A Retrospective Study Comparing Ridge Changes in Stone Casts after Ridge Preservation between Allograft and Xenograft when Using Acellular Dermal Matrix as an Occlusive Membrane

Li-Fan Chen

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Committee members:

Wai Cheung, D.M.D., MS

Rory O'Neill, D.M.D., B.D.S., M.Sc

An-I Tsai, D.D.S, PhD

Matthew Finkelman, PhD

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Abstract

Background: Bovine bone mineral (ABBMX) and freeze-dried bone allograft (FDBA) are popular grafting materials of choice in ridge preservation (RP) procedures. The aim of this retrospective equivalence study was to evaluate and to compare the dimensional changes after RP grafted either with ABBMX or FDBA, as well as the effect on the soft tissue dimensions in stone casts.

Methods: Stone casts of twenty-eight patients who received extraction and RP grafted with either ABBMX or FDBA were collected in this investigation with a healing period of 4-6 months. Acellular dermal matrix (ADM) was used as a protective membrane. Pre- and post-RP ridge widths, sectional tissue remodeling at 3-mm and 5-mm subgingivally and changes on the height of the adjacent papilla were recorded. Independent-samples t-test was used to compare baseline valuables, sectional ridge resorption, and the papillary height changes between the groups. Between-group comparisons after the surgery were carried out by one sided 95% confidence intervals for ridge width changes. Intra-group comparisons were performed by the paired t-test. The significance level for rejection of the null hypothesis was set at $\alpha = 0.05$.

Results: At the end of the follow-up period, at the 3-mm subgingival level, there was a reduction in the alveolar ridge width of 5.49±2.17 mm (39.38%) for the FDBA group and of 5.09±2.43 mm (36.46%) for the ABBMX group; whereas at the 5-mm subgingival level, there was a reduction of 3.62±1.70 mm (24.39%) for the FDBA group and of 2.65±1.56 mm (17.26%) for the ABBMX group. All intra-group changes were statistically significant ($p<0.0001$). Between the groups, a significant difference in tissue remodeling was found at the 5-mm subgingival level on the lingual side ($p=0.005$). Between the buccal and the lingual sides, a statistically significant difference was revealed at the 3mm subgingival level in the ABBMX group ($p=0.03$). In all cases, the papillae demonstrated a reduction in height regardless the material used.

Conclusions: In spite of the grafting materials used, RP does not predictably preserve the alveolar ridge to its full extent. The between group differences in post-RP ridge dimension if any, is most likely to be within 1.86 mm at the 3-mm subgingival level and 2.02 mm at the 5-mm subgingival level.

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A Retrospective Study Comparing Ridge Changes in Stone Casts after Ridge Preservation between Allograft and Xenograft when Using Acellular Dermal Matrix as an Occlusive Membrane

I. Introduction

Dental implants have been an important and predictable treatment modality to replace missing teeth in contemporary dentistry[1-3]. However, the nature and different degree of alveolar bone resorption after tooth extraction challenges precise implant placement. [4,5]

The physiology and anatomical changes after extraction were studied in the past.[6-9] Maxillary and mandibular bony complexes are composed of several anatomical structures, viz: the basal bone is the body of mandible and maxilla; the alveolar process contains the tooth roots; the bundle bone which is the bony structure lines the alveolar socket, extending coronally forming the crest of the buccal bone. After tooth extraction, bundle bone appears to be the first bone to be resorbed [10,11] whereas alveolar bone is gradually resorbed throughout life.[12]

In an histological study, Amler et al. scooped out the content of extraction wounds in human biopsies with small curets and found that the clot formed was being replaced with granulation tissue by the 7th day.[6] Replacement of this granulation tissue with connective tissue starts by the 20th day. Osteoid was present at the base of the socket at the 7th day and fills 2/3 of the socket by the 28th day. Epithelialization started on the 4th day and was completed after day 24. Epithelial migration proceeded from the margins of the socket simultaneously with the organization of the clot.

Pietrokovski and Massler observed the buccal plate in the maxilla and mandible showed more resorption than the palatal and lingual plate, and the amount of tissue resorbed was significantly greater in the molar regions than that in the incisor and premolar regions.[7]

Evian et al. showed histological results of extraction sockets in 4 weeks, viz: abundance of fibrous connective tissue and rows of osteoblasts were observed in the osteoid layer. At 6 weeks, osteoblasts are actively laying down new bone. At 8 weeks, trabeculae of new bone occupy the majority of the socket and fewer osteoblasts and less osteoid are present. At 10 weeks, trabeculae interconnected with a minimum of osteoid; by 16 weeks, dense bony trabeculation with fewer cellular elements and very little bone formation with few osteoblasts was observed.[13]

Regarding the timeline of anatomic change, Araujo et al. found the resorption of the buccal and lingual walls of the extraction site occurred in two overlapping phases.[14] During phase 1, the bundle bone was resorbed and replaced with woven bone. Since the crest of the buccal bone wall was comprised solely of bundle bone, this remodeling resulted in substantial vertical reduction of the buccal crest. Phase 2 showed resorption that occurred from the outer surfaces of both buccal and lingual bone walls.

Literature review has shown that healing of extraction sites without grafting is resorptive.[6,9,14-17] The width of the alveolar ridge experiences the greatest amount of bone resorption during the first six months, of which two thirds happens during the first three months. [17] Furthermore, the maximum loss of tissue contour takes place during the first month after tooth extraction. The systematic review by Tan et al., showed that in human hard tissue, horizontal dimensional reduction (3.79 +/- 0.23 mm) was more than vertical reduction (1.24 +/- 0.11 mm on the buccal, 0.84 +/- 0.62 mm on the mesial and 0.80 +/- 0.71 mm on distal sites) at 6 months.[12] Percentage vertical dimensional change was 11-22% at 6 months. Percentage horizontal dimensional change was 32% at 3 months, and 29-63% at 6-7 months. Soft tissue changes demonstrated 0.4-0.5 mm gain of thickness at 6 months on both the buccal and lingual aspects. Horizontal dimensional changes of hard and soft tissue (loss of 0.1-6.1 mm) were more substantial than vertical changes (loss 0.9 mm to gain 0.4 mm) during observation periods of up to 12 months. Thus, ideal placement of dental implants can be hindered owing to a lack of proper hard and soft tissue contours.

Rationale of Ridge preservation(RP)

In order to prevent further alveolar bone resoption after tooth removal, and also to avoid the morbidity of advanced surgery, various methods have been described to maintain alveolar ridge dimensions after tooth extraction, focusing mainly on the preservation of the hard tissue.

Brugnami et al. were the first one to implant bone graft into the extraction socket.[18] In the study, hard tissue biopsies of 7 sites in 6 patients were obtained 14 weeks to 13 months following extraction and grafting. The histological results showed that allograft has the potential to function physically as a nidus for appositional new bone growth in alveolar sockets following tooth extraction.

Lekovic et al. compared the outcome of alveolar ridge preservation with, and without using an absorbable barrier membrane in extraction sockets.[15] At 6 months, significantly less crestal bone loss (-0.38 mm vs. -1.50 mm), more internal socket fill (-5.81 mm vs. -3.94 mm), and less horizontal ridge resorption (-1.31 mm vs. -4.56 mm) was found in the membrane group than those in the control group. As this study suggested, successful early alveolar ridge augmentation (preservation) procedures may reduce, or eliminate the need for future ridge augmentation.

Even some degree of bone modeling and remodeling will occur after tooth extraction, different ridge preservation procedures resulted in significantly less vertical and horizontal contraction of the alveolar bone crest. Hence, ridge preservation has been widely investigated with different techniques and different materials. Autologous bone graft was reportedly the gold standard for bone regeneration,[19] Araujo et al. in 2011compared the outcomes between autologous bone graft and anorganic bovine bone mineral in ridge preservation, and found autologous bone chips placed in the fresh extraction socket will (i) neither stimulate nor retard new bone formation and (ii) not prevent ridge resorption that occurs during healing following tooth extraction.[20]

Anorganic Bovine Bone Mineral Xenograft (ABBMX)

Different approaches have been recommended to reduce ridge alterations in post-extraction sockets including the use of various biomaterials. Bio-Oss® , Anorganic bovine bone mineral xenograft (ABBMX) (Geistlich Pharma AG, Wolhusen, Switzerland) has been successfully used in several studies to preserve ridge dimensions following tooth extraction. quote reference only,It is a xenogenic bone substitute that has been proven to be both biocompatible and osteoconductive.

ABBMX is a natural, non-antigenic, porous bone mineral matrix. It is produced by the chemical removal of all organic components (calcium deficient carbonate apatite) from bovine bone. Owning to the low heat extraction process, ABBMX (Bio-Oss®)

maintains the exact trabecular architecture and porosity of the original bone. Therefore, it is physically and chemically comparable to the mineralized matrix of human bone. The formation and ingrowths of new bone at the implantation site of ABBMX is favored, due to its trabecular architecture, interconnecting macro and micro pores and its natural consistency. After implanting in the body, the graft will undergo physiologic recasting and become incorporated into bone over time. ABBMX is reportedly the most physiological bone substitute with eventual complete integration into bone. Studies have examined both the clinical and histological healing with this material. (Geistlich Pharma North America Inc. product instruction)

Anorganic bovine bone mineral xenograft (ABBMX) was used as human implanted bone graft in 1990.[21,22] Many articles have showed its capability of osteoconductivity and biocompatibility with no case report of disease transmission and rejection. Skoglund conducted a study in six patients with severely resorbed alveolar ridges grafted with ABBMX.[23] The observation period varied between 9 and 44 months. In five of six patients, long-term bone regeneration around the implants was observed. Histological examination of biopsy material obtained from the grafted area showed the ABBMX particles still present in all patients after the varying observation periods. Artzi et al. placed ABBMX in fresh extraction sockets of 15 patients, and primary soft tissue closure was performed to protect the graft particles via a pediculated split palatal flap. A histological examination of the grafted sites was done 9 months later. The investigators concluded that ABBMX particles were a biocompatible bone derivative in fresh extraction sockets and an appropriate treatment option for ridge preservation.[24,25]

Zitzmann et al. did a study in six partially edentulous patients, bone augmentation was necessary prior to implant placement because of severe alveolar ridge resorption.[26] The defect sites, all located in the maxilla, were filled with ABBMX and covered with a resorbable collagen membrane. He found similar results as shown in previous studies: the histological analysis revealed that the ABBMX particles occupied 31% of the total biopsy area. An intimate contact between woven bone and ABBMX was detected along 37% of the particle surfaces.[26] In a human study by Norton,[27] fifteen patients were treated consecutively for the repair of alveolar defects, and/or ridge maintenance at the site of extraction sockets, prior to implant placement. The primary goal was to evaluate the osteoconductivity of ABBMX, and, he found the mean percentage area of new bone formation was 26.9%, and the percentage of residual graft and connective tissue as 25.6% and 47.4% respectively. The mean percentage contact length between bone and residual graft was 34%. In an animal study by Indovina, four dogs had their mandibular and maxillary premolars extracted atraumatically.[28] The test sites were immediately grafted with anorganic bovine bone. He found the control (unfilled) and Bio-Oss sites were similar, with bone filling most of the extraction sites.

Santos et al. conducted an animal study, and used bovine bone mineral, synthetic hydroxyapatite and bioactive glass.[29] The results found bovine bone mineral showed a larger number of particles covered with osseous tissue than the synthetic substitutes.[29] However, Vance et al. in a human randomized clinical trial compared the xenograft covered by a collagen membrane with a allograft covered by calcium sulfate, and found the allograft mixed with an experimental putty carrier produced significantly more vital bone fill than did the use of the xenograft with no carrier material.[30]

Regarding the dimensional changes, Araujo et al. in an animal study found that the placement of ABBMX collagen in a fresh extraction socket served as a scaffold for tissue modeling but did not enhance new bone formation.[31] In comparison with the non-grafted sites, the dimension of the alveolar process as well as the profile of the ridge were better preserved in ABBMX collagen grafted sites. The grafted site showed 12±change 10% shrinkage comparing to non-grafted sites 35±change 10% shrinkage in coronal sections.[31]

In a human randomized clinical trial in which the xenograft was covered by a collagen membrane, Gholam Ali Gholami et al. showed that ridge width decreased from 7.75±±1.55mm to 6.68±±1.85mm. The histomorphometric evaluation revealed 20.62 ±±9.91% of the bone graft remained in situ for a 6-8 months period in nonmolar sites.[32]

Kim et al. also studied ridge preservation using collagen sponge and xenograft.[33] It was found xenograft prevents the horizontal resorption of the alveolar ridge, and the collagen sponge in the coronal portion blocks the infiltration of soft tissues to the apical area, and thus it has the advantage of enhancing bone fill. In this human study, twenty patients were divided in to the control and the experimental group, which contained 10 patients each. The control group patients were treatment planned for a 3-unit bridge. In the experimental group, using collagen sponge and xenogeneic bone graft, alveolar ridge preservation was performed simultaneously with tooth extraction. Implants were placed 3 months later. Clinical and histological evaluation and statistical analysis were performed. At 3mm subcrestal level, the resorption rate of the alveolar width, in the control group was shown to be 20.74% and that of the experimental group was 14.26%. An approximately a difference of 6% was observed, and it was statistically significant.

Based on the evidence, we can conclude that ABBMX is a long term scaffold and effective osteoconductive bone graft.

Freeze Dried Bone Allograft (FDBA)

Allograft material has been used in periodontal therapy for the last three decades. [34]It is generally used in one of the two forms: freeze-dried bone allograft (FDBA) and demineralized freeze-dried bone allograft (DFDBA). Both FDBA [35-38]and DFDBA[39-44] have been used successfully to regenerate the attachment apparatus during periodontal treatment.

Iasella et al. compared dimensional changes of extraction sockets with and without ridge preservation.[16] FDBA and a collagen membrane were used. After six months, the author concluded that sites treated with ridge preservation had significantly less dimensional changes than the sites without any treatment. When examining the sites histologically, including both vital and non-vital bone, the ridge preservation sites demonstrated more bone than the no-treatment sites.

Toloue et al. in a histological human study compared calcium sulfate (CS) to FDBA for alveolar ridge preservation and histologic analysis.[45] Both materials were grafted without membrane. They found an average of 32% new bone formation with 2.5% graft remaining for the CS group. In the FDBA group, the ridge decreased from 7.25±1.51 mm to 6.22±1.61 mm in 3 months period. Histomorphometric evaluation revealed 21.37 ±11.53% bone graft remained in this group.

Wood et al. conducted a human study which provides the first histologic and clinical evidence directly comparing the efficacy of ridge preservation with DFDBA versus FDBA in humans.[46] Significantly greater new bone formation with DFDBA was demonstrated. The DFDBA sites had a significantly greater percentage of vital bone than FDBA sites (38.42% versus 24.63%). The DFDBA also had a significantly lower mean percentage of residual graft particles (8.88%) when compared to FDBA (25.42%). However, the FDBA showed better dimensional ridge preservation.

The FDBA (MinerOss® , BioHorizons, Birmingham, Alabama) that we used in the present study is a mixture of mineralized allograft cancellous and mineralized allograft cortical chips that provide an osteoconductive scaffold to encourage bone growth. The bone grafting material has been placed on the market and used in clinic bone augmenting procedures; however, there is a lack of long-term clinical evaluation.

Ridge preservation is effective in preserving the original ridge anatomy. However, different techniques and different materials may result in a different outcome. Evidence suggests that xenograft may have better long term scaffold for bone regeneration, and less resportion comparing to allograft or autologous graft.[47] However, there is a lack of direct comparison and well controlled studies between these two bone graft materials.

Acellular Dermal Matrix Allograft (ADMA)

Many biomaterials are used as protective membranes for ridge preservation. ADMA (Alloderm® , BioHorizons, Birmingham, AL) is widely used in both medicine and dentistry for plastic and reconstructive surgery. ADMA is derived from donated human skin undergoing a multi-step proprietary process that removes both the epidermis and the cells which can lead to tissue rejection. ADMA has been used in a wide variety of soft tissue grafting procedures such as root coverage, soft tissue augmentation and guided bone regeneration with a consistent record of excellent results.[48-56] At beginning (1996), acellular dermal matrix was used as a permanent dermal transplant in full-thickness and deep partial-thickness burns. Histology of the dermal matrix showed fibroblast infiltration, neovascularization, and neoepithelialization without evidence of rejection.[57] In vascular and microvascular surgery, acellular dermis appears to be a promising material for use as a vessel substitute.[58] In1998, Rhee et al. use processed allograft dermal matrix for intraoral resurfacing, and found ADMA was successful as a substitute to autologous split-thickness skin grafts for resurfacing of intraoral defects.[59] ADMA may be considered a useful reconstructive option for patients with oral mucosal defects.[59]

Luczyszyn et al. evaluated the efficacy of ADMA as a membrane associated with a resorbable hydroxyapatite (RHA) in ridge preservation after extraction.[49] Single rooted teeth were selected in the study. In the control group, the extraction sockets were covered by ADMA alone; and in the test group, they were filled with HA before the placement of the ADMA. After 6 months, re-entry surgeries and biopsies were performed. The histological analysis showed bone formation in both groups although, in the group with RHA, the presence of a highly vascularized fibrous connective tissue surrounding the particles was a common finding. It was concluded that ADMA was able to preserve ridge thickness and increase the width of keratinized tissue.

Fowler et al. reported an acceptable esthetic result with no loss of ridge height or width with DFDBA and ADMA.[60] Soft tissue dimensions were also preserved. The two graft materials were well accepted by the body; healing was rapid and without significant discomfort. The technique illustrated provides the surgeon with another option to prevent ridge collapse and ultimately improve esthetics.

Novaes et al. reported ADMA could be used for guided bone regeneration with the advantage of forming soft tissue while acting as a barrier membrane in guided bone regeneration[61] Froum et al. also reported ADMA-covered sites resulted in more vital bone 6 to 8 months post-socket treatment than obtained in the ePTFE-covered sites regardless of bone replacement materials used. [62] Fotek et al. found buccal plate thickness loss was 0.44 and 0.3 mm, with a vertical loss of 1.1 and 0.25 mm, for ADMA and PTFE, respectively.[52] Bone quality assessment indicated D3 to be most prevalent (61%). Histomorphometric analysis revealed 41.81% versus 47.36% bone, 58.19% versus 52.64% marrow/fibrous tissue, and 13.93% versus 14.73% particulate graft remaining for ADMA and PTFE, respectively. The authors also concluded both membranes were suitable for alveolar ridge augmentation.

Histologically, Xie et al. reported the revascularization of the dermal substitutes could begin shortly after grafting.[63] The sponge-like structure of the substitutes was advantageous for the migration of the host fibroblasts into the substitute and for the secretion of the new extra-cellular matrix. The dermal substitutes could last in the wound for a long time with partial absorption and degeneration.

Surgical procedure and technique

Wang et al. in 2004 proposed 3 key points for the surgical ridge preservation procedure, which are stated as follows.[64] (a) extraction should be performed preserving as much of the alveolar process as possible. After severance of the supra- and subcrestal fibrous attachment using scalpels and periotomes, elevation of the tooth frequently allows extraction with minimal socket wall damage. (b) Extraction sockets should not be acutely infected and be completely free of any soft tissue fragments before grafting or augmentation is attempted. (c) Socket bleeding that mixes with the grafting material seems essential for success of this procedure.

Engler-Hamm et al. conducted a randomized clinical trial in humans.[65] Eleven patients completed this 6-month trial. Extraction and ridge preservation were performed using a composite bone graft of inorganic bovine-derived hydroxyapatite matrix and cell binding peptide P-15 (ABM/P-15), DFDBA, and a copolymer bioabsorbable membrane. Primary wound closure was achieved on the control sites, whereas the membrane left exposed at the test sites. Pocket probing depth on adjacent teeth, repositioning of the mucogingival junction, bone width, bone fill, and postoperative discomfort were assessed. Bone cores were obtained for histologically examined. The results showed no difference histologically between both techniques. Comparison of clinical variables between the two groups at 6 months revealed that the mucogingival junction was statistically significantly more coronally displaced in the control group than in the test group, with a mean of 3.83 mm versus 1.21 mm ($P = 0.002$). The study concluded that ridge preservation without flap advancement preserves more keratinized tissue and has less postoperative discomfort and swelling. Although ridge preservation is performed with either method, approximately 27% to

30% of bone width is lost.[65] Fickel et al, in an animal study showed better results when using flapless surgical technique in terms of dimensional changes.[66]

The grafting materials used in this study ABBMX (BioOss® , Luitpold Pharmaceuticals, Inc., headquartered in Shirley, NY),and FDBA (MinerOss® , BioHorizons, Birmingham, AL) are both available on the market for use in regenerative procedures. Comparison of the efficacy between the products in the RP procedure has not been studied yet.

Until now, it is still uncertain which combination of the technique and the material gives the most predictable outcome.[67] Hammerle et al. described in a systemic review that multiple factors should be considered for this procedure viz: conditions of the soft tissues, i.e., displacement of the muco-gingival junction, amount of keratinized mucosa; techniques for soft tissue management, i.e., raising of flaps yes/no; methods for soft tissue closure; influence of the hard and soft tissue anatomy following tooth extraction: presence or absence of bony socket walls, thickness of the bony socket walls, soft tissue area, volume, color, scars; effect of various biomaterials applied for ridge contouring and, finally, the effect of various biomaterials applied as barrier membranes.[68]

Thus, it was the aim of the following experimental investigation in humans, to evaluate socket preservation techniques (open technique and flapless) and their effects on tissue contour alterations after tooth extraction using different bone graft materials.

II. Specific Aims and Hypothesis

A. Aim

The goal of this retrospective equivalence study is to evaluate the effectiveness of the FDBA and ABBMX in ridge preservation (RP) with a collagen barrier membrane (ADMA) as determined by ridge changes in stone casts 4-6 months post-RP. The casts were compared from baseline to 4-6 months post-RP.

The primary aim of this study is to:

Compare changes in ridge dimension, between groups of sites grafted with FDBA (Allograft) and ABBMX (Xenograft) covered a collagen barrier membrane (ADMA) from baseline to 4-6 months post-RP in stone casts.

The secondary aim of this study is to:

Compare changes in ridge dimensions within the groups from baseline to 4-6 months post-ridge preservation with FDBA and ABBMX in stone casts.

B. Hypothesis:

There are no differences between (FDBA) allograft and (ABBMX) xenograft in ridge preservation (RP) determined by ridge width change in 4-6 months after tooth extraction in stone casts.

III. Research design and Method

A. Experimental design

This is a retrospective equivalence study in the efficacy of ridge preservation which was assessed in stone casts. A comparison was made between patients who received FDBA vs ABBMX as the bone grafting material with the same surgical technique by the same surgeon from 2009-2012.

There were 28 patients involved in the research who had extraction and RP procedure either the FDBA or the ABBMX was used.. Impressions for stone casts were taken from the appropriate arch pre-extraction and 4-6 months post-surgery.

Subject characteristics

Inclusion criteria:

1. Casts from patients who received ridge preservation in the molar region from 2010-2012 using either the FDBA or the ABBMX covered by the ADMA.
2. The included teeth must have the presence of at least 3 intact bone walls. Bone loss on the fourth wall, if any, must be less than 2mm (which was determined by reading the Axium case note).
3. The extraction sites must be bordered by at least one tooth which was determined by examining the stone cast.
4. The surgical technique used was a flapless with the exposure of the membrane.
5. The surgery was done by the same surgeon (co-investigator, Li-Fan Chen) and the casts were collected only from patients assigned to the surgeon.
6. The included patients must have a pre-surgical diagnostic stone cast, and a cast made from the impression that was taken from 4-6 months after the surgery. The second cast was indicated for the making of a surgical stent which would be used for implant placement.
7. The patient must not be a smoker.

Exclusion criteria:

1. Post surgical complications

B. Specific methods and techniques used throughout the study

Surgical procedure

The procedures were performed same techniques by one surgeon (LFC).

Patients will rinse with 0.12% chlorhexidine gluconate for 1 minute. One hour before the start of the surgical procedure, 600 mg of ibuprofen will be administered to the patient.

All patients will receive topical and local anesthetic prior to surgery. Adequate anesthesia using Bupivicaine 0.5% (5mg/ml) 1: 200,000 epinephrine (0.005mg/ml) and Lidocaine 2% (20mg/ml) with 1: 50,000 epinephrine (0.02mg/ml) will be administered. The included teeth will be extracted in an attempt to preserve all the socket walls with the aid of periotomes, and the sockets were debrided of any soft tissue.

With a periosteal elevator, the soft tissue surrounding the socket will be undermined. It extends 1-3 mm on the buccal and lingual plates. A piece of ADMA was hydrated (according to the manufacturer's instruction) in 0.9% sodium chloride saline solution for 5 minutes. The solution will be discarded and the container will be refilled with fresh saline. The material will be hydrated in the solution for another 5 minutes before trimming it properly. After trimming the proper size, one end of the ADM will be sutured underneath the palatal/lingual tissue with 5-O sutures.

Implantation of the bone graft Either ABBMX (BioOss® , Luitpold Pharmaceuticals, Inc., headquartered in Shirley, NY) or FDBA (MinerOss® , BioHorizons, Birmingham, Alabama) previously hydrated will then be placed into the socket flush with the alveolar crest. The bone graft will be prepared according to the manufacture's indications: it will be placed in sterile saline solution to hydrate the bone particles. Once the bone particles are embedded in the saline solution, gauze will be used to remove the excess of saline solution. The hydrated bone grafts particles will be delivered into the socket with a surgical instrument and packed. The other end of the membrane was tucked underneath the soft tissue.   A continuous figure 8 suture will then be placed over the membrane.

Stone cast measurements

Customized stent measurement

Manufacture of the reference stent:

For all the included subjects, an impression was taken with alginate impression material, mixed according to manufacturer's instructions and from these, pre-diagnostic casts were poured in stone. The cast was used to make an acrylic stent (1mm thickness) with a vacuum device. The stent was trimmed so that it covers at least one tooth mesially and distally to the involved site. Distal to the tooth, the stent will extend on the buccal and the lingual aspects. 3mm and 5mm subgingival guiding holes were made on the stent at the middle point mesio-distally of the included tooth for reference purposes. (Fig.1)

The second stone cast was made the same way 4-6 months after extraction. All the measurements were performed on the two sets of stone castsusing the same customized stent.

Measurement: All the measurements were carried out to the first decimal place.

1. Total Alveolar Width

This is the width of the alveolar ridge at the two interested levels as measured directly with a ridge mapping caliper (IFMI, Ridge Mapping Instrument, G. Hartzell & Son, Concord, CA, USA).(Fig 2) Reference marks were made on the acrylic stent corresponding to the 3 mm and 5 mm subgingival locations. Four measurements were recorded as follows:

- Baseline ridge width at 3 mm subgingivally (bW3mm)
- Baseline ridge width at 5 mm subgingivally (bW5mm)
- Post-RP ridge width at 3 mm subgingivally (post-RP W3mm)
- Post-RP ridge width at 5 mm subgingivally (post-RP W 5mm)

2. Remodeling of the Buccal and the Lingual Tissue

These were the horizontal linear differences between the baseline and the post-RP buccal and lingual tissue at the interested levels. Reference marks, previously mentioned, made on the acrylic stent corresponding to the 3 mm and 5 mm subgingival locations were used. In addition, a #40 endodontic reamer (Dentsply, Maillefer, York, PA, USA) with a rubber stopper and a North Carolina periodontal probe (Hu-Friedy, standard probe, CO, USA) was utilized for measuremet purposes. Measurements were made with the reamer at the interested points on the baseline and the post-RP casts. Eight measurements were recorded as follows:

- Baseline buccal tissue at 3 mm subgingivally (bB 3mm)
- Baseline buccal tissue at 5 mm subgingivally (bB 5mm)
- Baseline lingual tissue at 3mm subgingivally (bL 3mm)
- Baseline lingual tissue at 5mm subgingivally (bL 5mm)
- Post-RP buccal tissue at 3 mm subgingivally (pB 3mm)
- Post-RP buccal tissue at 5 mm subgingivally (pB 5mm)
- Post-RP lingual tissue at 3 mm subgingivally (pL 3mm)
- Post-RP lingual tissue at 5 mm subgingivally (pL 5mm)

Hence the equations for calculation of the remodeling were:

- Remodeling of buccal tissue at 3mm (rB 3mm): pB 3mm – bB 3mm
- Remodeling of buccal tissue at 5mm (rB 5mm): pB 5mm – bB 5mm
- Remodeling of lingual tissue at 3mm (rL 3mm): pL 3mm – bL 3mm
- Remodeling of lingual tissue at 5mm (rL 5mm): pL 5mm – bL 5mm

  (Table 5, 6)

3. Changes of the Papillary height

The buccal shell of the customized stent was trimmed away for the measurement of the papillary height. A notch was placed on the trimmed stent so that the line connecting the notch and the tip of the corresponding papilla is parallel to the long axis of the involved tooth. Measurements were made on both sets of casts for the mesial and the distal papilla of the involved tooth. (Fig 3) Four measurements were recorded:

- Baseline mesial papillary height (bMPH): the distance between the mesial notch and the tip of the mesial papilla at baseline.
- Baseline distal papillary height (bDPH): the distance between the distal notch and the tip of the distal papilla at baseline.
- Post-RP mesial papillary height (post-RP MPH): the distance between the mesial notch and the tip of the mesial papilla on the post-RP cast.

Post-RP distal papillary height (Post-RP DPH): the distance between the distal notch and the tip of the distal papilla on the post-RP cast. Thus, the changes of the papillary heights are:

- Change of the mesial papillary height (ΔMPH): post-RP MPH – bMPH
- Change of the distal papillary height (ΔDPH): post-RP DPH – bDPH (Table 7)

C. Sample size calculation

With a sample of 14 in each group, we had 80% power to test whether the two groups result in differences in ridge width of no more than 1.0 mm difference, assuming a common population mean between groups and a common standard deviation of 1 mm (nQuery Advisor, 7.0).

D. Statistical analyses

Quantitative data were summarized as mean ± standard deviation, and categorical data were summarized as count and percentage. We used the independent-samples t-test to compare baseline valuables, sectional ridge resorption, and the papillary height changes between the groups. Between-group comparisons after the surgery were carried out by one sided 95% confidence intervals for ridge width changes at 3mm and 5mm subgingivally owning to the nature of the study design. Intra-group comparisons were performed by the paired t-test. All calculations was carried out to unlimited decimal places and then rounded off to the first two decimal places. The significance level for rejection of the null hypothesis was set at $\alpha = 0.05$. All analyses were done using SPSS (Version 19).

The demographic information was provided for these two groups, and the location of the tooth site was documented. (Table 1) The primary outcome with a different way of measurement was collected (Table 2, 3, 4, 5). The change of papillary height was also measured (Table 6).

IV. Results

Descriptive results

Twenty-eight patients were included in the study. Each group had 14 subjects. Fifty-six stone casts were collected; each patient had pre-operative and post-healing stone casts poured and fabricated. The mean±SD age was 49.29± 16.13 years for the ABBMX group and 52.93±16.93 years for the FDBA group. Smokers were excluded from the study, and there were no post-operative complications. The average timeline for the post-healing impression was 5.44±0.82 months in the FDBA group and 5.09± 2.43 months in the ABBMX group. In the FDBA group, we had 6 molars in the maxilla and 8 molars in the mandible; in the ABBMX group, we had 4 molars in the maxilla and 10 molars in the mandible. The summary of the demographic information is shown in Table I.

The baseline and post-RP ridge width distributions for both groups are provided via side by side box plot (Fig 4). The changes of ridge width at the two levels of interest are provided via side by side box plot. (Fig 5) The distributions of sectional ridge changes are provided via side by side box plot (Fig 6). The distributions of papillary height changes are provided via side by side box plot (Fig 7). From the above figures, we observe a wide range of seventy- five percentile distributions.

<u>Analytic results</u>

Clinical Parameters -ridge width changes at 3mm and 5mm subgingivally

Summary statistics for variables over time are shown in Table 2 and Table 3. There was no statistically significant difference between the groups for the clinical variables at baseline. Based on a one sided 95% confidence interval, the resorption of FDBA was no worse than 1.88mm at 3mm subgingivally and 2.02 mm at 5mm subgingivally when compared with those of ABBMX. Regarding intragroup changes over 4-6 months, there was a 39.89% ridge dimensional change in the group with FDBA and a 36.46% ridge dimensional change in the group with ABBMX at 3mm subgingivally. There was 24.39% resorption in the group with FDBA and 17.26% resorption in the group with ABBMX at 5mm subgingivally. All of these intra group changes were statistically significant ($p<0.001$).

Comparing ridge width changes between maxilla and mandible, at the 3mm subgingival level, the FDBA group demonstrated a 5.90±1.65 mm changes in the maxilla and 4.95±2.46 mm changes in the mandible; at the 5mm subgingival level the changes were 3.70±1.09 mm in the maxilla and 2.82±1.88 mm in the mandible respectively.(Table 4) . At 3mm subgingival level, the ABBMX group demonstrated a 5.30±0.88 mm in the maxilla and 5.00±2.79 mm in the mandible, at the 5mm subgingival level, the changes were 3.10±1.09 mm in the maxilla and 2.47±1.84 mm in the mandible respectively. (Table5, 6) The differences between the maxilla and the mandible were not statistically significant and the summary of the distribution is shown in Table 6.

Clinical Parameters -remodeling of the buccal and lingual tissue

The comparisons on the section remodeling are shown in Table 5. When comparing between the groups at two levels of interest, the only significant difference was found at the 5mm subgingival level on the lingual side 1.58±1.58mm vs 3.61±1.9mm ($p=0.05$). Intra group comparisons at the two levels of interest reveled a statistically significant difference at the 3mm subgingival level between the buccal and the lingual sides in the ABBMX group 4.73±2.06mm vs 2.89±2.19mm ($p=0.03$).

Clinical Parameters -adjacent papillary height changes

The changes of the papillary height on the adjacent teeth are shown in Table 6. In all cases, the papillae demonstrated a reduction in height regardless the material types. The reduction of the papillary height on the mesial side of the included teeth averaged 1.76±0.84 mm for the FDBA group and 1.26±0.85 mm for the ABBMX group. The reductions of the papillary height on the distal side were 1.76±0.88 for the FDBA group and 1.88±1.24mm for the ABBMX group respectively. The differences between the groups were statistically not significant.

V. **Discussion_**

Discussion of results

In this retrospective equivalence study, based on the analysis, it was found in the most of case scenario, the reduction of the ridge width in the FDBA group would be no more than 1.88 mm at 3mm and 2.02 at 5mm subgingival levels. In addition, the 36.46%(ABBMX) to 39.87 %(FDBA) correspoinding to 5.09mm 5.49mm of reduction in ridge width at the 3mm subgingival level were revealed during the healing period. Likewise, 17.26 %(2.65mm, ABBMX) to 24.39 %(3.62mm, FDBA) were noticed at the 5mm subgingival. As far as the sectional tissue remodeling is concerned, both groups demonstrated reduction in width at the 3mm subgingival level. However, the difference between the buccal and lingual tissue was statistically significant in the ABBMX group. Moreover, at 5mm subgingivally, a significant different reduction was found between the groups on the lingual side. Finally, the papillary height on both side of the involved teeth showed reduction in all cases.

Clinical Parameters -ridge width at 3mm and 5mm subgingivally

ABBMX was chosen to be the graft material in the control group because it was the most studied material in ridge preservation to maintain the anatomic ridge morphology.[24-27,30-33,69-73] To our best knowledgement, this is the first study investigation looking at the efficacy of ridge preservation utilizing free- dried bone

FDBA and ABBMX as the grafting materials. Our hypothesis was that the clinical performance of FDBA would be equivalent to that of the ABBMX. This pilot study provided preliminary results on this product with the purpose of evaluating it as an alternative material in preserving ridges. In this study we used molar sites because there was limited evidence regarding these remodeling after the ridge preservation in “molar” sites according to our literature search. Only one clinical trial showed the effect of ridge preservation in molar sites.[33]

Comparing to the previous studies, we found more post-RP resorption in both groups. With ABBMX, Kim et al. found a 14.26% ridge width change at 3months[33]; Barone et al. had a 24% change at 7-9 months[70]; Gholami et al. observed a 13.8% change at 6-8 months[32], and Mardas et al. got a 23.3 % change at 8 months[72]. With FDBA, Iasella et al. found 13% ridge resorption at 6 months[16], and Wood et al. had a 20.9% change at 5 months[46]. However the present study showed more dimensional changes; which were 39.89% with FDBA and 36.46% with ABBMX. The reasons for the differences are discussed as follows.

I. Extraction sites

In most of the published studies, either single rooted teeth[22,28,30,43,45,48,51,52,69,73] or a combination of single and multi-rooted teeth were involved[17,27,32,62,65]. To the best of our knowledge, only one study included molars. [33] Moya-Villaescusa & Sanchez-Pe´rez investigated 100 extraction sites with radiographic measurement, and found a tendency towards greater vertical dimension loss in multi-rooted teeth.[74] There was no statistically significant difference though. This observation had also been discussed by Engler-Hammet al.[65] In his 6 months clinical trial, he had a mean 24-28 % ridge resorption in 11 subjects with regards to the ridge width, and he concluded that the greater amount of resorption may be due to a larger proportion of molar sites subjects. Schropp also found the percentage reduction was somewhat larger in the molar regions than in the premolar regions.[17]

II. Different levels and different methods of measurement

Levels

In the previous studies, the levels of measurement and the methods they used are different. Engler-Hamm and Kim measured 3mm below the alveolar crest which included hard tissue only.[33,65] Schropp measured the widest part of the study casts, which included both soft and hard tissue. There was a different degree of resorption at different levels..[75] Kerr observed different ridge width resorption at different levels subcrestally. They were 2.2mm at 0mm level, 1.3mm at 3mm level, 0.59mm at 6mm level, and 0.28 at 9mm level. He concluded more resorption occurred at the more coronal level. In our study, the 3mm subgingival measurement is more coronal than the bone level measurement, and that contributed to the greater percentage of resorption. Our finding agreed Kerr's conclusion. In our study, the remodeling rates were substantially different at the two levels (3mm and 5mm).

In 1961, Gargiulo observed a consistent distances of 3mm from the free gingival margin to the crestal bone, which was termed as "biological width". Lanning et al. in 2003 also observed this phenomenon.[76] Therefore, it seems to be reasonable for us to correspond with the results at 3mm subgingivally from our study to those at crestal level from other studies; at 5mm subgingivally to those at 2-3 mm subcrestally. .

Different method

Differences in sample sizes, different behaviours of study populations, varied observation time points and measurement parameters also contributed to the different results. Many studies, for example, Lekovic et al. 1997, 1998; Camargo et al. 2000; Iasella et al. 2003 and Pelegrine et al. 2010[15,19,73,77] employed re-entry methods, utilizing an acrylic stent, a titanium pin or screw as fixed reference points from which to obtain dimensional changes.. In our study, the dimensional changes were measured on study casts viz the outcome included dimensional changes combining the soft and hard tissue. The way of measurement included dimensional changes from the soft and the hard tissue. Tan et al. discussed in the review article that the different methods of measurement may result in certain discrepancies. Measuring on study casts, the combined hard and soft tissue horizontal reduction was 5.1 mm at 6 months corresponding to a weighted mean reduction of 3.79mm to (2.46mm to 4.56 mm) hard tissue reduction when measuring clinically with bone mapping or CBCT scan. Hence, at 6 months post-extraction, the combined hard and soft tissues demonstrated a tendency towards a more substantial reduction than hard tissue alone.[12] However, in Lekovic's study, he claimed the changes in model measurements were similar to those seen clinically.[15]

III. Time

As Schropp and colleagues stated most of the resorption occurred in the first 3 months, and further resorption continued until 12 months.[17] Length of the follow-up period may play a role in the difference of the outcomes. Kim et al. in their 3months human study found 14.26% reduction with the ABBMX. Our study had greater width resorption (17.26%) than that of Kim's. The difference in time of measurement may be another factor.

The reference points in our study were 3mm subgingivally and 5mm subgingivally because the 3mm subgingival level is the ideal position for implant platform. We used the 5mm subgingival level as a reference to compare with previous studies, which provided more linear information. So we can conclude from these studies that the gingival level measurement has a 3mm discrepancy compared to the bone level measurement. In conclusion, in the ridge preservation technique in molar extraction sites, we have less dimensional changes at 3mm subcrestally, and 5mm subgingivally. However, we had difficulty in preserving the width of the ridge at the ideal vertical implant platform position; which showed 36-39% width resorption, and this is another reason that in Kim's study, 3 out 10 patients still needed additional bone graft when implants were placed.[33] The benefit of ridge preservation in molar sites can provide better ridge width at the apical level for achieving better primary stability, but additional hard and soft tissue grafting maybe necessary to achieve ideal implant treatment outcome.

In our study we observed more ridge resorption in the maxillary sites compared to the mandibular sites. The summary of the comparisons are shown in Table 4. This outcome confirmed the findings of Iasella. However, it is different than Schropp's.

Clinical Parameters -remodeling of the buccal and lingual tissue

Both groups demonstrated reduction in ridge width at the 3 mm subgingival level on both sides (i.e. buccal and lingual) of the ridge. (Table 5, 6) At the 3mm subgingival level which corresponds to approximately the crestal level of the ridge, an average of 1 mm vertical resorption had been reported. [16] The amount of horizontal reduction on hard tissue at this level is thought to be a combined effect from both horizontal and vertical resorption of the hard tissue. Furthermore, in a stone cast study such as the current one, the total amount of horizontal reduction also includes the change in the thickness of the soft tissue. It was found that the amount of resorptions between the buccal and the lingual tissue were statistically significant in the ABBMX group. (Table 5, 6) The difference could probably be explained by the less resorption and hence, the better preserved lingual tissue. It was also noticed that on the lingual side, there was significantly less resorption in the ABBMX group than that in the FDBA group at the 5 mm subgingival level. The difference between the groups on the lingual side at t he 3 mm subgingival level was not statistically significant. Since horizontal resorption is the only source of reduction in ridge width at the more apical level, this outcome implies that the ridge on the lingual side grafted by the ABBMX was better preserved than that by the FDBA.

An interesting finding in the present study was that except for one occasion, resorption on the buccal side was not significantly greater than that on the lingual side. (Table 5, 6) This is in contrary with certain previous studies which suggested that tissue loss is more pronounced on the buccal aspect than from the lingual or palatal aspect.[7,14,17,70] Soft tissue involvement, impression techniques, variation in anatomy and selected sites may all contribute to the outcomes. More investigations are suggested to study the tissue changes on the buccal/facial and lingual/palatal sides separately.

Clinical Parameters -adjacent papillary height

Over the years, implant esthetics has been brought under the spotlight. More and more research have discussed on the topic of papillary height around implant sites. Jemt, in 1997, proposed a papilla index for evaluating the papillary height after implant treatment. [78] Investigators proposed that in single implant restorations adjacent to natural teeth, the level of the marginal soft tissues and interproximal papillae is dictated by the attachment level on the adjacent teeth (Salama 1998; Grunder 2000; Kan

2003)[79,80 81] In four studies, Iasella et al.(2003); Serino et al(.2003); Barone et al.(2008) and Aimetti et al.(2009) measured vertical dimensional changes on the mesial and distal bone plates[16,70,82,83]. They found the resorption around 0.4 to 0.8mm over 3-7 months because the mesial and distal bone levels are held by the adjacent teeth. The studies were largely conducted on single rooted teeth? On the other hand, when the distance between the adjacent teeth increases, the resorption rate (0.4 mm - 0.8 mm) may not held true. (Elian 2003)[84] Measuring the height of the papillae before and after the healing period of ridge preservation aimed to provide further information on biological change on the tissue critical to implant esthetics. The current study demonstrated consistent height reduction, an average of 1.7 mm (1.26 mm – 1.88 mm) on the papillae in both groups. Whethe this observation indicates that the dimension of buccal papilla tissue cannot be maintained with ridge preservation, or other factors such as the pressure from impression material, error introduced during the cast fabrication process, or simply a matter of the length of follow-up period may also play a role are non-conclusive. Neverthless, clinical studies with long-term follow-ups are recommended to further investigate the 3-D changes on the papillae at the future implant sites.

Limitation

When calculating the sample size, the standard deviation of the variable we used was half the size of which was later found in the study. As a result, the sample size may not be adequate to support some of the conclusions. Moreover, even though we tried to control the variables, owing to the retrospective nature, we were not able to control the quality of impressions taken or stone casts poured which may affect the accuracy of the actual dimension. Furthermore, due to mucosa mobility, the study casts might not be ideal representatives of the sites.

Future research

This study provided clinical information on the performance of a mineralized FDBA grafting extraction siteswhen compared that of a bovine bone mineral ABBMX. Future studies with histological analysis of the sites should be conducted. Since ridge preservation is a treatment modality in which several factors such as various kinds of surgical techniques and grafted materials may change the outcome. Further research is necessary.

With computer software assisted analysis, the stone casts scanned into digital files, will be more accurately measured. Human bias will therefore, be eliminated. With the aid of advanced technology, we can provide better analysis of morphological change in three dimensions in the further studies.

VI. Conclusion

Within the limits of the study, it is concluded that in spite of the grafting materials used, ridge preservation does not predictably preserve the alveolar ridge to its full extent. The differences in ridge width after a 6 months healing period if any, is most likely to be within 1.86 mm at the 3-mm subgingival level and 2.02 mm at the 5-mm subgingival level. No significant differences were found between the maxillary and the mandibular sites in either group and at either level. The lingual tissue was better preserved than the buccal tissue at a more coronal level when grafted with the bovine bone mineral. The lingual tissue was also better preserved when grafted with the bovine bone mineral than that being grafted with the mineralized FDBA at a more apical level. The heights of the papillae on the adjacent teeth were reduced by an average of 1.7 mm in all the cases.

Tables

Table 1: **Summary of Demographic Data**

	FDBA	ABBMX
Subject numbers	14	14
Mean±SD (Age)	52.93±16.93	49.29±16.13
Sex (Male/Female)	6/8	9/5
Tooth type (Molar)	14	14
Tooth position (Maxilla/ Mandible)	6/8	5/9
Mean (SD) time in months after extraction	5.44±0.82	5.35±0.83

Table 2: **Comparison Horizontal Ridge Width (mm) at 3 mm Level**

Variable	FDBA(mean± SD)	ABBMX (mean± SD)	
bW 3mm	13.94±1.95	13.96±2.02	*0.97
post-RP bW 3mm	8.44±2.22	8.88±2.59	
Difference	5.49±2.17	5.09±2.43	†1.86mm
Difference percentage	39.38	36.46	
P value	<0.0001	<0.0001	

Baseline ridge width at 3 mm subgingivally (bW3mm)

Post-RP ridge width at 3 mm subgingivally (post-RP W3mm)

*Between-group comparisons at baseline are carried out by independent-samples t-test.

† Between-group comparisons after the surgery are carried out by one-sided 95% confidence intervals

Intra-group comparisions between baseline and post-RP are carried by paired t-test.

Table 3: **Comparison Horizontal Ridge Width (mm) at 5 mm Level**

	FDBA(mean± SD)	ABBMX (mean± SD)	
bW 5mm	14.84±2.29	14.95±2.33	*0.897
Post-RP W 5mm	11.21±2.14	12.3±2.67	
Difference	3.62±1.70	2.65±1.56	†2.02mm
Difference percentage	24.39	17.26	
P value	<0.0001	<0.0001	

Baseline ridge width at 5 mm subgingivally (bW5mm)

Post-RP ridge width at 5 mm subgingivally (post-RP W 5mm)

*Between-group comparisons at baseline are carried out by independent-samples t-test.

† Between-group comparisons after the surgery are carried out by one-sided 95% confidence intervals.

Table 4: **Comparisons of Horizontal Ridge Changes (mm) in Maxilla and Mandible**

	Maxilla	Mandible	P value
FDBA at 3mm subgingival level	5.90±1.65	4.95±2.46	0.287
FDBA at 5mm subgingival level	3.70±1.09	2.82±1.88	0.838
ABBMX at 3mm subgingival level	5.30±0.88	5.00±2.76	0.130
ABBMX at 5mm subgingival level	3.10±0.14	2.47±1.84	0.310

Between maxilla and mandible sites comparisons are carried out by independent-samples t-test.

Table 5: **Remodeling of the Buccal and the Lingual Tissue (mm) at 3mm Level**

	FDBA(mean± SD)	ABBMX(mean± SD)	p-value
rB3mm	4.22±*1.74*	4.73±*2.06*	0.488
rL3mm	4.38±*1.96*	2.89±*2.19*	0.069
P value	0.824	0.03	

Remodeling of buccal tissue at 3mm (rB 3mm): pB 3mm – bB 3mm

Remodeling of lingual tissue at 3mm (rL 3mm): pL 3mm – bL 3mm

Table 6

Remodeling of the Buccal and the Lingual Tissue (mm) at 5 mm level

	FDBA(mean± SD)	ABBMX(mean± SD)	p-value
rB5mm	3.21±*1.21*	2.29±*2.66*	0.248
rL5mm	3.61±1.9	1.58±1.58	0.005
P value	*0.512*	*0.395*	

Remodeling of buccal tissue at 5mm (rB 5mm): pB 5mm – bB 5mm

Remodeling of lingual tissue at 5mm (rL 5mm): pL 5mm – bL 5mm

Between-group comparisons at baseline are carried out by independent-samples t-test.

Between buccal and lingual comparisons are carried out by independent-samples t-test.

Table 7

Adjacent Papillary Height Change (mm) (n=14 for each group)

	FDBA	ABBMX	P value
ΔMPH (mean+SD)	1.76±*0.84*	1.26±*0.85*	0.13
ΔDPH (mean+SD)	1.76±*0.88*	1.88±*1.24*	0.767

Change of the mesial papillary height (ΔMPH): post-RP MPH – bMPH

Change of the distal papillary height (ΔDPH): post-RP DPH – bDPH

Between-group comparisons are carried out by independent-samples t-test.

Figures

Figure 1 ridge width measurement

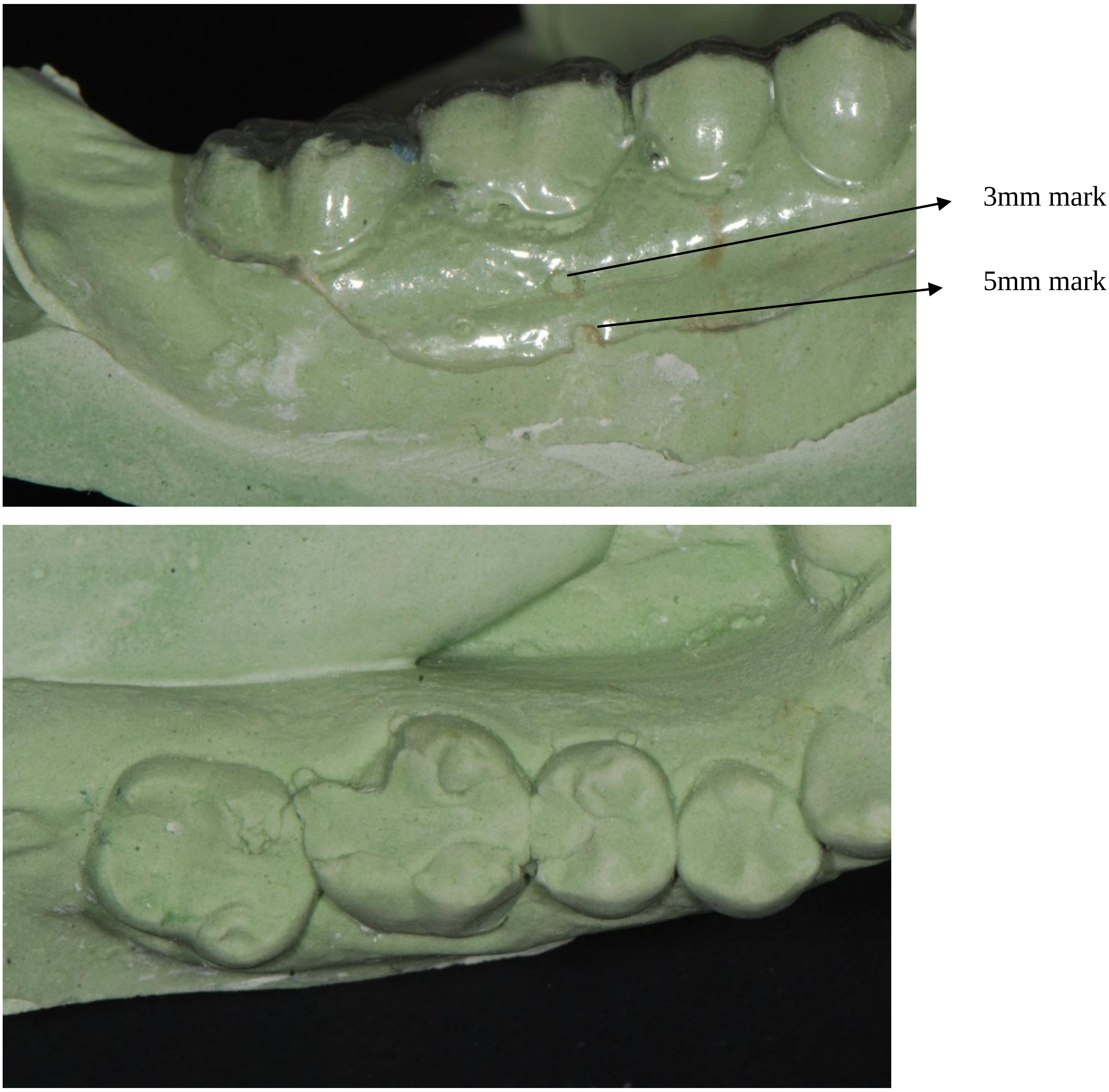


Figure 2 buccal and the lingual Tissue remodeling measurement

Initial measurement

Post-RP measurement

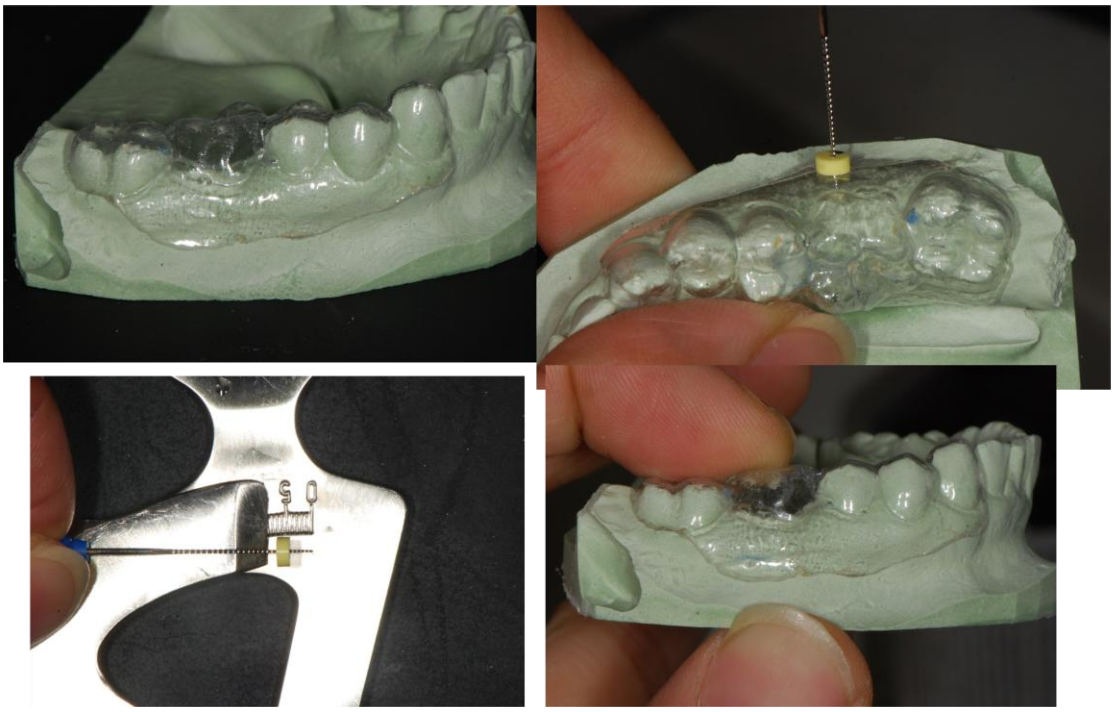
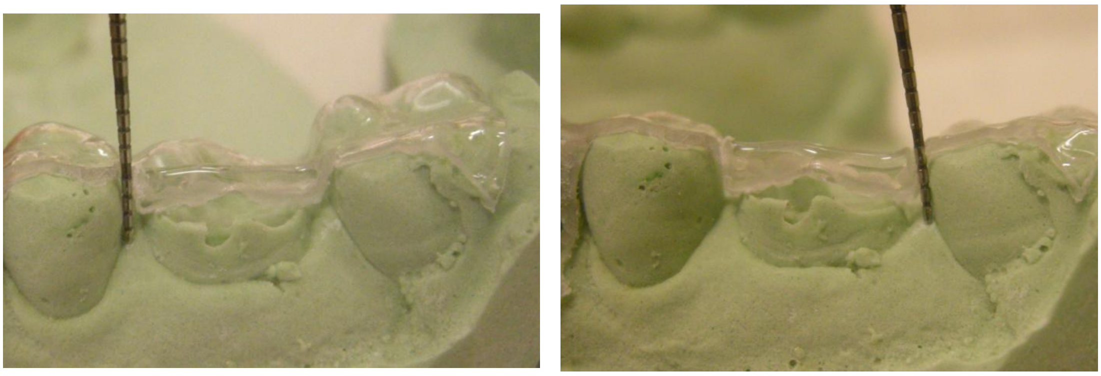


Figure 3

papillary height measurement

Initial measurement



Post-RP measurement

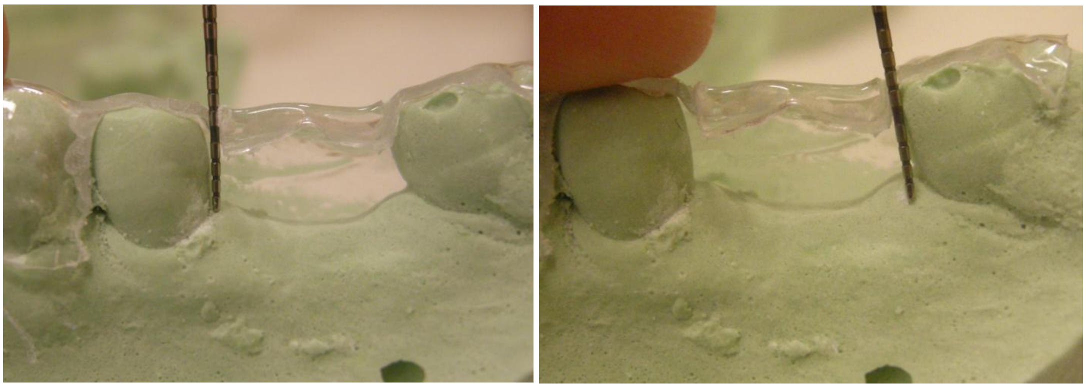
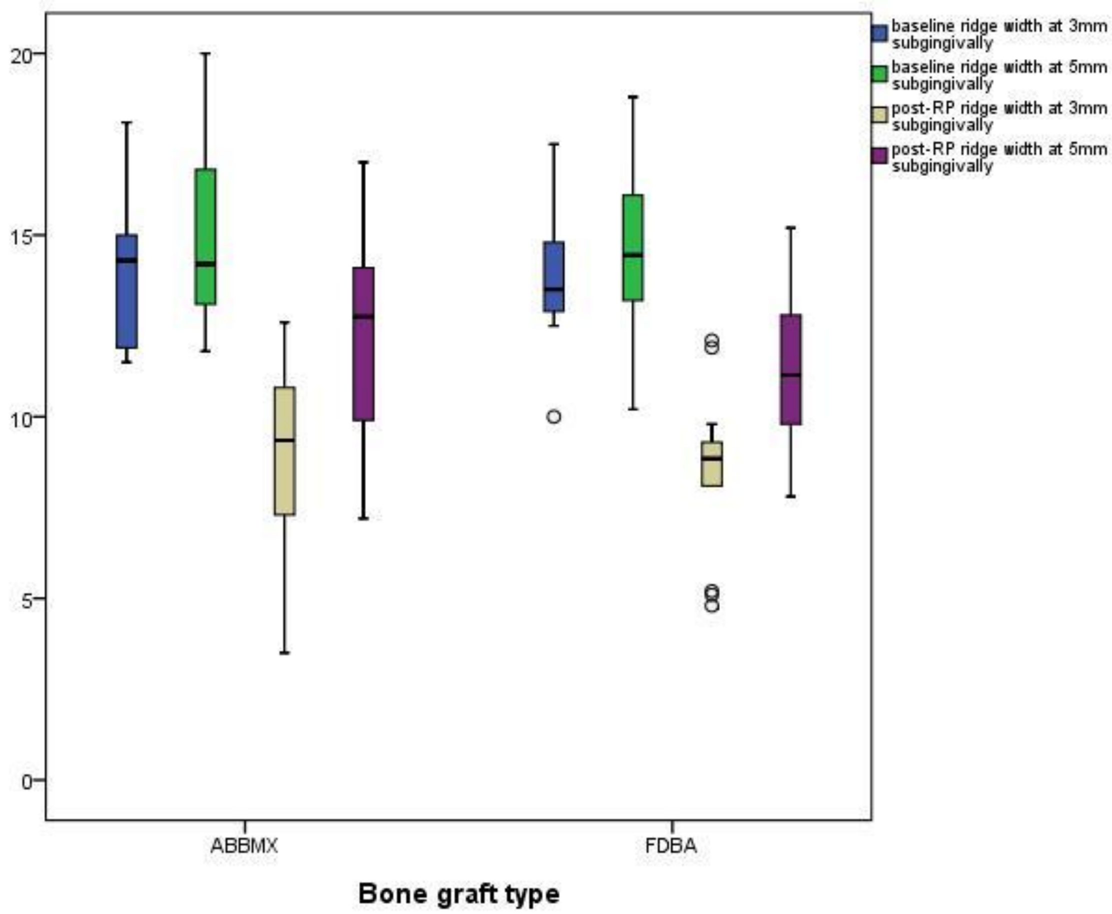
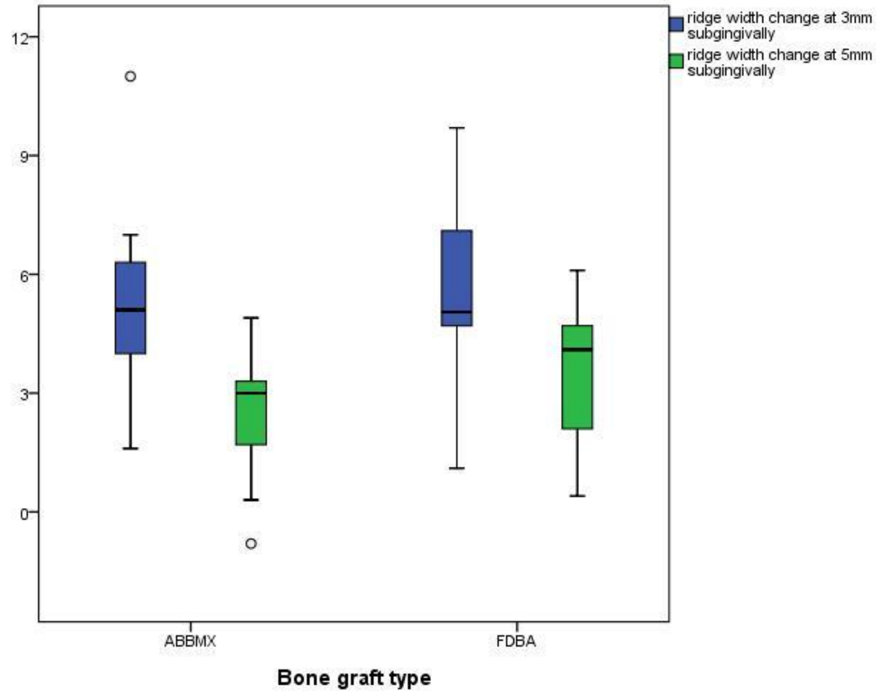


Figure 4



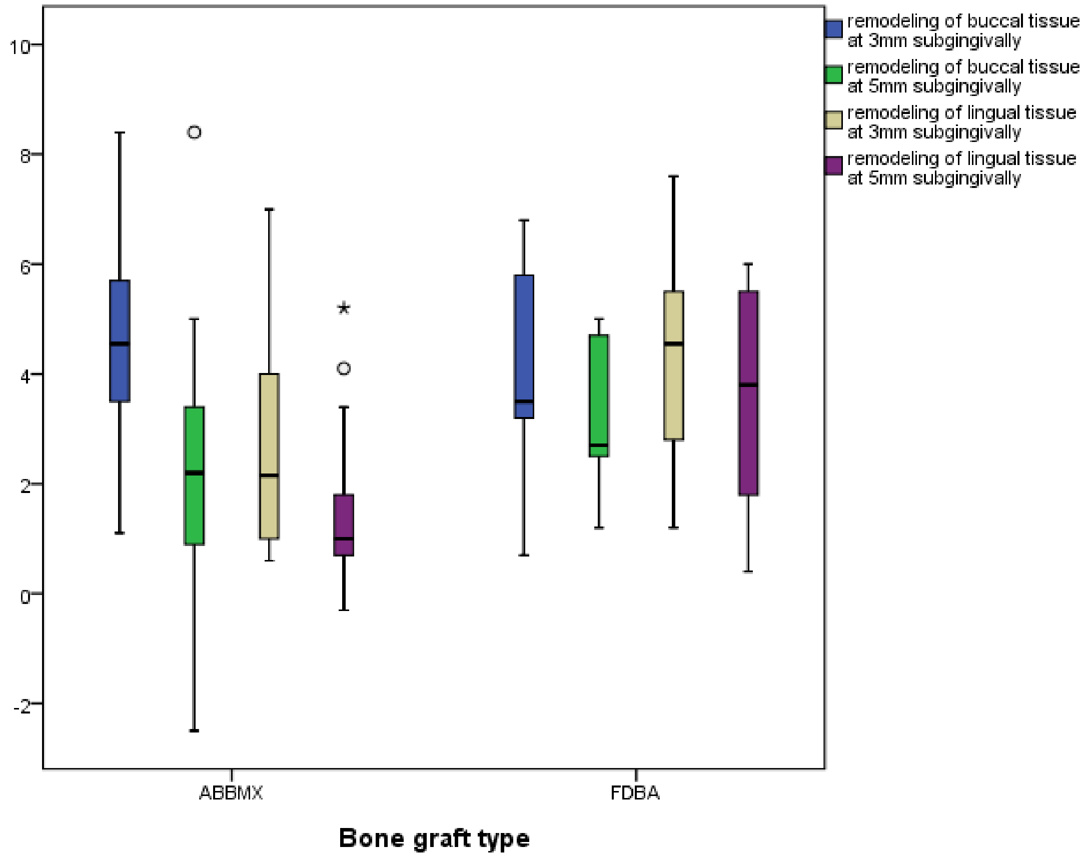
Comparison of the ridge width (mm) at 3mm and 5mm subgingival levels between FDBA and ABBMX group at baseline and 4-6-months post-RP.

Figure 5



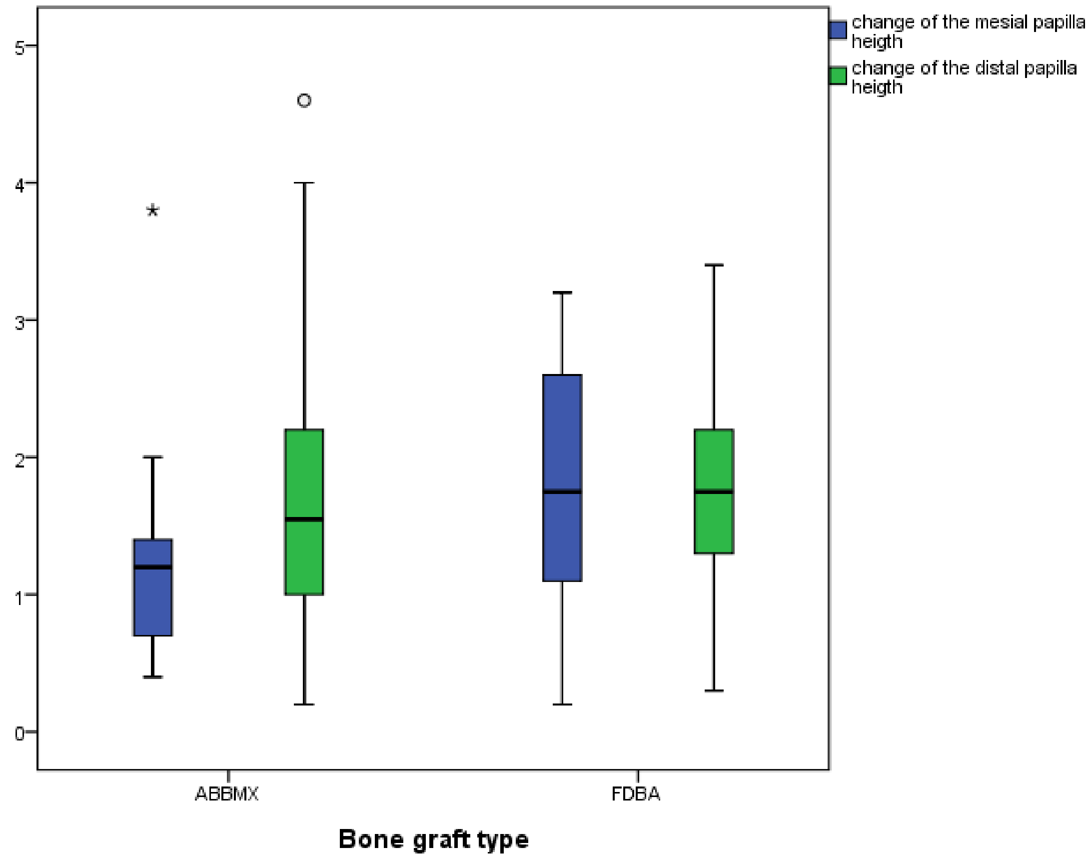
Comparison of the ridge width changes in millimeters at 3mm and 5mm subgingivally on FDBA and ABBMX groups from baseline to 4-6-months post-RP.

Figure 6



Comparison of the remodeling of the buccal and the lingual tissue at 3mm and 5mm subgingivally on FDBA group and ABBMX group from baseline to 4-6 months post-RP measurements.

Figure7 *7*



Comparison of change of the mesial and distal papillary height on FDBA group and ABBMX group from baseline to 4-6 months post-RP measurements.

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