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Original Article

Case series of maxillary anterior bone augmentation with a novel biphasic calcium phosphate: a clinical and radiographic pilot study

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The purpose of this pilot case series was to evaluate the clinical and radiographic outcomes of employing newly developed alloplastic biphasic calcium phosphate (BCP) in guided bone regeneration (GBR) for maxillary anterior peri-implant defects. Six peri-implant dehiscence defects were grafted with BCP. For all included treatment sites, clinical (defect width [DW] and defect height [DH]), radiographic (horizontal hard tissue thickness [HT]), patient discomfort, and early wound healing outcomes were evaluated. At re-entry surgery, all surgical sites indicated a change in DW, DH, HT0, HT1, HT2, and HT3 from 4.08±1.39 mm to 1.13±1.76 mm, 3.57±1.42 mm to 0.58±1.09 mm, 2.18±0.66 mm to 1.50±0.53 mm, 2.11±0.57 mm to 1.73±0.28 mm, 2.22±0.54 mm to 1.75±0.26 mm, and 2.63±0.87 mm to 1.83±0.46 mm, respectively. Significant differences were discovered between paired DW and DH ($p<0.05$), whereas radiographic parameters had no significant differences. The severity of pain and swelling was 4.8±1.9 and 6.5±1.9, respectively, and the duration of pain and swelling was 4.5±3.8 and 5.8±2.9 days, respectively, according to early postoperative discomfort assessment. No adverse reactions occurred at any treatment site. In terms of clinical and radiographic outcomes, the newly developed BCP is acceptable biocompatible and suitable for the GBR of maxillary anterior peri-implant dehiscence defects within the limitations of this study.

Key Words: Allografts; Bone regeneration; Bone substitutes; Dental implants

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Introduction

Guided bone regeneration (GBR) is widely used for the treatment of peri-implant defects. Numerous clinical, radiographic, and histological studies have demonstrated the predictability and reliability of this treatment modality [1,2]. After extraction or loss of teeth, alveolar bone resorption occurs, and the buccal bony walls are the most significantly affected [3-5]. In particular, the buccal aspect of the maxillary anterior area is very thin and vulnerable to resorption, leading to insufficient buccal volume, which may cause critical esthetic and functional problems [6,7]. Therefore, GBR is frequently used to augment or maintain the dimensional stability of the maxillary anterior esthetic region.

The gold standard for bone grafting material is still autogenous bone. However, autogenous bone grafting may cause several surgical complications and unexpected adverse reactions, such as severe patient discomfort, nerve injury, and donor-site related morbidity [8]. Therefore, alternative bone grafting biomaterials, including allografts, xenografts, and synthetic grafts, have been continuously evaluated and have been successfully applied in clinical practice [9].

Biphasic calcium phosphate (BCP) is a synthetic grafting material composed of hydroxyapatite (HA) and beta-tricalcium phosphate (β-TCP) in different ratios [10]. BCP has osteoconductive properties and functions as a scaffold that provides space for vascular ingrowth, cell infiltration, and calcified tissue deposition [11]. HA resorbs slowly and remains relatively stable, whereas β-TCP resorbs faster and releases calcium and phosphate ions to induce new bone formation [12]. Several preclinical in vitro studies have assessed the usage of different HA and β-TCP ratios in BCP, with some authors reporting no difference between different ratios in histological and volumetric outcomes, while other studies have reported a significant difference [13-16].

BCP has been effectively and successfully used to reconstruct horizontal and vertical peri-implant bone defects in preclinical and clinical studies [17-19]. Despite these successful outcomes, the optimal ratio of HA to β-TCP has not yet been determined, and its physical and chemical properties are still being studied [16,20]. This pilot study aimed to evaluate the clinical and radiographic outcomes of newly developed BCP in GBR for maxillary anterior peri-implant defects.

Materials and Methods

Ethics

This study was a retrospective case series of six enrolled patients from the periodontology departments of two dental hospitals (Yonsei University Gangnam Severance Hospital and Wonwkang University Daejeon Dental Hospital) between November 2020 and July 2022. For this study, institutional IRB approval was obtained by Wonkwang University Daejeon Dental Hospital (approval No. W2011/001-001) and Yonsei University Gangnam Severance Hospital (approval No. 3-2020-0441). This study was conducted in accordance with the revised Declaration of Helsinki and Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.

Inclusion and exclusion

The following inclusion criteria were applied: 1) age (≥ 20 y), 2) maxillary anterior area (from the right canine to the left canine), 3) ≥1 mm width or height of buccal dehiscence intrabony defect after implant placement, 4) fill out the self-assessment questionnaire about early postoperative discomfort, 5) good or stable oral hygiene (full mouth bleeding and plaque scores <25%), and 6) adequate general medical condition for surgery. The following exclusion criteria were applied: 1) non-contained intrabony defect after implant placement, 2) current heavy smoking ≥20 cigarettes/day, 3) uncontrolled periodontal status or systemic condition, 4) pregnancy or lactation, and 5) bone metabolic disease.

Surgical procedures

All cases were assessed using preoperative cone-beam computed tomography (CBCT) scans, and all surgical procedures were performed by two experienced dental surgeons (JHL and DWL). A full-thickness mucosal flap was elevated, and dental implants were placed according to the manufacturer's recommendations (TSIII [Osstem, Seoul, Korea]; Astra OsseoSpeed TX [Dentsply Sirona Implants, Mannheim, Germany]; Anyone [Megagen, Daegu, Korea]).

Buccal dehiscence defects were filled with the alloplastic BCP bone-graft substitute (Bone Matrix I 0.25 g [0.6–1.0 mm]; Megagen, Daegu, Korea), and subsequently covered with a resorbable cross-linked collagen barrier membrane (Ossix Plus 15×25 or 25×30 mm; Datum Dental Biotech, Lod, Israel). No additional pins or screws were used to fix the collagen membrane. With or without vertical or periosteal-releasing incisions, the flap was repositioned using interrupted and horizontal mattress sutures with absorbable (6-0 Vicryl; Johnson & Johnson, New Brunswick, NJ, USA) and non-absorbable (4-0 Dafilon [B. Braun Surgical, Tuttlingen, Germany]; 4-0 Biotex [Purgo, Seongnam, Korea]) monofilament (Fig. 1). All patients received postoperative medications, including antibiotics and analgesics three times a day for 3–7 days, and 0.12% chlorhexidine solution for rinsing two times a day for 2 weeks. Sutures were removed two weeks after implant surgery with GBR, and re-entry surgery was conducted at 16–20 weeks after implant placement.

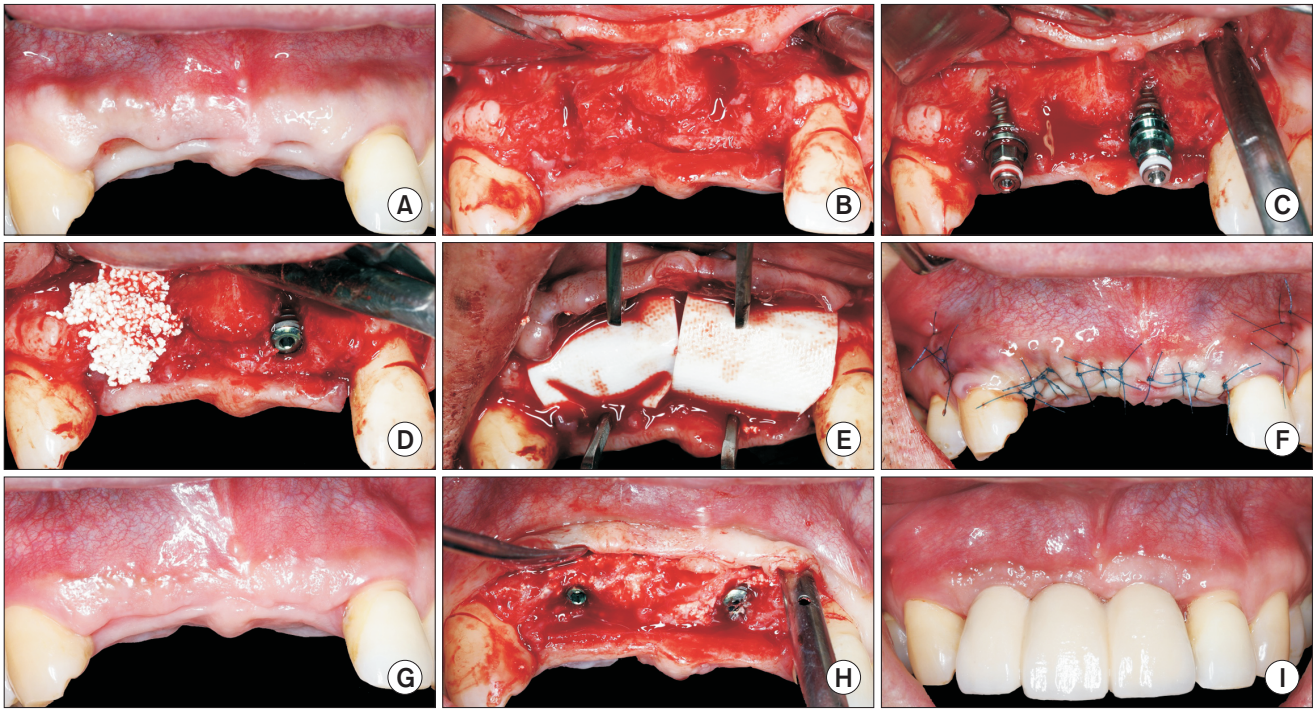

Fig. 1. Representative clinical photos of the dental implant and guided bone regeneration (GBR) procedures. (A) Initial intraoral photograph. (B) Full-thickness mucosal flap elevation. (C) After dental implant installation. (D) GBR with alloplastic biphasic calcium phosphate bone-graft substitute. (E) Covered with a resorbable collagen membrane. (F) Primary and tension-free closure with vertical and periosteal-releasing incisions. (G) 18 weeks after the implant surgery and before the re-entry surgery. (H) Facial view during the re-entry surgery. (I) Clinical view at final prosthesis delivery.

Table 1. Baseline characteristics of the enrolled patients

Case No.	Age (y)	Sex	Position	System	Diameter (mm)	Length (mm)
1	61	M	#22	Osstem TSIII	3.5	10.0
2	48	M	#12	Osstem TSIII	4.0	10.0
3	48	M	#21	Osstem TSIII	4.0	10.0
4	60	M	#21	Osstem TSIII	3.5	10.0
5	67	M	#13	Astra OsseoSpeed TX	4.0	9.0
6	61	M	#11	Megagen Anyone	4.0	8.5

M, male.

Clinical and radiographic outcomes

Primary outcome: defect width (DW, measured as the horizontal distance of the buccal dehiscence defect) and defect height (DH, measured as the vertical distance from the implant shoulder to the most apical point of the buccal dehiscence defect) were calculated before the GBR procedure and during re-entry surgery using a periodontal probe.

Secondary outcomes: Based on sagittal sections of CBCT scans, horizontal lines perpendicular to the implant long axis from the implant shoulder (horizontal hard-tissue thickness [HT0]), 1 mm (HT1), 2 mm (HT2), and 3 mm (HT3) below were drawn, and the HT was assessed at each level after implant surgery and before re-entry surgery. During suture removal, postoperative discomfort (including severity and duration of pain and swelling) and early wound healing outcomes (including wound dehiscence and inflammatory reactions, such as pus or abscess formation) were assessed using a self-reported method and oral examination. The severity of pain and swelling was measured using a visual analog scale (VAS).

Statistical analysis

Baseline characteristics were summarized using the median and 95% confidence intervals. The primary and secondary outcomes of the patients were analyzed using the Wilcoxon signed-rank test on pairs. All statistical analyses were conducted using IBM SPSS Statistics (Version 28; IBM Co., Armonk, NY, USA), with a probability level of 0.05.

Results

Six cases were included, based on the inclusion and exclusion criteria, comprising six male with a mean age of 57.5±7.7 years. The detailed baseline characteristics of the patients are presented in Table 1.

Clinical and radiographic outcomes

Table 2, Figs. 2 and 3 show the clinical and radiographic measurements after implant surgery and before re-entry surgery, respectively. At re-entry surgery, all surgical sites

Table 2. Changes of clinical and radiographic outcomes

Case No. (n=6)	Clinical outcomes		Radiographic outcomes			
	ΔDW (T0, T2) (mm)	ΔDH (T1, T2) (mm)	ΔHT0 (T1, T2) (mm)	ΔHT1 (T1, T2) (mm)	ΔHT2 (T1, T2) (mm)	ΔHT3 (T1, T2) (mm)
1	−2.5 (2.5, 0.0)	−3.0 (3.0, 0.0)	−1.54 (2.30, 0.76)	−0.49 (2.20, 1.71)	−1.31 (3.11, 1.80)	−1.45 (3.52, 2.07)
2	−4.0 (4.0, 0.0)	−5.0 (5.0, 0.0)	−0.13 (1.73, 1.60)	−0.05 (1.50, 1.45)	−0.76 (2.31, 1.55)	−1.43 (3.40, 1.97)
3	−3.0 (3.0, 0.0)	−5.5 (5.5, 0.0)	−0.89 (2.56, 1.67)	−0.87 (2.66, 1.79)	−0.98 (2.35, 1.37)	−1.83 (3.24, 1.41)
4	−3.5 (3.5, 0.0)	−3.0 (3.0, 0.0)	−1.06 (3.24, 2.80)	−0.61 (2.80, 2.19)	−0.12 (2.19, 2.07)	−0.33 (2.24, 1.91)
5	−2.4 (5.9, 3.3)	−0.5 (3.2, 2.7)	0.00 (1.79, 1.79)	−0.27 (2.06, 1.79)	+0.18 (1.79, 1.97)	+0.63 (1.79, 2.42)
6	−2.3 (5.6, 3.3)	−0.9 (1.7, 0.8)	−0.44 (1.44, 1.00)	0.00 (1.44, 1.44)	+0.16 (1.56, 1.72)	−0.39 (1.56, 1.17)
Median (95% CI)	−2.75 (−3.90 to −2.31)	−3.00 (−5.40 to −0.57)	−0.66 (−1.44 to −0.02)	−0.38 (−0.81 to −0.00)	−0.44 (−1.24 to 0.17)	−0.91 (−1.75 to 0.44)

ΔDW, changes of defect width; ΔDH, changes of defect height; ΔHT, changes of hard tissue thickness at implant shoulder (ΔHT0), 1 mm (ΔHT1), 2 mm (ΔHT2), and 3 mm (ΔHT3); T0, before the guided bone regeneration (GBR) procedure; T1, after implant surgery with GBR; T2, re-entry surgery; CI, confidence interval.

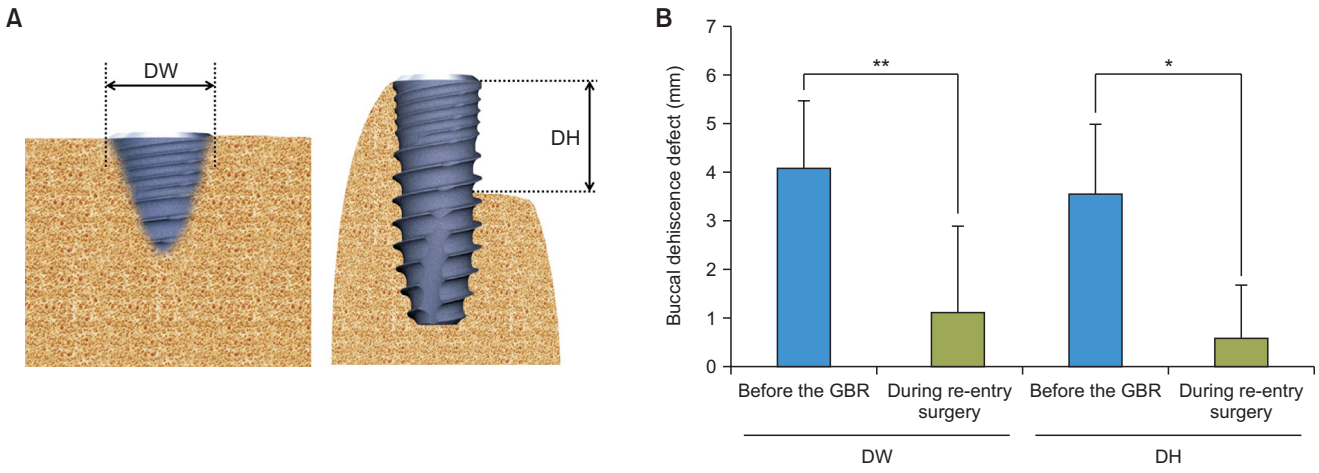

Fig. 2. Comparison of clinical outcomes after treatment for maxillary peri-implant dehiscence defects. (A, B) Clinical outcomes measured in terms of the DW and DH. DW, defect width; DH, defect height; GBR, guided bone regeneration. *p-value <0.05, **p-value <0.001.

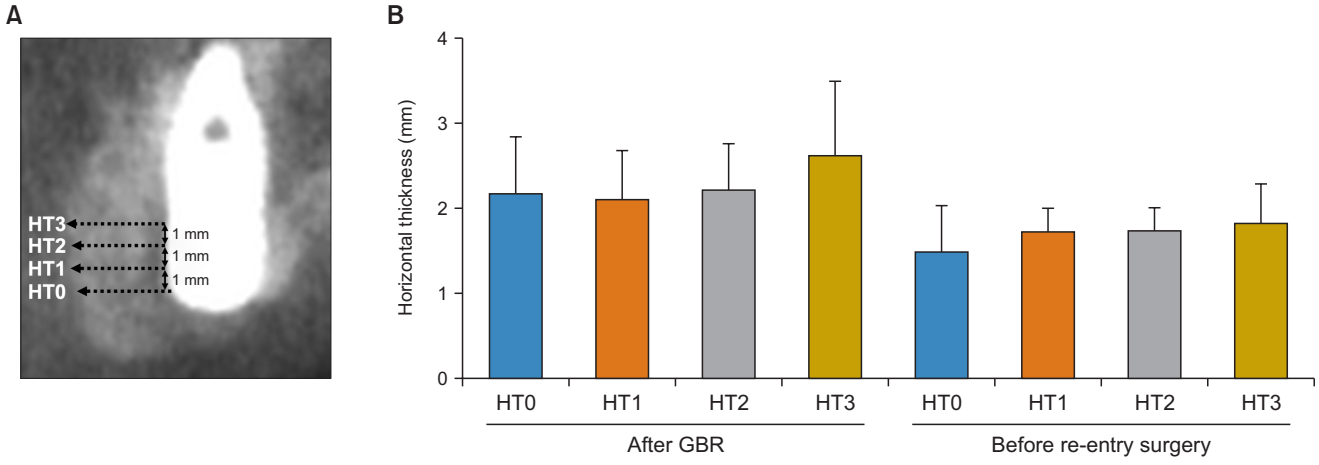

Fig. 3. Comparison of radiographic outcomes after treatment for maxillary peri-implant dehiscence defects. (A, B) Radiographic outcomes measured as horizontal hard-tissue thickness (HT). GBR, guided bone regeneration.

showed a buccal bone thickness change in HT0, HT1, HT2, and HT3 from 2.18±0.66 mm to 1.50±0.53 mm, 2.11±0.57 mm to 1.73±0.28 mm, 2.22±0.54 mm to 1.75±0.26 mm, and 2.63±0.87 mm to 1.83±0.46 mm, respectively. No significant differences were found between the paired HTs (p>0.05). On the other hand, the DW value decreased from 4.08±1.39 mm to 1.13±1.76 mm (p<0.001). The corresponding DH value decreased from 3.57±1.42 mm to 0.58±1.09 mm (p<0.05).

Early postoperative discomfort and wound healing outcomes

In two of the six cases, the early postoperative discomfort-related survey was not conducted due to time constraints. As a result of assessing the discomfort while suture removal, the severity of pain and swelling was 5.5 and 6.0 on VAS score, and the duration of pain and swelling was 3.0 and 4.5 days, respectively. At the same time, wound dehiscence or inflammatory reaction was not noted at all treatment sites (Table 3).

Table 3. Early postoperative discomfort and wound healing outcomes

Case No. (n=6)	Early wound healing		Post operative discomfort[a]			
	Wound dehiscence	Inflammatory reaction	Severity of pain (VAS score)	Duration of pain (d)	Severity of swelling (VAS score)	Duration of swelling (d)
1	No	No	6	10	5	10
2	No	No	6	2	9	5
3	No	No	5	4	7	4
4	No	No	2	2	5	4
5	No	No	-	-	-	-
6	No	No	-	-	-	-
Median	-	-	5.5	3.0	6.0	4.5

VAS score, 0: no pain and swelling, 10: worst imaginable pain and swelling.
VAS, visual analog scale; -, not applicable.
[a]In two cases out of six cases, the early postoperative discomfort-related survey was not conducted due to time constraints.

Discussion

A recent systematic review and meta-analysis reported no significant differences in the percentage of new bone formation between any bone-graft materials [21]. Nevertheless, within the limited evidence available, autogenous bone still showed the highest amount of new bone formation, and synthetic grafts showed a higher percentage of bone formation than xenogeneic or allogeneic grafts [21]. The results where BCP and xenografts are compared are not consistent, however in general, BCP generally showed less residual grafting material and the rate and volume of new bone formation was comparable to xenografts [17-19].

Specifically, BCP has shown comparable favorable outcomes with deproteinized bovine bone mineral (DBBM), which is one of the most frequently used xenogeneic bone substitute materials [14,15]. A recent clinical study comparing histomorphometric outcomes of sinus floor elevation with BCP and DBBM demonstrated that the amount of new bone was similar between the two grafts (BCP 35.9%; DBBM 35.4%). However, there was lesser remaining grafting material (BCP 25.3%; DBBM 45.9%) and greater non-mineralized tissue (BCP 38.1%; DBBM 18.2%) in BCP than that in DBBM after 6 months of healing [14]. Another comparative study evaluated BCP and DBBM when used for socket preservation [15]. Histomorphometric analysis performed 6 months after the procedure showed no significant difference in new bone formation and residual materials between the two groups. The percentages of new bone formation were 26.47% and 30.47%, while the residual materials were 13.1% and 17.89% in the BCP and DBBM groups, respectively.

The ratio of HA and β-TCP and the porosity of the particles determine the biodegradation rate and are also related to the amount of bone apatite-like crystals that are associated with bioactivity [22,23]. Therefore, BCP prepared with various ratios of HA and β-TCP can determine the degradation rate, which is a major clinical advantage of BCP in response to the bone-graft environment. The ratio of HA and β-TCP of BCP used in the current study is 60:40, however, there are diverse results according to the ratio of HA and β-TCP. An in vivo study demonstrated that BCP with HA and β-TCP ratios of 60:40 and 20:80 showed similar osteoconductivity and biodegradation rates [13]. Conversely, another in vivo study reported that 10:90 HA and β-TCP showed better and more noticeable osteoclastic activity, biodegradation rate, dissolution, and new bone formation than 60:40 HA and β-TCP [16].

Several clinical studies have reported that regardless of the type of bone grafting material used for the GBR procedure for the maxillary esthetic region, it is clinically stable and maintained despite the decrease in hard-tissue volume and thickness over time. In a 3-year follow-up retrospective study of single-tooth implant surgery combined with GBR using DBBM, the reduction in buccal hard-tissue thickness was approximately 1 mm after 1 year and 1.5 mm after 3 years [24]. Another prospective clinical study of immediately placed implants with simultaneous GBR with

DBBM and autogenous bone chips also reported that the reduction of the buccal HT was 0.94±0.51 mm at the implant shoulder level after 1 year follow-up [25]. In a recent randomized controlled clinical trial using BCP in the GBR procedure, the percentage of HT0 reduction was approximately 34% after 6 months of healing [18]. In this study, a buccal hard-tissue thickness reduction of 25.5% occurred after an average of 18 months, which is consistent with the results of previous studies.

In the present study, the GBR procedure was performed using the newly developed alloplastic BCP bone graft, with a 60:40 HA to β-TCP ratio, and cross-linked resorbable collagen membrane in the maxillary anterior region. This novel BCP has a relatively large pore structures and high compressive strength, and is considered to be advantageous for neovascularization and new bone formation. It was found that more than 90% of peri-implant dehiscence defects were completely resolved. Significant improvement of radiographic outcomes (mean ΔHT 2.41±0.90 mm) after regenerative treatment of peri-implant dehiscence defects were noted, which was maintained without a statistically significant change in the buccal hard-tissue thickness at the re-entry surgery. Moreover, patient-experienced discomfort was observed within 1 week on average, and severe adverse reactions associated with GBR failure were not observed in any enrolled patient.

Therefore, although our analysis relied on a limited number of cases and was subject to selective biases inherent to a retrospective study design, the newly developed BCP is biocompatible and suitable for GBR of maxillary anterior peri-implant dehiscence defects in terms of clinical and radiographic outcomes. Further prospective and longitudinal studies are needed to confirm these preliminary results.

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Conflicts of Interest

The authors declare that they have no competing interests.

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