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Original Article

Biomechanical and radiological assessment of immediate implants for alveolar ridge preservation

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ABSTRACT

Background: The aim of this study was to evaluate the stability of immediate implant placement for alveolar bone augmentation and preservation with bovine bone graft following atraumatic tooth extraction.

Materials and Methods: This was a prospective interventional study with convenient sampling (n = 10). Thirty patients aged between 18 and 40 years, who needed noncomplicated tooth extraction of mandibular premolar tooth, were sequentially divided equally into three groups. In Group I, simple extraction was done and the empty extraction socket left to heal conventionally. In Group II, extraction sockets were filled with lyophilized bovine granules only. In Group III, immediate implants were placed into extraction sockets, and the buccal gap was also filled with bovine granules. All groups were subjected to cone beam computed tomography scan for radiological evaluation. Assessment of biomechanical stability (radiofrequency analysis [RFA] was performed at 9 months postoperative for Group III to assess the degree of secondary stability of the implants using Osstell. Repeated measure analysis of variance (ANOVA) test was applied when comparing within each group at three different time intervals, whereas one-way ANOVA was applied followed by *post hoc*-tukey test when comparing between groups. $P < 0.05$ was considered statistically significant.

Results: Radiological assessment reveals a significant difference of bone resorption in alveolar dimension within Group I; 1.49 mm ($P = 0.002$), and 0.82 mm ($P = 0.005$), respectively, between day 0 and 3 months. Comparison between Group I and III showed a highly significant difference of bone resorption in ridge width at 3 months 2.56 mm ($P = 0.001$) and at 9 months interval 3.2 mm ($P < 0.001$). High RFA values demonstrating an excellent biomechanical stability were observed in Group III at 9 months postoperatively.

Conclusion: The insertion of immediate implants in extraction sockets with bovine bone augmentation of the buccal gap was able to preserve a greater amount of alveolar ridge volume.

Key Words: Cone beam computed tomography, Immediate Dental Implant Loading, ridge, preservation

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INTRODUCTION

Bone resorption is a factor of concern following exodontia due to the morphological alterations which occur in the alveolar process in both the vertical and horizontal dimensions of the residual socket. Dental implants are the best replacement alternative for missing teeth if enough bone is available to restore tooth structure and function. Unfortunately, the unavoidable circumstances of losing the volume of alveolar bone following tooth extraction pose a challenge to a successful dental implantology rehabilitation process.

The alveolar bone is a highly dynamic bone supporting the tooth and its surrounding structures. It physiologically resorbs when the tooth is lost. The average of 40%–60% of original height and width is expected to be lost after tooth extraction, with the greatest loss happening within the first 2 years. This can negatively influence bone volume that is needed for future planned dental implant placement.[1,2]

A recent systematic review evaluated the dimensional changes in the hard and soft tissues of the alveolar process following tooth extraction. The review concluded that after 3 months of healing, the horizontal resorption of the alveolar bone was 2.2 mm at the crest. After 6 months of healing, the vertical resorption of the alveolar bone was 11%–22%, whereas the horizontal resorption of the alveolar bone was 29%–63%.[2,3]

The contour loss occurs at a more significant rate during the early postextraction period, especially within the first 6 months. These changes in the buccal alveolar bone plate result in a collapse of the alveolar process, especially in the maxillary bone. Ridge resorption proceeds quickly after tooth extraction and significantly reduces the possibility of placing dental implants which then requires the need for bone grafting procedures. Bone grafting in dentistry is still the key to success in bony defects reconstruction when restoring the anatomy and function of the bone. Although bone tissue exhibits a large regeneration potential and may restore its original structure and function completely, bony defects in the jaw may often fail to regenerate and provide adequate functionality, due to various reasons. To facilitate and promote healing, bone graft materials with known and predictable biological activity should have been placed into bony defects.[4,5]

The concept of immediate implant placement at the time of tooth extraction was first introduced by Schulte *et al*.[6] on animal studies. Since then, many follow-up studies examining different variables have supported the concept of immediate implant placement. Lazzara[7] pioneered a major contribution to immediate implant placement in human studies which recommended the insertion of an implant into a fresh extraction socket. They advocated immediate implant placement primarily to reduce the number of surgical interventions needed to perform an implant-supported rehabilitation and shorten the treatment time. In addition, it was previously advocated that immediate implants placement could also potentially reduce the extent of alveolar bone resorption after tooth loss. Implants immediately placed into extraction sockets have been reported to have predictable healing in a submerged environment. Placement of implants immediately into extraction sites allow the surgeon to idealize the position of the implant appropriately with a better rehabilitation of the normal contour to the facial aspect of the final restoration.[6-8]

Immediate implant placement can also be a major psychological benefit as well as time reducing for patients wearing a transitional prosthesis. By understanding the biomechanical and biological properties of bone, we understand what type of bone grafts or bone substitute could be used to reconstruct large bony defects. However, the processed graft material cannot exert its biological activity in isolation; it depends on the surrounding environment of cells to respond to their signals and the blood supply. It is very important to study and compare the results of each graft material since the principles and indications of each type are different.

The aim of this study was to evaluate the stability of immediate implant placement for alveolar bone augmentation and buccal plate preservation with bovine bone graft following atraumatic tooth extraction. The null hypothesis was the placement of bovine bone graft with immediate implants into extraction sockets will not preserve the alveolar bone socket dimensions and buccal plate.

MATERIALS AND METHODS

This prospective interventional study with convenient sampling was conducted on patients visiting the University Dental Hospital Sharjah, United Arab Emirates. Randomization was applied in the distribution of the subjects to one of the three groups. All patients seeking treatment at the University Dental Hospital Sharjah were first screened in the Urgent Care department. Patients with mandibular single-rooted teeth (specific tooth with criteria) indicated for extraction underwent clinical examination and were randomly assigned to one of the three study groups by the urgent care dentist by a randomly selected sealed envelope which contains the group number and was then sent to oral surgery department with the closed envelope having the name of the patient with the assigned group, and was opened by the investigator who performed the treatment. The investigator performed the specific technique in tooth extraction and utilized specific materials for each group. By this procedure, we ensure the randomized distribution of the subjects to one of the three groups. Ethical approval was obtained from the Ethical and Research Committee, University of Sharjah and from Human Research Ethics Committee University Sains Malaysia, ethical number (No: DFCM/18/02/14/027) and (USM/JEPeM/15020045), respectively.

Thirty patients seeking treatment in the University Dental Hospital Sharjah were first screened in the urgent care department. Patients with mandibular single-rooted premolar teeth indicated for extraction underwent clinical examination and were accordingly screened for eligibility based on specific inclusion and exclusion criteria.

Patients meeting the inclusion criteria are healthy, age was between 18 and 40 years, who underwent mandibular premolar single rooted tooth extraction without any traumatic loss of the bony socket wall. Adequate soft-tissue health and quantity are necessary to obtain a complete crestal primary wound closure. The selected cases also need bone availability apical to the extraction site for stabilization of the implant. Patients with bone diseases or systemic diseases related to bone pathologies such as diabetes mellitus and hormonal imbalances and those who underwent head and neck radiotherapy including heavy smokers are excluded from the study.

The patients were sequentially divided into three groups; ten participants in each group. In Group I (control group) the participants underwent extraction of the assigned tooth without placement of bovine bone graft and without a dental implant. The alveolar socket was allowed to heal conventionally.

In Group II, the participants underwent extraction of the assigned tooth and placement of lyophilized freeze-dried bovine bone granules-OsteoLemb measuring about 0.5–1cc in volume with a particle size of 0.25–0.5 mm [Figure 1]. In Group III, participants underwent tooth extraction and placement of 4.1 mm × 14 mm-ITI dental implant system, (Straumann Institute, Waldenburg, Switzerland). The implant was inserted into the extraction socket, and the buccal gap was further augmented with bovine bone granules provided by University Sains Malaysia-Tissue Bank [Figure 2]. In both Groups II and III, lyophilized bovine pericardium membrane was also provided by University Sains Malaysia-Tissue Bank. Pericard-Lemb was suitably trimmed and sutured over the alveolar sockets to prevent any dislodgement of the bone granules and to allow coverage of the surgical sites. This bovine bone graft act as an osteoconductive potential and scaffolds, they will generally resorb and replaced entirely with the patient's own bone.

Bovine bone granules and pericardium membrane processed by University Sains Malaysia-Tissue Bank, School of Medical Sciences, were approved by Quality Management System and medical supply ISO certified complying with procurement, processing and use as a medical product. The grafts were prepared according to the tissue bank instructions.

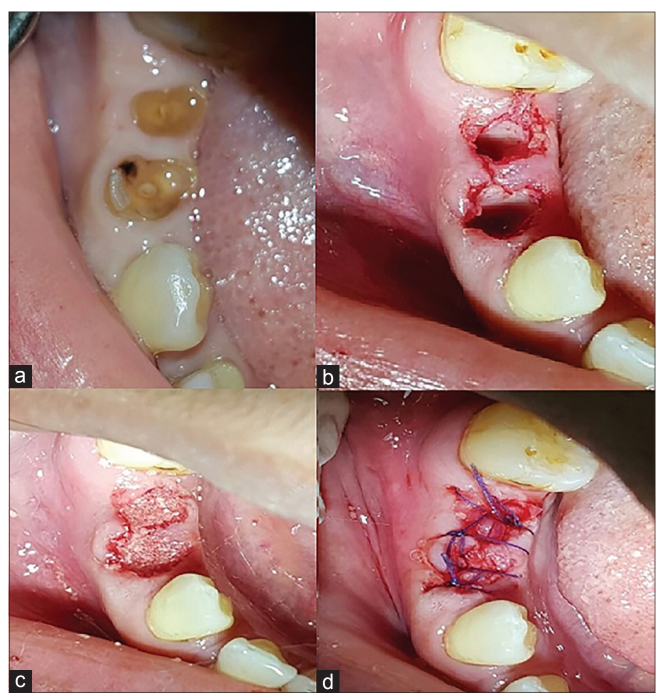

Figure 1: Socket preservation clinical steps (a and b) atraumatic extraction of mandibular premolar teeth, (c and d) bovine bone graft granules was augmented into the extraction socket and covered with pericardium membrane and vicryl suture.

The bovine granules and pericardium were procured from veterinary certified cows/cattle to ensure they were free from infectious disease. Only the pericardium with negative global swab cultured for microbial and fungal contaminants was processed. Cleaning, cutting, sizing, shaping, chemical treatment, lyophilization, and packing of the bovine bone graft were performed under controlled conditions (clean room environment) and then soaked in 0.05% sodium hypochlorite followed by lyophilization process. The pericardium was tripled packed and sterilized with 25 kGy gamma irradiation at Malaysian Nuclear Agency. This membrane has a bioabsorbable effect and allows ideal healing to take place after its resorption and was used to cover the grafted alveolar extraction socket in the intervention groups.

Clinical assessment was performed at set intervals of 7 days, 3 months and finally at 9 months. The early postoperative clinical evaluation includes assessment of the wound for pain, paraesthesia, swelling, wound closure, the presence of granulation tissue, the condition of the bone and the soft tissue surrounding the implant for (Group III). Status of the adjacent teeth and the presence of any infection was assessed and recorded.

Radiofrequency analysis (RFA) values were measured by Osstell device; Osstell, Integration Diagnostics Ltd., Gothenburg, Sweden. The application was at 9 months post-operative for Group III. They were performed by removing the cover screws of the implants followed by application of the smart-peg screw into the implant head [Figure 3]. This measures the implant stability quotient (ISQ) unit value as shown as a scale of reading on the device screen.

All groups were subjected to cone beam computed tomography (CBCT) scan for radiological evaluation immediately after the surgical procedure at day 0, at 3 months and at 9 months postoperative using Sirona Dental Systems, (GALILEOS SIDEXIS). CBCT was performed in three different views; coronal, sagittal, and axial involving linear measurements of the socket alveolar bone for marginal bone analysis. Radiographic image analysis was performed by the oral radiologist in the dental hospital at three different time intervals; once in a week as an inter-reviewer assessment by evaluating linear measurements and the mean reading was taken for each measurement.

Linear distance measurements between selected points on the socket alveolar bone were done. CBCT images were performed to quantify the amount of postoperative alveolar bone structural changes in coronal, sagittal, and axial views [Figure 4a and b].

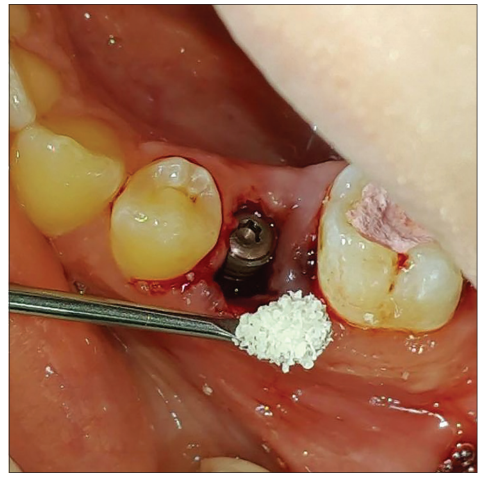

Figure 2: Buccal gap formation when the immediate implant placed lingual to the lower premolar socket and further augmented with bovine bone granules.

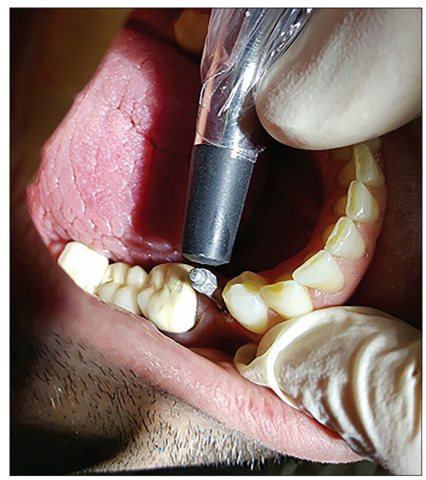

Figure 3: Smart-peg screwed into the implant head and measurement of the secondary stability by Osstell machine transducer tip.

“A” represents the distance linear measurement of the buccolingual dimension of socket alveolar ridge from the coronal tip of the buccal crest to lingual crest; whereas “B” represents the similar buccolingual dimension measurement at 3 mm apical to the coronal crest at “A.” “C” represents the buccolingual dimension at 5 mm apical from the crest. “D” represents the buccolingual dimension distance at 7 mm apical from the crest. “E” represents the vertical distance from the mid-way of “A” and perpendicular down to the base of the socket and finally, “F” represents the vertical distance from the mid-way of A and perpendicular down to the lower border of the mandible. Among those linear measurements, due to the alteration of the alveolar socket morphology by introducing the implant apical to the base of the socket by 3-4 mm, there were common identified and relevant points which share the same dimensions for the three groups; "A, B, and C" which represent the horizontal dimension of the alveolar ridge and "F" represents the vertical height of the alveolar ridge[9] [Figure 5a-c].

The exposure parameters of the CBCT machine were set on standard resolution settings throughout the study period, i.e., 85 kV, 5 mA with 80 kHz. The high-resolution setting was not used to reduce patient's exposure and to minimize artifact.[10]

Metal streaking is at its highest when the radiation dose is increased and when the X-ray beam passes through the greatest thickness of tissues and metals. In our study, the readings were done at the mid-point of the implant, to standardize the reading and to reduce metal artifacts to its minimum as the X-ray is passing through the half thickness of the implant.[11]

The mean and standard deviation (SD) of linear measurement of bone dimension at three different time intervals from three different views in the three groups using repeated measures analysis of variance (ANOVA) test.

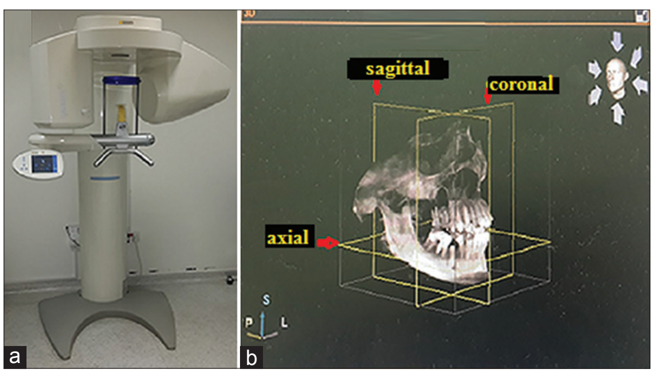

Figure 4: (a) Galileos cone beam computed tomography machine, Sirona Dental Systems, GALILEOS SIDEXIS Germany, with three different views (b); coronal, axial and sagittal.

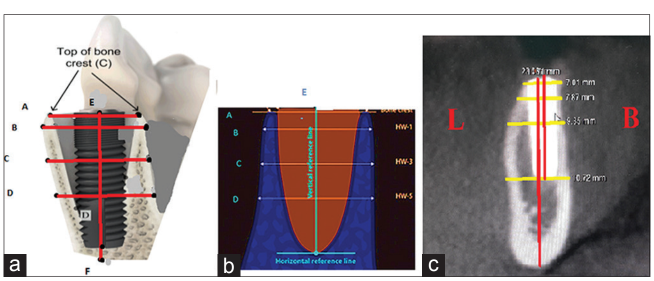

Figure 5: (a) Schematic diagram of linear measurements of the immediate implant and (b) the socket alveolar bone. (c) Radiological – coronal view showing the linear measurements of the alveolar bone with the immediate implant.

For comparison within groups at three different time intervals, repeated measure ANOVA within-group analyses was used whereas comparison between groups, one-way ANOVA was used followed by *post hoc*-tukey test.

RESULTS

There were 13 males and 17 females aged between 18 and 40 years. One immediate implant per patient was performed in Group III, making a total of 10 implants for the whole group. There was no infection, inflammation nor pain encountered in the three groups at 9 months and no other postoperative complications have occurred during clinical follow-up, except for a very mild decreasing pain and paraesthesia among one patient of injury in Group III participants that was recovered completely at 9 months follow-up. There was a complete closure of the sockets and no difference in healing clinically between groups at 3 and 9 months postoperatively.

For comparison of bone level resorption within groups by repeated measure analyses of variance, Group I shows significant differences of bone resorption in ridge width in three different views; coronal, axial, and sagittal. There was no significant difference in bone resorption within the interventional Group II and III as shown in Table 1.

For comparison of bone level among groups in coronal, sagittal, and axial views, ANOVA was conducted and shows a significant difference in bone resorption [Table 2].

At 3 months interval, there was a significant difference in linear measurement A in the comparison between Group I and III; $P = 0.001$. At 9 months interval, also there was a significant difference between Group I and III; $P < 0.001$. A significant difference in bone resorption was also observed at 9 months interval when we compared to Group II and III as shown in Table 2.

RFA analysis of the immediate implants was performed at 9 months postoperative for Group III. RFA value units demonstrated a mean numerical value of 78.4 (SD ±2.45) at the buccal surface, 78.7 (SD ±3.23) at the lingual surface, 78.6 (SD ±4.42) at the distal surface and 78.6 (SD ±4.42) at the mesial surface [Table 3].

Table 1: Mean difference of alveolar bone resorption in three views among the three groups at day 0-3 months interval

Views	Group					
	Control I		II		III	
	MD (95% CI)	*P*	MD (95% CI)	*P*	MD (95% CI)	*P*
Coronal A	1.49 (0.63-2.35)	0.002	0.29 (−0.21-0.78)	0.36	0.40 (−0.46-1.27)	0.60
Coronal B	0.82 (0.28-1.36)	0.005	0.75 (−0.84-2.34)	0.59	0.38 (−0.40-1.16)	0.55
Sagittal E	1.67 (0.26-3.08)	0.02	1.41 (−0.72-3.53)	0.25	0.06 (−0.47-0.59)	≈1
Axial A	1.50 (0.64-2.36)	0.002	0.41 (−0.13-0.94)	0.15	0.47 (−0.44-1.38)	0.49
Axial B	0.82 (0.28-1.36)	0.005	0.91 (−0.68-2.50)	0.38	0.68 (−1.47-2.83)	≈1

MD: Mean difference (mm); CI: Confidence interval for difference

Table 2: Comparison of mean difference of bone resorption between all groups in three views at three different time intervals (n=10)

Views	Group	Interval					
		Day 0		3 months		9 months	
		MD (95% CI)	*P*	MD (95% CI)	*P*	MD (95% CI)	*P*
Coronal A	Group I-Group II	−0.2 (−1.9-1.52)	0.95	−1.41 (−3.10-0.25)	0.09	−1.28 (−2.82-0.269)	0.10
	Group I-Group III	−1.50 (−3.20-0.26)	0.095	−2.56 (−4.22-−0.90)	0.001	−3.2 (−4.70-−1.62)	<0.001
	Group II-Group III	−1.26 (−2.99-0.41)	0.16	−1.14 (−2.80-0.51)	0.20	−1.90 (−3.43-−0.34)	0.011
Coronal B	Group I-Group II	−1.60 (−3.66-0.48)	0.18	−1.65 (−3.35-0.05)	0.06	−2.40 (−3.87-−0.90)	0.001
	Group I-Group III	−1.64 (−3.72-0.43)	0.16	−2.10 (−3.80-−0.38)	≈1	−3.34 (−4.83-−1.85)	0.00
Sagittal A	Group I-Group III	−1.70 (−2.71-−0.67)	0.001	−2.16 (−3.0-−1.40)	<0.001	−2.10 (−3.40-−0.82)	<0.001
	Group II-Group III	−1.33 (−2.35-−0.31)	0.007	−1.71 (−2.51-−0.90)	<0.001	−1.60 (−2.87-−0.33)	0.009
	Group I-Group II	−0.62 (−2.15-0.92)	0.56	−0.34 (−1.52-0.90)	0.75	−0.11 (1.87-1.65)	0.98
Sagittal B	Group I-Group III	−2.22 (−3.75-−0.70)	0.003	−2.40 (−3.58-−1.21)	<0.00	−1.82 (−3.60-−0.05)	0.03
	Group II-Group III	−1.61 (−3.14-−0.08)	0.03	−2.10 (−3.24-−0.87)	<0.00	−1.71 (−3.50-0.06)	0.05
Axial A	Group I-Group III	−1.50 (−3.35-0.43)	0.14	−2.50 (−4.22-−0.80)	0.003	−3.23 (−4.80-−1.66)	<0.00
	Group II-Group III	−1.00 (−2.90-0.90)	0.38	−1.0 (−2.70-0.80)	0.36	−2.0 (−3.50-−0.36)	0.01
Axial B	Group I-Group II	−1.91 (−4.14-0.33)	0.10	−1.81 (−3.90-0.31)	0.09	−2.40 (−4.0-−0.80)	0.002
	Group I-Group III	−1.14 (−3.40-1.10)	0.41	−1.30 (−3.40-0.85)	0.29	−3.21 (−4.80-−1.62)	0.000

MD: Mean difference (mm); CI: Confidence interval for difference

Table 3: Mean and standard deviation of Group III radiofrequency analysis scale values at 9 months' interval in 4 surfaces measurement (n=10)

Surface application of osstell	Mean±SD	SEM
Buccal	78.40±2.50	0.78
Distal	78.60±4.43	1.40
Lingual	78.70±3.23	1.02
Mesial	78.60±4.43	1.40

SD: Standard deviation; SEM: Standard error mean

DISCUSSION

In this study, all extraction socket wounds in the control group healed uneventfully. There was no untoward reaction or rejection of bovine bone graft in Group II, and all implants in Group III osseointegrated successfully. This study also showed that the bovine bone xenograft is biocompatible and did not exert any immunological reaction when implanted alone in the extraction socket, or when implanted along in the presence of the titanium implant surface.

The amount of postoperative inflammation and edema were very minimal, as shown by the minimal degree of pain suffered by the patient. It is interesting to note that when the lyophilized bovine bone granules inserted into the extraction socket in Group II patients, they were surrounded by bleeding extraction socket walls and that helped in enhancing the formation of the blood clot. This phenomenon favorably allowed invasion of capillaries into the grafted area easily since this freeze-dried bovine bone are known to be good osteoconductors. The capillaries bring with their calcium ions, the stem cells, and growth factors and make them ready to play the role in the healing process after the acute inflammatory phase subsides. However, our observations contradict with Kassim *et al.*[12] when they stated that healing is compromised when associated with ridge preservation using socket grafting necessitates a commitment to a delay placement protocol. This controversy could be due to the material used in their study or the technique performed which led to the impairment of the healing process in their findings.

In Group III, following immediate implant placement, an amount of bovine bone granules were inserted in the buccal gap in the coronal part of the extraction socket. In that situation, the bovine bone granules were in contact with a metal implant surface on one side lingually and were only exposed to the vascularized socket walls on its outer labial side, i.e., the bundle bone side. Despite being in this situation, there was no event where the bone granules were extruded or acted as a foreign body. This means that there was an adequate formation of a clot in the coronal portion of the implanted socket and ingrowth of capillaries into the xenograft that should have had proceeded successfully.

The placement of an implant into a fresh extraction socket resulted in a direct bone-to-implant contact in the apical osseous region, while a buccal marginal gap is created in the most coronal portion. In this study, we used bovine pericardium membrane to manipulate and secure the bovine granules from dislodgment following grafting and augmenting the buccal gap in the most coronal part of the socket. Our study also confirms the advantage and importance of this barrier membrane needed to protect dislodgment or migration of the bone graft granules from the augmented extraction socket. The bio-resorbability property of this bovine pericardium membrane used in this study avoids the need for a second procedure to remove the membrane. This is in agreement with many animal and human clinical trial studies which supported immediate implant placement therapy and reported success and survival rates similar to implants placed into a healed socket. Clinical outcomes of the implants placed in extraction sockets do not differ from those placed in the mature bone.[8,13-15]

Thus, the case of delayed implant placement into completely healed edentulous sites shall gradually lose its dominance in dental practice. However, both immediate and delay implant placement have their indications and advantages. A thorough understanding of dimensional ridge alterations post extraction revealed that this approach frequently complicates therapy, and a healing period of at least 6 months post extraction before implant placement is not really attractive anymore to patients in daily practice. Thus, the timing of implant placement has become an important issue in the dental community in the past 15 years.[16] The rationale for this procedure is to decrease the restorative time, to promote bone-to-implant contact and to preserve alveolar bone height and width.

There was no metal streaking observed in all CBCT image measurements throughout the study. In a study done by Yuan *et al*.[17] comparing artifacts of seven dental materials, the results showed that the titanium alloy was having an average of artifact/streaking influence on images when compared to the biggest impact of nickel-chromium alloy and the least influence of polymerized resin.

The amount of bone resorption in the control group was evaluated. We found that the largest amount of bone resorption occurred in the coronal portion of the alveolar ridge as demonstrated in different views of CBCT at 3 months; which showed significant changes in the horizontal bone loss. This finding is highly supported in the literature by Tan *et al*.[2] when they stated that changes in the buccal alveolar bone plate resulting in the horizontal collapse of the alveolar process at 6 months of healing range between 29% and 63% of bone resorption.[18]

In this study, it has been shown that following tooth extraction in the control group, the buccal side of the alveolar process resorbed more extensively than that of the lingual side. Araújo and Lindhe[5] demonstrated in their study that showed sockets when left empty without bone grafting following tooth extraction underwent 3 times the amount of horizontal resorption as compared to sockets filled with xenograft when they compared sockets healing without treatment (control) and sockets treated with Bio-Oss collagen (test). After 6 months of the healing period, biopsies were obtained. Histometric analysis revealed that the dimensional changes in the apical and middle portion of the sockets were moderate in both groups. However, in the control sockets, there was a 35% reduction of ridge width demonstrating 3 times bone loss when compared with the tested sockets treated with Bio-Oss collagen where there was only a 12% bone loss.

Marginal gaps occurring between the implant surface and socket wall may predictably heal with bone formation when the gap is <2 mm. This hypothesis is supported by Paolantonio *et al*.[15] when 48 healthy patients received at least four fixtures in each of two symmetrical quadrants, underwent placement of one experimental fixture placed in a fresh extraction socket and one contralateral fixture in mature bone. However, in our Group III patients, the width of the buccal gaps in all the cases was > 2 mm, due to the anatomically much wider width of the coronal part of the alveolar socket and a more slender root of the mandibular premolar tooth selected in the study. Thus during immediate implant placement surgery, the selected implants engage about 34 mm apical to the apex of the socket and were fully surrounded by bone only at its apical third. Our implants were also placed slightly in a lingual position and enabling about two-third of the implant surface been in contact with the lingual wall of the extraction socket. All these surgical measures ensured successful implant placement following the achievement of good primary stability. However, the buccal gap in the coronal part of the extraction socket which was >2 mm is considered a critical-size defect that was also successfully addressed using freeze-dried bovine bone granules.[19]

Clinical evidence in this study has demonstrated the insertion of bovine bone granules in the gap between the implant surface and the bony socket wall that has successfully prevented resorption of the buccal bundle bone. Immediate implants placed alone into fresh extraction sockets without grafting the coronal gap has failed to prevent the resorption of the alveolar bone ridge.[1,8,13] This observation is in agreement with a study by Wang and Lang,[18] where they successfully reduced soft-tissue recession as well as vertical and horizontal alveolar bone resorption following the use of bone fillers in residual defects around immediate implants placed in well-preserved, intact alveoli socket. The insertion of bovine bone granules in the gap between the implant and the bony socket wall has successfully prevented resorption of the buccal bundle bone.

Cardaropoli *et al*.[1] demonstrated in a series of clinical as well as experimental studies that immediate implant placement does not prevent the physiologic resorption of the buccal alveolar bone crest. Lately, researchers demonstrated the use of a bone substitute to fill in the gap between the buccal surface of the implant and the inner surface of the buccal plate; this will prevent or minimize the resorption process of the socket alveolar bone. In other words, it prevents the collapse of the bony socket walls, and it is in agreement with our study.[13]

Socket preservation using bone substitute is also widely used in dental practice and has a positive influence in maintaining the ridge dimension, but there are factors that should be considered as the choice of bone substitute, the degree of bioresorbabilty or degradation rate of the bone substitute to allow new bone formation and the time when the prosthetic rehabilitation is needed. Nevertheless, if the site of ridge preservation is not suitable for immediate implantation due to local infection and if the prosthetic treatment plan is not yet confirmed, it is then recommended to preserve the ridge with bone substitute alone. Our study finally proves that socket preservation using bovine bone is able to preserve the dimensions of the alveolar ridge following tooth extraction but using an immediate implant along with the bovine bone substitute demonstrated much better clinical and radiographic results in ridge preservation.

This study also showed that lyophilized bovine bone granules are a suitable choice of bone substitute for combined immediate implant-bone graft socket augmentation due to its delayed resorption property that allows it to stay longer in the grafted socket site, protecting and preserving the viability of the thin buccal bundle bone plate, acting as a filler that holds the blood clot, providing an osteoconductive surface for capillaries and allowing homing of stem cells and growth factors. Lyophilized bovine bone granules also act as a temporary bone substitute, keeping the space which later resorbs and is replaced by patient's own bone. It thus preserves and continues to support the bundle bone.

The maximum amount of bone resorption in the control Group I occurred during the time interval between day 0 and 3 months. The volume of resorption was significant during that period followed by a lower and lesser resorption rate at the interval between 3 and 9 months. This is highly supported in the literature by Wang and Lang[18] and his group when they stated that changes in the buccal alveolar bone plate result in the collapse of the alveolar process at 3 months of healing ranging between 29% and 63% of horizontal resorption.[2,20]

All immediate implants in Group III participants osseointegrated well and gave high values of ISQ when the Osstell machine measurement was employed at 9 months postoperative. We recorded high threshold readings for RFA unit values between 75 and 80 in Group III, where bone grafts been inserted into the buccal gap around the coronal part of the implant surface. This finding is similar to the results obtained in a study done by Quesada[21] and his group where they interpreted results of RFA readings in immediate implant therapy to resemble the reading of a conventional dental implant that has osseointegrated successfully within the bone of a healed socket without any bone augmentation. These findings further suggest that bovine bone granules placed to fill the buccal gap between the socket wall and the implant surface is no more in its granule composition and had resorbed completely inviting new host bone formation. This new bone must have been in direct contact with the implant surface contributing to successful "osseointegration."

RFA assessment was added to measure the degree of osseointegration precisely on the buccal side where we placed our bone graft material to fill the gap between the outermost implant surface and the inner surface of the buccal plate. In addition to that, RFA gives us a biomechanical response regarding the quality of the bone-implant interface and how much of the implant surface is in direct contact with vital bone, specifically the buccal part which have been augmented with bovine bone at the day of the immediate implant. A lower RFA value would have suggested a poorer osteoconductive property of the bovine bone leading to incomplete osseointegration.

In this study, when comparing within each group separately, it has been shown that after tooth extraction, the alveolar bone socket in the control Group I has resorbed more extensively with significant bone resorption of about 1.5 mm. No significant bone resorption occurred in Group II and III. This is in agreement with Cardaropoli *et al*.[1] and Paolantonio *et al*.[15] when they stated that sockets left untreated exhibits a large amount of bone resorption.

When comparing between groups, there was minimal difference in vertical ridge resorption in the alveolar bone dimensions between Group II and III at 9 months postoperative in our study; however, there was a significant difference between Group I and Group III at the same time interval; (1.90 and 2.56 mm respectively). This finding coincides with a study done by Heinemann *et al*.[22] where they compared the healing capacity of three differently treated socket groups following tooth extraction. The first group had the extraction socket implanted with bio-oss and immediate implant while the second group had received bio-oss only. The third group was left to heal in a conventional way. At the end of the study, Heinemann *et al*.[22] noticed that there was no significant difference in vertical bone resorption between the second group (Bio-Oss collagen without implantation) and the third group (control); while comparison between the first and the third group showed a significant difference between Group I (bio-oss with immediate implant) and Group III (control group).

Apparently, there was no significant vertical resorption observed in Group I. Significant difference of vertical bone resorption was observed in Group I and II by 1.75 mm (P = 0.04) and 1.91 mm (P = 0.005), respectively. These findings are in agreement with many previous systematic reviews which they observed that the mean vertical ridge resorption of 1.24 mm at 6 months post extraction.[8,21,23] However, contrariwise, when we compared Group III with other groups, there was no significant difference in vertical bone resorption observed at the 3 time intervals which coincide with many previous studies.[12,24]

CONCLUSION

This study demonstrates that socket preservation using bovine bone alone is able preserve the dimensions of the alveolar ridge following tooth extraction but using an immediate implant along with the bovine bone substitute demonstrate better clinical and radiographic results in ridge preservation. The use of lyophilized demineralized bovine bone granules to fill in the buccal defect in the coronal portion of the immediate implant seems essential in preserving the alveolar bone dimension, in particular, the thin buccal plate. The high level of the biomechanical property of immediate implants was considered by the high frequency of ISQ values.

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or nonfinancial in this article.

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