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Clinical and Radiographic Evaluation of Autogenous Bone Graft with or without rhBMP-2 for Horizontal Ridge Augmentation Associated with Simultaneous Implant Placement

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Abstract

The goal of this study was to evaluate the efficacy of autogenous bone grafts with and without recombinant human bone morphogenetic protein-2 for rehabilitation of narrow alveolar ridge width by dental implants. Twelve patients (2 males and 10 females), ranging from 36 to 60 years and a mean age of 47.08 years, were divided into two study groups. One received autogenous bone graft (A1) and the other group autogenous bone graft with rhBMP-2 using a collagen membrane (A2). All patients were clinically evaluated and received a CBCT for an accurate measurement of the alveolar ridge width, height, and after six months postoperatively. The mean difference in primary and secondary alveolar bone width (after 6 months) in group A1 was 4.14 mm, with a statistically significant difference ($p < 0.05$). Also, the mean difference in primary and secondary (after 6 months) alveolar bone width in group A2 was 5.14 mm, with a significant difference between them (P-value 0.00). The addition of rhBMP-2 increased the extent of bone width regeneration compared with the autogenous bone graft used alone. Both study groups showed a statistically significant increase in bone width at 6 months, with the highest increase observed in group A2 **(**ABG + rhBMP-2).

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Introduction

The greatest changes occur during the initial six months post tooth extraction, with average horizontal and vertical bone resorption of 3.79 and 1.24 mm respectively [1]. All these changes are more appreciable round the buccal plate [2]. After tooth loss, alveolar bone resorption is attributed to disuse atrophy, diminished blood supply, localized inflammation [3], or mechanical pressure from an ill-fitting prosthesis [4]. This defect caused by the loss of a tooth may be further complicated due to prior (time lapsed) bone loss secondary to localized periodontal disease, presence of an endodontic lesion or trauma. This defect is further jeopardized when the alveolus has lost its walls or height.

In contrast, the extraction-induced loss of teeth frequently results in a decreased vertical and horizontal alveolar ridge which complicates implant placement. Several surgical techniques, including onlay (veneer) block bone grafting with intraoral sources, guided bone regeneration/particulate bone grafting, ridge splitting/expansion and distraction osteogenesis were proposed to reconstruct narrow alveolar ridges [4].

The physiologic properties of autogenous bone graft have established the standard for success for bone grafting, and therefore this is why we compare the results of alternatives to what we already know about bone void with autogenous bone. Donor site morbidity in the case of autogenous bone has been an area of major concern for patients and surgeons alike, particularly considering its demonstrated effectiveness [5]. Autogenous grafts serve as the "gold standard" since they maintain cell viability and induce no immunological response in the recipient. These contain live osteoblasts and osteoprogenitor stem cells and undergo healing by osteogenesis. They provide all three elements for tissue engineering: scaffold, cells, and a signaling molecule as an added advantage. When vascularization is sufficient,

osteoprogenitor cells (or preosteoblasts) proliferate and span between the graft and the host bone. An interesting fact is that the preosteoblasts are also the first forming deposits of new bone [6].

Bone morphogenetic proteins (BMPs) are a group of regulatory glycoproteins that belong to the transforming growth factor-beta superfamily. These molecules mainly promote differentiation of mesenchymal stem cells (MSCs) into chondroblasts and osteoblasts [7]. BMPs can induce different types of cell attraction depending on the concentration gradient and they may act as a chemotactic, mitogenic/or differentiating agent. BMPs are known to induce a variety of cell types in a mesenchymal progenitor lineage including chondroblasts and osteoblasts. Thus, BMPs may have direct or indirect effects on bone formation. BMP acted on a wide spectrum of cells which includes fibroblasts, mesenchymal connective tissue cells, muscle-derived connective tissue cells, astroglial lineage and more. The bone marrow stromal cells represent an important source of mesenchymal pluripotent progenitors, which have the potential to differentiate into numerous cell lineages under affable conditions [1,2,8].

As rhBMP-2 has been used in many bone augmentation procedures for the regeneration of high-quality, high-density bone due to its potential for local bone formation and leading to osseointegration of received dental implants as shown by numerous studies. It has been shown that rhBMP-2, alone or in combination with graft materials, represents a key alternative to autogenous bone grafts for alveolar ridge maxillary sinus augmentation (9-11).

Materials and Methodos

This prospective clinical study was conducted from April 2024 to October 2025 in the Dental Implant Unit of the Department of Oral & Maxillofacial Surgery, Faculty of Dentistry, University of Baghdad. Twelve patients (2 males and 10 females), with an average age of 36–60 years and a mean age of 47.083 years, participated in this study. They presented with partially edentulous narrow alveolar ridges with an average of 3-5 mm, and (Mean A1 group 3.906± SD 0.384, A2 group mean 3.931 ± SD 0.29) in either the maxilla or the mandible. Thirty-two DIs were placed simultaneously with alveolar bone augmentation procedures using autogenous bone grafts, with or without rhBMP-2, for the rehabilitation of the narrow alveolar ridge with dental implants (Medentika® Quattrocone, Germany). All patients met the eligibility criteria after a thorough preoperative evaluation, which involved detailed dental and medical history, clinical examination, and radiographic assessment, using OPG for preliminary evaluation of the alveolar ridge width, height and vital anatomical structure, followed by CBCT for an accurate measurement of the alveolar ridge width, height and bone density and stability at the day of operation and after six months post operatively.

The Research Ethics Committee at the Faculty of Dentistry, University of Baghdad, approved the study protocol (protocol reference number 1052), and each patient signed informed consent to participate in the study. Healthy individuals without any systemic disease, patients aged ≥18 years, for both genders, implant insertion site ≥ 6 months after extraction (delayed protocol), presence of a partially edentulous narrow alveolar ridge which was measured by bone caliper and CBCT requiring alveolar bone augmentation and simultaneous dental implant placement (advanced cases according to SAC classification), narrow alveolar ridge width 3-5 mm, Adequate bone height to allow implant placement ≥ 10 mm, and reasonable oral hygiene and compliance with postoperative instructions were selected for this study. Patients with uncontrolled systemic diseases (e.g., uncontrolled diabetes mellitus, osteoporosis, or immunosuppressive conditions, etc. and any condition influencing bone healing, history of radiation and chemotherapy to the head or neck region for at least 5 years, Heavy smokers (≥20 cigarettes per day), women pregnant or lactating, patients with untreated periodontal disease or active oral infections, patients with psychological disorders affecting treatment compliance, and insufficient bone height preventing primary implant stability ≤ 9 mm were not included.

Panoramic radiographs were taken before surgery to assess the height of the alveolar bone and key anatomical structures such as the mental foramen, maxillary sinus, and the floor of the nasal cavity in relation to the implant recipient site. These images also helped identify any pathology in the implant area. All patients underwent preoperative CBCT scans to precisely evaluate alveolar bone height and width at the implant recipient site. In the current study, CBCT images were acquired using the OP 3D Pro scanner (Kavo) in the Radiology Department. Cone beam CT images were stored in the Digital Imaging and Communications in Medicine (DICOM) format. The collected data were processed using OnDemand 3D Dental 1.0.10.746, a specialized companion software for this CBCT machine that provides axial, coronal, sagittal, and 3D views via multiplanar reconstructions. Then, two measurements were obtained from the labial to the lingual cortical plates, 2.4 mm below the crest of the alveolar ridge. The mean value for augmented bone width was then calculated as shown in Figure 1.

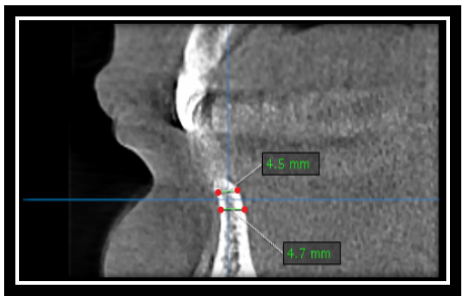


Figure 1. A preoperative coronal view to evaluate alveolar bone width at the implant recipient site, tooth #24.

For both groups, the procedure was performed by the researcher under the supervisor's guidance. In all cases, the surgical field was anesthetized with 2% lidocaine hydrochloride with adrenaline 1:80,000 (New Static, Colombia). through the conventional infiltration technique. Surgery was commenced with a three-sided mucoperiosteal flap. A horizontal mid-crested incision was made by scalpel No. 3 and blade No.15, with a slightly palatal/ lingual bias incision in the mesiodistal direction along the length of the narrow alveolar crest of the bounded and free end saddle ridge. Two vertical incisions were additionally placed anteriorly and posteriorly in relation to the horizontal incision. Reflection of a full thickness mucoperiosteal flap was performed using Howarth's mucoperiosteal elevator to expose the narrow alveolar bone.

All residual soft tissue should be removed using a periodontal curet. If necessary, osteoplasty was performed on knife-edge crests to a maximum depth of 2 mm or to remove ridge irregularities, thereby creating a flat platform and increasing the width of the alveolar bone for the dental implant bed. This procedure was performed using a low-speed surgical straight handpiece with a carbide round bur, with continuous irrigation of copious, cooled normal saline. In both groups, implant bed preparation was performed using the Medentika® Quattrocone kit. The procedure began with a marker drill, followed by a pilot one, and then sequentially larger drills were used, accompanied by copious irrigation with normal saline, until the desired diameter and depth were achieved according to the manufacturer's guidelines. A dental implant engine with an angled handpiece was set at 600 to 800 rpm and a torque

of 35 Ncm to ensure precise site preparation. Drill size was increased as required by the specific dental implant diameter. The implants were installed by a surgical implant micromotor angle handpiece with a torque of 35 Ncm and a speed of 35 rpm. Seating of DI was completed manually into its final position at the crestal level of the alveolar bone with the aid of a ratchet if needed. The last step of DI installation is securing the cover screw to the implant using a hex driver.

Subsequently, the buccal or labial aspect of the narrow alveolar ridge was decorticated using a low-speed surgical implant angle handpiece operating at 800 rpm with a pilot drill and copious irrigation with cooled normal saline,

Augmentation of the decorticated alveolar ridge in group A1: autogenous bone graft alone. ABG was harvested from the retromolar area, symphysis, parasymphysis, and maxillary tuberosity using the Safe Scraper Twist disposable bone collector. The collected ABG was stored in the collector chamber of the Safe scraper for subsequent application to the buccal aspect of the narrow alveolar ridge defect, as in Figure 2. While in group A2: autogenous bone graft mixed with rhBMP-2, ABG was collected as described for group A1 and combined with moistened rhBMP-2 granules (0.4–1.0 mm), packaged (0.25 g) in a 1:1 ratio. This mixture was then applied to the dehiscent buccal aspect of the alveolar ridge as in Figure 3, and the collagen membrane (BiOTECK Biocollagen®) was subsequently trimmed with scissors along all borders to the required dimensions to cover the augmented bone site.

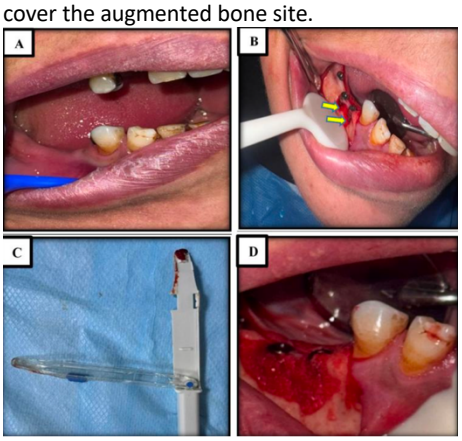


Figure 2. Group A1. (A) Preoperative at tooth site #29 & #30 & #31. Edentulous narrow alveolar ridge; (B) Implant placement & dehiscence of buccal aspect of alveolar bone(arrows); (C) ABG is stored in safe scraper® after collection; (D) ABG placed on the defect buccal aspect.

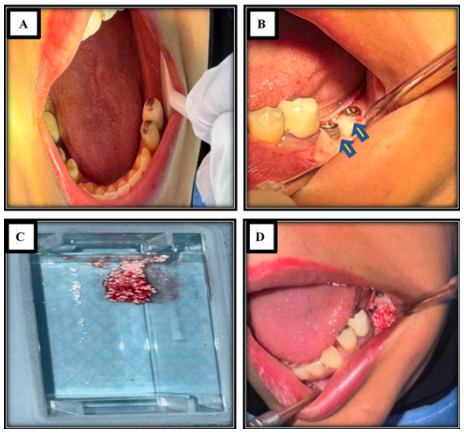


Figure 3. Group A2, (A) Preoperative at tooth site #18 & #19; (B) Implant placement & dehiscence of the buccal aspect of alveolar bone(arrows); (C) Mixture (autogenous bone graft & rhBMP-2); (D) Placement of the mixture on the dehiscence buccal aspect.

Finally, in both groups, wound closure was achieved by repositioning the mucoperiosteal flap and suturing it with a simple interrupted technique using 4/0 non-absorbable nylon monofilament suture (Figure 4).

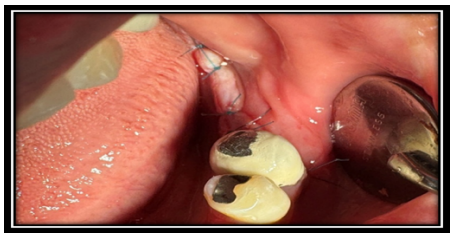


Figure 4. Wound closure.

The patients were instructed to attend for follow-up 7-10 days postoperatively for clinical examination if there were any complications, including edema, slight oozing from the incision line, numbness, or suture removal. Then, after 6 months, fix the healing abutments (gingival formers) to the implants and leave them in place for 10-14 days to allow the soft tissue to contour around the implant necks. Finally, patients were referred to the prosthodontic department for prosthesis construction (Figure 5 left and right).

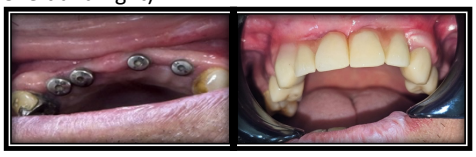
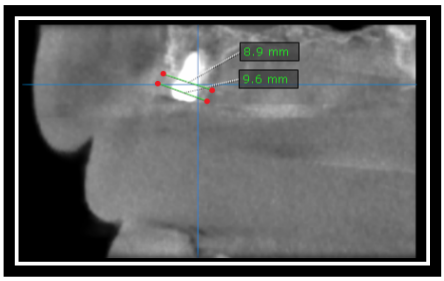


Figure 5. Gingival formers (left) Healing abutments at tooth sites #7, #8, #9, & #10; (right) The final fixed implant prosthesis.

In the cross-section (coronal view), augmented bone width was measured by adjusting the horizontal reference line at the center of the selected DI. Two measurements were obtained from the labial to the palatal cortical plates, 2.4 mm above the crest of the alveolar ridge. The mean value for augmented bone width was



then calculated (Figure 6).

Figure 6. Coronal view of CBCT to evaluate grafted alveolar bone width at the implant site #6, twenty-four weeks following GBR.

Results

Table 1 summarizes the preoperative evaluation.

Table 2 shows that the mean difference in primary and secondary (after 6 months) alveolar bone width in group A1 was 4.14 mm, with a highly significant difference between them (P-value 0.01). Also, the mean difference in primary and secondary (after 6 months) alveolar bone width in group A2 was 5.14 mm, with a highly significant difference between them (P = 0.00).

Table 3 shows the comparison of secondary bone width between study groups showed that A2 was significantly greater than A1.

The mean value of bone gain in group A2 (5.14) was higher than the mean value of bone gain in group A1 (4.14), with a significant difference ($p < 0.05$) between them (Table 4).

Discussion

This study's objective was to assess the clinical and radiographic outcomes of autogenous bone grafts with or without rhBMP-2 placement for horizontal ridge augmentation in conjunction with immediate implant placement. Adequate bone dimensions are important for successful osseointegration of the implants and long-term maintenance in patients with significant jaw atrophy. The most significant dimensional alterations of the alveolar process occur in the initial period of healing after tooth extraction, with mean horizontal and vertical bone resorption of 3.79 mm and 1.24mm, respectively, stressing the need for appropriate augmentation procedures [1,2].

The results indicated that both groups showed significant bone gain at six months of follow up with evidence of successful bone regeneration. This is in accordance with previous studies that showed bone morphogenetic proteins (BMP) treatment considerably enhances periodontal and peri-implant tissue regeneration [7,8].

Additionally, use of rhBMP-2 associated with graft materials has provided better clinical results in augmentation procedures compared to using the graft material alone [8], such as in maxillary sinus grafting where addition of rhBMP-2 to the graft material markedly improved the clinical outcomes of implants placed into grafted maxillary sinuses [9].

Group A2 exhibited a significant increase in bone gain, likely because rhBMP-2 is the most powerful osteoinductive factor known [3,8], promoting mesenchymal stem cells to differentiate into osteoblasts and chondroblasts, especially at early stages of bone healing and regeneration. Bone morphogenetic proteins (BMPs) are a family of regulatory glycoproteins, which belong to the transforming growth factor-beta superfamily and possess chemotactic properties and can attract many types of cells depending on their concentration gradient either as mitogenic or differentiating agents [7,8]. Recent studies show that rhBMP-2 induces osteogenic differentiation of mesenchymal stem cells by increasing mitochondrial activity and initiates the entire cascade of bone formation [12,13], supporting this mechanism. We obtained a mean bone gain of roughly 4.3 mm by treating sites with rhBMP-2/ACS vs 2.6-mm sites treated solely with autogenous bone graft ($p < 0.05$); thus, demonstrating the positive impact of rhBMP-2 on restoring alveolar ridge augmentation [10]. Likewise, Kader and Elbokle (2017) showed that rhBMP-2 was better than autogenous bone graft for the reconstruction of maxillary anterior alveolar ridge defects [3].

Because of their osteogenic, osteoinductive and osteoconductive properties, autogenous bone grafts are still the gold standard in periodontal practice and ridge augmentation [5,6]. Moreover, autogenous grafts are considered as ideal since they retain cellular viability and do not cause any immunogenic reaction in the patient. In contrast to other bone grafts, these allow the healing through osteogenesis with live osteoblasts and osteoprogenitor stem cells, correspond to all three necessary tissue engineering components for an effective bone tissue construct as scaffold (bone), sparse cells and signaling molecules [6].

In conclusion, the results of this investigation support the application of autogenous bone graft combined with rhBMP-2 as an effective approach for horizontal ridge augmentation that can lead to predictable and improved bone regeneration to accommodate immediately placed endosseous dental implants. The combination therapy overcomes the limitations of stand-alone autogenous bone grafts by utilizing osteoinductive signaling from rhBMP-2 to augment regenerative capacity while still retaining the biologic advantages of autogenous tissue. These findings add to the emerging evidence base of data supporting clinical application of rhBMP-2 for alveolar bone augmentation and provide a rationale for additional investigations on dosage levels, carrier systems and longer-term outcomes.

Conclusion

The mean bone gain in autogenous bone graft + rhBMP-2 was 5.14 mm, higher than in autogenous bone graft alone.

Future studies should focus on the long-term effect of these sites, which rhBMP-2 concentrations and carriers may be most effective to a specific condition, and whether systemic conditions as well as local inflammatory factors can predict the success of implant supported rehabilitations. Larger samples and longer follow-up are encouraged to approve the efficacy of these findings and develop evidence-based clinical protocols for rhBMP-2 use in horizontal ridge augmentation procedures.

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Table 1. Preoperative evaluation of alveolar bone length and width allocation according to the study groups by CBCT.

Study groups	Preoperative Measurements by CBCT BH (mm)		Preoperative Measurements by CBCT BW (mm)	
	Mean ± SD	Min - Max	Mean ± SD	Min - Max
A1	11.12 ± 0.781	10-12 mm	3.90 ± 0.38	3.4-5mm
A2	10.3 ± 0.542	10-12 mm	3.93 ± 0.29	3.0 – 4.8mm

Table 2. Distribution of mean changes, primary and secondary, of alveolar bone width measured by CBCT with each study group.

	Groups	T1 BW (mm)	T2 BW (mm)	Mean difference (mm)	T test	P-value
A1	Minimum	3.4	7.2	4.14	2.86	0.01
	Maximum	5	9.4			
	Mean	3.9	8.04			
	±SD	0.38	0.51			
A2	Minimum	3	8.5	5.14	4.62	0.000
	Maximum	4.8	9.8			
	Mean	3.93	9.07			
	±SD	0.52	0.48			

Table 3. Distribution statistical test of secondary bone width among study groups.

Study groups	Mean difference T2- BW (mm)	T test	P-value
A2-A1	1.03	5.79	0.000

Table 4. Intra comparison descriptive and statistical test of bone gain among groups.

	Study groups of bone gain (mm)	
	A1	A2
Minimum	3.2	4.5
Maximum	4.7	5.7
Mean	4.14	5.14
±SD	0.41	0.34
T test	7.46	
P-value	0.000	