Original Article

Evaluation of the Effectiveness of Ridge Preservation Using β-Tricalcium phosphate, Platelet Rich Fibrin and Recombinant Bone Morphogenetic Proteins (rhBMP-2) Followed by Delayed Implant Placement-A Clinical and Radiographic Study

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ABSTRACT

Background

The successful insertion of dental implants is highly proportional to the condition and quantity of the alveolar bone at the edentulous area. This pilot study aimed at evaluating clinically & radiographically the efficacy of preservation of alveolar ridge by making use of platelet- rich fibrin (PRF) & β – tricalcium phosphate {TCP)+rh- bone morphogenic protein (BMP)-2 followed by delayed implant placement.

Materials & Methods

Post-extraction sockets were augmented using a combination of autologous PRF and alloplastic bone graft (β-TCP) mixed with growth factor rh-BMP 2. At three months, the clinical and radiographic study was carried out, and implants were placed using two staged protocols. Outcome clinical parameters involving mean modified plaque index (MPI), modified bleeding index (MBI), clinical implant mobility score (CIMS), full mouth plaque index (FMPI), full mouth papillary bleeding index (FMPBI), probing measurements such as probing pocket depth (PPD), gingival recession (GR), and width of keratinized gingiva (WKG) around implants were evaluated.

Results

A total of 12 sockets in 9 patients were treated using the ridge preservation technique. At three months after extraction & ridge preservation, baseline evaluation revealed minimal buccolingual dimensional changes (7.0 mm ± 1.21 mm). Following implant placement, radiographic evaluation at 3 months showed minimum vertical & horizontal loss in bone (mesial: 0.33 ± 0.33, distal: 0.25 ± 0.33). Use of rhBMP-2+ β -TCP+rh-BMP-2 reduces the dimensional changes owing to 100% survival of the implants.

Conclusion

Atraumatic extraction employing ridge preservation using PRF & β -TCP+rh-BMP-2 followed by delayed implant placement minimizes dimensional changes and helps in the improved success rate of the implant

Keywords

alveolar ridge augmentation; platelet rich plasma; rhbmp 2 protein

CLINICAL RELEVANCE

Preservation of ridge width and height is critical for achieving predictable implant stability and long-term success, especially in cases where bone resorption is expected to compromise implant placement. This study demonstrates that combining PRF with β-TCP and rhBMP-2 for ridge preservation after tooth extraction can effectively maintain alveolar bone dimensions and provide a stable foundation for delayed implant placement. The findings suggest that this

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approach not only minimizes the need for additional grafting procedures but also supports favorable soft tissue outcomes and high implant survival rates. For clinicians, this indicates a practical and biologically driven strategy to enhance implant success in routine practice, particularly in patients at risk of ridge collapse following extractions.

INTRODUCTION

For substituting single or multiple teeth that are missing, implants have become an extremely predictable surgery in the course of rearmost decades [1] , providing a higher quality of life to patients. Alveolar ridge resorption is a common physiological change that comes about after tooth extraction [2,3] . Most of the dimensional changes that take place in the empty extraction socket take place in the initial first year following the extraction and in the first three months the majority of the bone loss i.e., around two thirds takes place [4]. This, in turn, prevents placement of implants of adequate dimensions [5,6] . These dimensional shrinkages have been reported to be reduced by socket grafting. The procedure includes grafting materials accompanied by barrier membranes or without barrier membranes or without barrier membranes [7] . Furthermore, this procedure can ease implant placement as it decreases the necessary requirement for further regenerative therapy [8]. Therefore, ridge preservation can be put up for optimization of the restorative and aesthetic outcomes by keeping volume of the ridge stable [9]. Conserving the alveolar ridge can be accomplished successfully using a variety of bone grafts through osteogenesis, osteoinduction, and osteoconduction. Tricalcium phosphate (TCP), which is an alloplastic material, is found to be a favorable alternative to bone substitutes or the use of autogenous bone [10]. β-tricalcium phosphate is depicted in both studies carried out on humans and animals, was found to be reduced and then renewed by vital bone within a period of six to twelve months. Recently, Choukroun et al. [11] suggested autologous platelet-rich fibrin (PRF) for ridge preservation as a grafting material. The alveolar socket augmented using the PRF matrix displayed rapid clinical healing. It is also reported to avail excellent bone density for implant placement [12]. The rate of success of implants put down in extraction sockets that have been grafted is documented to be analogous to the speed of success of implants put down in indigenous bone [13]. In addition to these biomaterials, including growth factors in the course of regenerative therapy gives a chance to speed up the formation of new bone and preservation of ridge [9]. TGF- proteins, known as bone morphogenetic proteins (BMP) are cysteine proteins that have been used in tissue engineering products for bone grafting as a powerful osteo-inductive component [14] that can stimulate bone growth through the differentiation of pluripotential cells into osteoblasts [15]. A study has shown a significantly enhanced osteogenesis and more formation of bone accompanied by rhBMP-2 infused β-TCP scaffold in cranial bone defect model in rabbits [16] since calcium phosphate is found to have a more affinity for proteins such as BMP. So this study examined the efficacy of conserving ridge using a combination of PRF, β-TCP, and recombinant human bone morphogenetic protein-2 through dimensional changes and simultaneous radiographical early crestal bone changes occurring after implant placements.

MATERIALS AND METHODS

The study protocol was approved by an institutional ethical committee. Patients were made acquainted with the motive and design of the study. Written informed consent was taken. A total of nine systemically healthy patients were included. Inclusion criteria included patients with more than 18yrs of age, teeth that are to be extracted due to root fractures, endodontic failures, internal and external resorption, presence of non-restorable carious lesions/residual roots, good oral hygiene defined as full mouth plaque score $\leq$ 25%, presence of opposing natural tooth, presence of adjacent teeth and thick gingival biotype with the radiographic and clinical appearance of intact alveolar bony walls. The bone healing process, which would be at risk in immunodeficient patients like a patient suffering from diabetic conditions, a bone disorder such as osteoporosis, hematological conditions, and allergic reaction to titanium and pregnant and lactating mothers, were excluded from the study.

This study was carried out for fifteen months. Nine patients, each having one or two teeth or root stumps suggested for extraction in the upper and/or lower jaw were included. Extractions were performed atraumatically without reflecting the flap [17]. Sockets after the extraction were augmented by making use of autologous platelet-rich [18] fibrin and alloplastic bone graft (β-TCP) (OSTEON) mixed with growth factor rh-BMP-2, which was prepared as stated by the manufacturer's instructions. rhBMP2 solution was prepared (vial was briefly centrifuged before opening to bring the contents to the bottom), and lyophilized solution was reconstituted with sterile 20mM acetic acid to a concentration of 0.1mg/ml, which induced osteogenesis and angiogenesis. At three months of ridge/socket preservation, the dimensions were recorded at the edentulous site. The edentulous site was then carefully analyzed, and appropriate dimensions of implants (ORA) were placed utilizing a two-stage protocol. Every patient was on antibiotics (Capsule Amoxicillin, 500 mg, and Tablet Ibugesic T.I.D.) for a duration of 5 days after surgery. Patients were advised not to use tooth brush over the treated area. A chlorhexidine digluconate rinse (0.12%) was advocated twice a day, preferably for a minute. Suture removal was done after 7 to 14 days of implantation, and patients were assessed for any post-operative pain, discomfort, or presence of suppuration from the implant site and/or any post-operative complications. Second-stage surgery was undertaken after four to six months post-implant placement. After the collar of the gingiva was formed, abutments were connected, and definitive metallo-ceramic restorations were placed. Probing depth surrounding implants that are mesial, buccal, distal, and lingual or palatal areas were calculated using UNC-15 plastic probe. In accordance with the clinical implant mobility scale Mobility of implants were evaluated at baseline and three months after permanent restoration. IOPA, that is, an intraoral periapical radiograph, was taken with a long cone paralleling method just immediately after an implant was placed, immediately after the final prosthesis and three months after final prosthesis. With the help of a film mount millimeter grid scale Radiographic measurements were recorded. To determine the vertical radiographic bone level, the distance was measured from the implant shoulder to the most coronal bone that is in contact with implant. At the same time, the radiographic horizontal distance between the implant to the crest of the alveolar bone was measured to assess horizontal bone loss. All measurements were carried out on mesial and distal sides of each implant and considered in millimeters. For every implant, mean vertical and horizontal loss were measured on mesial and distal surfaces at base line of bone that is immediately after the final prosthesis, three months after the final prosthesis. Immediate post- operative IOPA/ radiograph was taken at baseline and to verify complete seating or right position of the implants.

Three months after the definitive metal-ceramic restoration was placed, an entire re-evaluation was done. Outcome clinical parameters involving mean modified plaque index (MPI), modified bleeding index (MBI) [19], clinical implant mobility score CIMS [20], full mouth plaque index (FMPI) [21], full mouth papillary bleeding index (FMPBI) [22], probing measurements such as probing pocket depth (PPD), gingival recession (GR), and width of keratinized gingiva (WKG) around implants were evaluated. The mean FMPI and FMBI score was measured at baseline, six, and nine months follow-up.

RESULTS

A total of 9 systemically healthy patients (Table no.1) underwent atraumatic extractions of 12 teeth with simultaneous ridge/socket preservation. The extraction sockets were filled with a combination of PRF, β-TCP, and rhBMP-2; followed by delayed implant (ORA®) placement using two-stage protocol. The FMPI and FMPBI scores at baseline, 6 months and at 9 months follow up are presented in Table 2.

Pre-operatively the clinical and radiographic measurements were recorded (Table 3). The ridge dimensions were recorded with the mean mesiodistal width was 10.58 ± 2.50 mm (Range: 6 to13 mm), buccolingual 7.80 ± 1.19 mm (Range: 6.5 to 9 mm) and apico-coronal length of the root pieces was measured in radiograph (IOPA) which was 8.13 ± 1.93 mm (Range: 6 to12 mm). After atraumatic extraction the labial/buccal cortical plate was intact at all the 12 extraction sites. The mean thickness of buccal marginal bone was found to be 1.04 ± 0.33mm (Range:1 to1.5mm). The mean buccolingual, mesiodistal and apico-coronal length of the root pieces were 5.18 ± 1.58 mm (Range: 3-8 mm), 2.98 ± 0.61mm (Range: 2 to 4.5 mm) and 7.97 ± 2.83 mm (Range: 5-15 mm), respectively (Table 4).

At three months of ridge/socket preservation, the dimensions were recorded at the edentulous site. The mean mesiodistal width was 10.58 ±2.50 mm (Range: 6-13 mm), buccolingual 7.0 ± 1.21 mm (Range: 5-8 mm), and apico-coronal length / residual bone height was measured on panaromic radiographs and was found 14.08 ± 1.73 mm (Range: 12.-18 mm) (Table 5). The edentulous site was then carefully analyzed, and appropriate dimensions of implants were selected for each site. All the implants (ORA®) were placed according to their predetermined optimal prosthetic positions. All surgical interventions and post-operative healing were uneventful, without any post-operative complications and pathologic radiographic evidence. The soft tissue architecture remained stable with the preservation of adequate attached gingiva. The prosthetic rehabilitation was functional and in good condition throughout the study period.

In the present study, all 12 sites with implants were evaluated. The clinical parameters were measured around implants 3 months after fixed restorations, including MPI, MBI, PPD, GR, and WKG. Mean MPI and MBI scores were found to be satisfactory as shown in Figure no 1 . All implants showed clinical implant mobility score (CIMS) of 0 at 3 months after fixed restoration indicating that all the implants were stable and healthy.

Standardized IOPA was taken using the parallel cone angle technique for radiographic analysis. A grid-scale was used to measure marginal bone loss around implants immediately after the placement of fixed restorations and 3 months following placement of fixed crown prosthesis. There was statistically significant bone loss observed at 3 months after fixed restoration on distal surface of implant when compared with mean marginal bone level at baseline by using student's paired t-test (Table 6).

Table 1. Patient characteristics

Number of patients	09
Number of implant sites	12
Mean age	21 to 45 years (mean age 30.55±6.4)
Number of sites in mandible	06
Number of sites in maxilla	06
Number of single rooted teeth	03
Number of multi-rooted teeth	09
Residual bone height (range)	12-18mm

Table.2 Comparison of Full Mouth Plaque Index (FMPI) Full Mouth Papillary Bleeding Index (FMPBI) scores between baseline, at 6 Months and at 9 Months follow up (MV ± SD)

Parameters	At baseline	At 6 months	Difference	p-value	At 9 months	Difference	p- value
FMPI	0.63± 0.20	0.51± 0.05	0.11± 0.18	0.046*	0.38± 0.08	0.13±0.06	0.001*
FMPBI	0.61± 0.11	0.49± 0.05	0.11± 0.10	0.002*	0.39± 0.07	0.10±.06	0.001*

*Statistically significant (p<0.05)

Table.3 Pre-operative clinical measurements at extraction site

Extraction site	Mesio-distal width (mm)	Buccolingual width (mm)	Apico-coronal length of root-piece in radiograph (mm)
#46	13	7	8
#15	9	6.5	12
#16	11	6.6	7
#46	12	8.5	8
#47	10	9	6
#26	12	8.5	6
#36	12	9	8
#46	10	9	8
#26	13	8	6.5
#11	6	6	11
#12	6	6.5	10
#36	13	9	7

Table.4 Intra-surgical measurements of thickness of marginal buccal bone and dimensions of extracted roots (mm ±SD)

Extraction Site	Thickness of buccal marginal Bone (mm)	Mesiodistal width of root at marginal bone (mm)	Buccolingual width of root at marginal bone (mm)	Apico-coronal length of root (mm)
#46	1	Mesial:- 2.3	Mesial :-6.5	8
		Distal:- 3	Distal:-6.5	11
#15	1	4	8	15
#16	1	Mesial:- 3.6	Mesial:-4.2	6
		Distal:- 2.6	Distal:-5.1	5
		Palatal:- 2.5	Palatal:-4.2	8
#46	1.5	Mesial: - 2.5	Mesial: -6	6
		Distal: - 4	Distal:-5	10
#47	1.5	Mesial:- 2	Mesial:-5	5
		Distal: -3	Distal:-5	7
#26	1	Mesial:-2.5	Mesial:-5.4	4
		Distal:-2.5	Distal :-5.1	7
		Palatal:-3.5	Palatal:-4.5	5
#36	1	Mesial:-3.2	Mesial :-7.4	9
		Distal:-2.7	Distal :-7.3	12
#46	1	Mesial:-3.2	Mesial:-4	4
		Distal:-3	Distal:-6.6	10
#26	0.5	Mesial:-3.3	Mesial :-5.4	6
		Distal:-3.3	Distal:-5.4	8
		Palatal:-4.5	Palatal:-4.7	7.5
#11	1	2.5	3	12
#12	0.5	2.5	3	10
#36	1.5	Mesial:-3	Mesial :-5.8	6
		Distal:-2.5	Distal:-6	10

Table.5 Pre-operative clinical measurements at edentulous sites after ridge preservation

Sites of implant (n=12)	Mesio-distal width (in mm)	Buccolingual width (in mm)	Residual bone height (in mm)
#46	13	6	15
#15	9	6	13
#16	11	7	13
#46	12	8	13
#47	10	8	13
#26	12	8	12
#36	12	8	15
#46	10	8	18
#26	13	7	12
#11	6	5	15
#12	6	5	15
#36	13	8	15

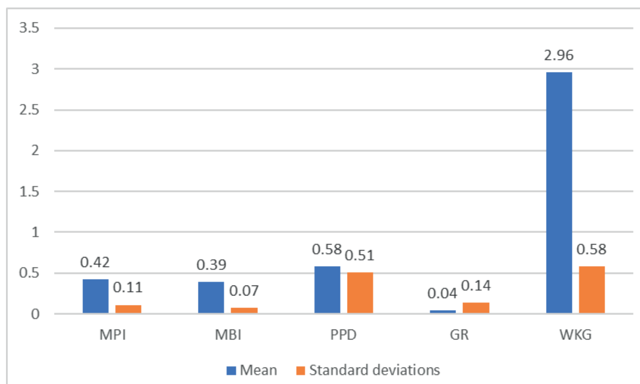

Figure 1. Measurements of clinical parameters around implants at 3 months after fixed prosthesis

Table. 6 Mean radiographic crestal bone levels at implant site on mesial and distal surfaces at baseline and 3 months after final restoration (Mean ± SD) (The Vertical Distance between Shoulder of the Implant and the Most Coronal Bone to Implant Contact)

Surface	At baseline	At 9 months (3 Months after Final Prosthesis)	Difference (mean bone loss)	*P* value
Mesial	0	0.33±0.33	0.33±0.33	0.005*
Distal	0.04±0.14	0.29±0.33	0.25±0.33	0.026*

*Statistically significant ($P < 0.05$)

Clinical data around implants after 3 months of loading indicated healthy peri-implant tissue. Minimal buccolingual dimensional changes of alveolar ridge of about 7.0 mm ± 1.21 mm were seen after socket preservation. Radiographic analysis after 3 months showed minimum vertical and horizontal bone loss around implants. (mesial: 0.33 ± 0.33, distal: 0.25 ± 0.33). Placement of delayed implants in preserved ridges after atraumatic extraction showed 100% survival, after a period of 3 months

DISCUSSION

The study evaluated the efficacy of ridge preservation with alloplastic bone graft (β-TCP), PRF, and rhBMP-2 followed by delayed implant protocol using clinical and radiographic parameters. The study emphasized the success rate of delayed implant protocol at the sites where atraumatic extraction was done and the ridge was preserved with grafting materials. None of the patients lost any implants during the study. All 12 surgical sites healed uneventfully. Postoperatively there was no complication reported. In most cases, the pain was negligible, with minimum discomfort caused by swelling. Each patient who participated showed maintained oral hygiene throughout the study. The FMPI score was less at the baseline and was less in the period of 9 months period, i.e. <1. In a similar way, full mouth papillary bleeding index i.e. FMPBI score, was less, i.e., < 1 at baseline and during nine months of observation duration. It was the consequence of the recurrent oral hygiene commands that were provided to the patients during the study duration. Control of plaque is necessary for the lifelong stability of the clinical results of implants. However, the impact of oral health on the accomplishment of implants has been controversial. However, it is commonly believed that the accumulation of microbial plaque could lead to a negative mucosal reaction. In this study, mean FMPI scores and FMBI scores were less, i.e., <1 in every patient indicating satisfactory oral hygiene status and gingival state all along the study duration.

In this study, every implant displayed a clinical implant mobility score, i.e. CIMS of zero, at three months after the prosthesis. Satisfactory results were obtained from clinical parameters surrounding the implant three months after the prosthesis. The indices also showed satisfactory plaque control and gingival conditions around implants. The radiographic analysis in our study showed the implants were well implanted in bone and the changes of the bulk of coronal bone to implant contact were registered on the mesial tooth surface and distal tooth surface of implants at baseline and at three months after fixed prosthesis. Mean vertical bone loss (distance between shoulders of the implant to most coronal bone) both on the mesial surface and distal surface was 0.33mm and 0.25, respectively, at three months after fixed prosthesis. Fickl et al. [23] stated that the group without flap had a diminished radius of resorption in comparison to the flap group. Contrarily, Araujo and Lindhe [3] observed that dimensional alteration is affected only in the short term if the flap is raised at the time of extraction. The mean changes with the height of the alveolar ridge at the mid-buccal region were found in several studies.

The height of the alveolar ridge from baseline to re-entry was found to be in the range of 1.3 ± 1.9 millimeters and 0.5 ± 1.1 millimeters after alveolar ridge preservation and in between 0.8 ± 1.6 millimeters and 1.2 ± 0.6 millimeters in the control groups. The lowering in height was not statistically significant at baseline and re-entry [24], while another study documented a rise in height rather than loss with ARP i.e., Polylactic and Polyglycolic sponge [25]. From a total of four studies in two, the height, which was reduced, was statistically markedly minor in the test groups, i.e., with ARP, in comparison to the controls, i.e., without ARP [26]. Leukocyte platelet-rich fibrin was first depicted by Dohan et al. [27]. It is a platelet concentrate of 2nd generation. They were reported to be used for enhancing wound healing in numerous surgeries. He et al.[28] compared the influence of biological features of PRP and PRF on the proliferation and multiplication of rat osteoblasts. It was observed PRF is found to have more controlled and, for a long period, the release of the growth factors as that to PRP. Furthermore, PRF depicted better effects on the proliferation and multiplication of osteoblasts. In the study, it was found that the healing of extraction sockets in terms of hard as well as soft tissue was faster in the PRF group. This led us to derive a similar conclusion. Blending the growth factors know to speed up bone repair and encourage fibroblasts to proliferate. Growth factors have also been proven for the growth of vascularity, i.e., the blood supply to tissues, amount of production of collagen, multiplication of mesenchymal stem cells and endothelial cells, along with osteoblasts having a major function in the speed and bulk of formation of bone. This is mediated by Platelet-Derived Growth Factors and Transforming Growth Factors [29]. In May 2005, Dohan and Diss at the symposium on growth factors, presented the clinical trials distinguishing the growth factors content of PRF and PRP [27]. Preclinical studies have assessed the initiation and rectification of defects in bone in numerous conditions [30]. A study that was carried out earlier showed that in humans, rhBMP-2 depicted safety and technical viability. Howell et al.[31] emphasized the efficacy of 0.43 mg/ml rhBMP/absorbable collagen sponge in conserving local ridge and augmentation. The author also reported that rhBMP was bearable locally and systemically without any adverse effects. In a study conducted by Fiorellini et al. [32], it was found that 1.50 mg/ml CrhBMP-2/ACS had remarkably more desirable outcomes following bone augmentation than the control patients. The sufficiency of bone for dental implant was around twice more in the rhBMP-2/ACS group than in the non-treatment or placebo group.

Huh J B et al.[33] the randomized double-blinded clinical trial demonstrated β-TCP/HA glazed with ErhBMP2 showed that it is more efficacious in conserving alveolar bone than β-TCP/HA alone. β-TCP is found to be biocompatible and osteoconductive in the studies that were carried out clinically [34]. One of those studies has displayed unexpected results with β-TCP due to the particles. The reason revealed was that the particles got encapsulated with fibrous tissue. More studies have proposed that the resorption of β-TCP is very faster, leading to the loss its space-making capacity. To deal with this, a biphasic calcium phosphate has been formed. It is composed uniformly of a 60/40 combination of hydroxyapatite and β-TCP. β-TCP will dissolve, providing calcium and the extent of formation of bone. HA keep up the scaffold as it resorbs slowly [35].

In this study β -Tricalcium phosphate was supposed to be osteoconductive. It behaved as a scaffold in the study. This was completed, as few studies have evaluated the osteoconductive features of calcium phosphate. Bowers et al.[36] documented bone and formation of osteoid surrounding graft particles and revealed that β-TCP was found to serve as a center for new bone formation. Wada et al.[37] found that osteoblasts were present on the surfaces of β-TCP particles. The study also revealed osteoblasts and the formation of osteoid surrounding β -TCP particles while drilling is done for an implant; results are based on the preparation of the osteotomy area without any trauma i.e., atraumatic. So, bone is vital by the side of the implant at placement [38]. The minimum temperature for bone existence is 47ºC/1 minute [39]. This temperature is very often increased, leading to osteocytic destruction. Osteocytic destruction is because of heat generated due to friction, mechanical vibration, and inadequate blood supply after capillary destruction. This may take time in osseointegration. Therefore, authors documented rapid rates of osseointegration for implants placed by the delayed placement method in comparison to instantly placed implants [40]. However, long- term follow-up is essential to comment on the success rate of the implant. The present study's findings confirm that atraumatic extraction followed by ridge preservation minimizes dimensional changes and helps in the improved success rate of the implants. After three months of loading, all the parameters reached a level of statistical significance. However, the results should be interpreted with caution since the smaller sample size and a short period of follow-up limit the significance of the study.

CONCLUSION

Using rhBMP-2+ β -TCP+rh-BMP-2 reduces the dimensional changes owing to 100% implant survival. Atraumatic extraction employing ridge preservation using PRF & β -TCP+rh-BMP-2 followed by delayed implant placement minimizes dimensional changes and helps in the improved success rate of the implants.

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Conflicts of Interest: "The authors declare no conflict of interest."

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