, the implants were placed. t): Exposed #15 and16 areas. The titanium screws fixing the block is observed, and bone healing was very good. u): View of implants placed on the site. v): Panoramic radiography after the #12, 21, 15, and 16 implants were placed. w): View of the #45 and 46 implants exposed while doing the secondary surgery after 2 months. x): Panoramic radiography 6 months after the final prosthetic delivery.

8. Extraction socket preservation or reconstruction (Figure 23)

The resorption of the residual alveolar bone in the vicinity of extraction sockets reportedly occurs primarily during the initial period after tooth extraction; in cases wherein teeth are infected with periodontal diseases, it shows more severe resorption [73]. Severe resorption of the alveolar bone may cause aesthetic problems in the anterior teeth. In addition, normal, natural healing may be difficult since the soft tissues may fall down into the defective area if there is progressive periodontal disease or periapical inflammatory lesion, or in case of serious defects of the surrounding bone wall after tooth extraction. Therefore, the preservation or reconstruction of the extraction sockets should be considered positively in case of serious defects after tooth extraction [74]. Ridge preservation methods using various bone graft

materials were introduced and reported to be effective in preventing vertical and horizontal ridge resorption [75-77]. Kim, et al [78] reported an actual case of extraction socket preservation and reconstruction using autogenous tooth bone powder and block. They reported good healing of extraction socket after 3~3.5 months, and they could successfully perform the placement of implants.

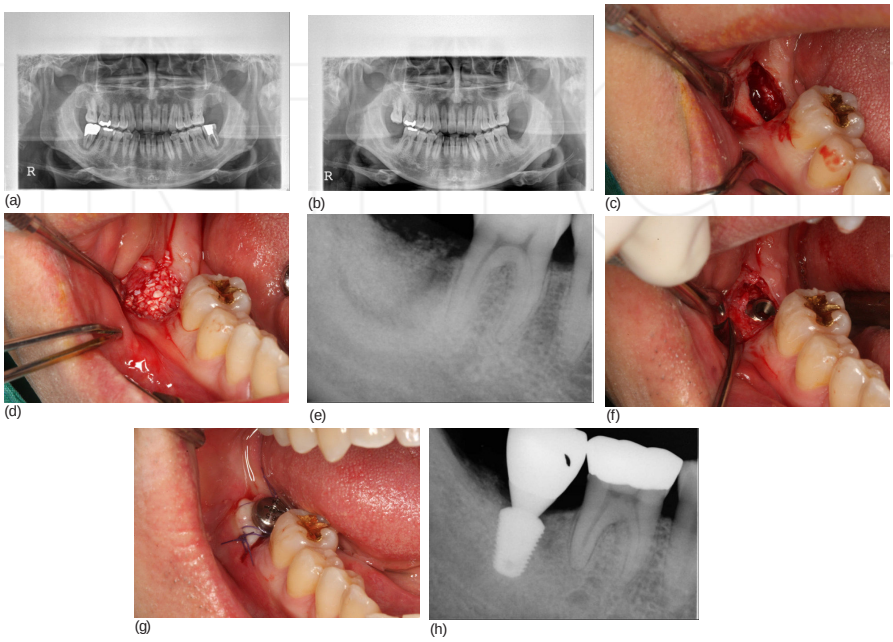

Figure 23. Extraction socket graft and delayed implant placement were performed on a 48-year-old male patient. (Kim Y.K., et al. Extraction socket preservation and reconstruction using autogenous tooth bone graft. J. Korean Assoc. Maxillofac. Plast. Reconstr. Surg., 2011.). a): Initial panoramic radiographic view, Periapical radiolucent lesion was observed at #37, 47 area. Radiolucent lesion was extended to the vicinity of the inferior alveolar canal. b):. Panoramic radiograph 3 months after extraction. c): The mucoperiosteal flap was elevated for implant placement 3 months after #47 extraction. The healing of extraction socket was poor. It was impossible to install the implants because of inadequate stability. d): Autogenous tooth bone graft powder was grafted into the socket. e): Postoperative periapical radiograph. f): Implant was installed 3 months after socket graft. Primary implant stability was excellent. g): Second surgery was performed 2.5 months after implant placement. h): Periapical radiograph 14 months after the final prosthetic delivery.

9. Conclusion

It is obvious that autogenous tooth bone graft materials(AutoBT) are safer than allogeneic and xenogeneic bon egraft materials; the fact that they are compared with the healing performance of free autogenous bone graft in histological view is clear evidence. AutoBT can be used safely

in a variety of bone reconstructive procedures such as sinus bone graft, GBR, ridge augmentation and extraction socket graft.

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