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Original Article

A novel buccal bone augmentation technique around non-contained and exposed implant threads: Clinical, histologic and histomorphometric evaluations on the treatment outcome

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Abstract *Background/purpose:* Buccal dehiscence defects around dental implants pose a significant clinical challenge, particularly when minimal residual bone remains. This prospective study aimed to evaluate a novel two-layer bovine-derived grafting approach—a moldable paste-type material layered with particulate bone—protected by a collagen membrane to encourage new bone formation on exposed implant threads.
Materials and methods: Three partially or fully edentulous patients requiring implant-supported rehabilitation were enrolled. A total of 17 implants were placed; among these, three "study implants" exhibited pronounced buccal bone dehiscences and were grafted with the investigated protocol. Six months postoperatively, the designated study implants were

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retrieved en bloc and processed for histologic and histomorphometric analyses. Bone-to-implant contact (BIC) was measured on both buccal and lingual aspects to assess new bone formation on previously exposed implant threads.
Results: All implant sites healed uneventfully, without complications such as wound dehiscence or infection. Histology showed newly formed mineralized tissue in direct contact with the implant surface, supported by a mean total BIC of 67.32 ± 6.27 %. The mean buccal BIC was 66.56 ± 5.52 %, suggesting that some degree of new bone formation occurred in the areas of original thread exposure, although residual graft particles were frequently noted.
Conclusion: Within the limits of this preliminary study, the findings suggest that the combined bovine-derived paste and particulate graft technique may help regenerate buccal bone and facilitate osseointegration on exposed implant threads. Further investigations with larger patient samples and extended observation periods are needed to corroborate and refine these encouraging early results.

Introduction

Dental implant therapy has become a predictable treatment modality for partially and fully edentulous patients, demonstrating long-term clinical success since Brånemark's pioneering work in 1965.[1,2] Thus, the year 2025 is very special as we celebrate the 80th anniversary of modern dental implants.[3]

Despite improved implant survival rates, clinicians increasingly encounter complex cases, including immediate implant placement and simultaneous bone augmentation.[4] Following tooth extraction, resorption of the alveolar ridge often results in significant buccal implant thread exposure when implants are positioned in prosthetically driven locations.[5–8] Exposed implant threads result in reduced bone-to-implant contact (BIC) and an esthetic catastrophe, such as tissue discoloration, if the patient has a thin phenotype around the implant area.[9] Recent evidence supports high rates of osseointegration and long-term clinical success for implants placed in both native and regenerated bone.[10–13] Advances in biomaterials have expanded options for clinicians, facilitating predictable bone regeneration outcomes.[10–14] Nonetheless, this predictability also depends on crucial factors such as the patient's systemic condition, anatomical condition, quality of the remaining native bone, and clinicians' clinical experience.[4,10,12,13,15] Proper surgical techniques and careful biomaterial selection are critical, especially in cases involving substantial bone volume augmentation due to existing alveolar defects. Multiple case reports have demonstrated the clinical success of bone formation around exposed implant threads when a guided bone regeneration (GBR) technique has been employed.[10–13,15]

Benic et al. proposed a classification system to guide bone augmentation decisions during dental implant placement.[4] Class 2 defects involve dehiscences where adjacent bone walls provide stability, allowing GBR with resorbable membranes and particulate grafts. However, over-grafting is often necessary to compensate for resorption and achieve optimal ridge contour.[16] In contrast, Class 3 defects lack such support, necessitating rigid space maintenance with non-resorbable membranes, such as titanium-reinforced d-PTFE. While these membranes improve graft containment, they complicate primary closure, increasing the risk of membrane exposure, infection, and delayed healing.[17,18] These challenges contribute to higher post-operative complications, emphasizing the need for innovations that enhance predictability while reducing surgical risks.

To address these challenges, a novel bovine-derived paste-type bone graft that is moldable in situ was developed for non-contained Class 3 defects. Unlike particulate grafts, this paste material enhances handling and stability, potentially reducing reliance on non-resorbable membranes. This study aimed to assess this innovative approach's clinical efficacy and histologic outcomes.

Materials and methods

This prospective, proof-of-principle study evaluated clinical and histologic outcomes of a bovine-derived paste-type bone graft combined with particulate graft and resorbable cross-linked collagen membrane for guided bone regeneration (GBR) in non-contained buccal defects. The study assessed the healing characteristics of this grafting technique around implants placed in prosthetically driven positions with anticipated buccal thread exposure. The study protocol was reviewed and approved by the Institutional Review Board at the Dentalevo Institute in Bucharest, Romania (DEI-2023-1001-R0).

Three partially or fully edentulous patients requiring implant-supported prostheses (4–6 implants each) were enrolled. Within each case, a designated research implant site met the following criteria: (1) the presence of a non-contained buccal bone defect requiring augmentation at implant placement, and (2) implant location allowing removal without compromising the overall prosthetic design. These "research implants" were placed specifically for retrieval and histologic analysis six months postoperatively. All patients provided informed consent in accordance with the Declaration of Helsinki (1975, revised 2000).

Patients aged 20–70 years seeking implant-supported rehabilitation were eligible if they were non-smokers without significant systemic diseases or medications affecting bone healing. Exclusion criteria included

pregnancy, nursing, malignancy history, autoimmune disease, uncontrolled diabetes (HbA1c $>$ 6.5 %), previous implant failures at the site, immediate implant placement, and active infection.

Before surgery, participants underwent comprehensive evaluation, which included clinical photography, periapical radiographs, and cone-beam computed tomography (CBCT) to confirm prosthetic and anatomical suitability. The selected implant sites exhibited non-contained buccal dehiscence defects necessitating GBR and were chosen carefully to preserve the integrity and long-term function of the final prosthesis.

Dental implants and bone grafting materials

Dental implant system: (IB-T, Internal Bone Level Tapered) dental implants with sandblasted, large grits, acid-etched surface (G·DIFF, ACH Medical Co., Ltd., Gyeonggi-do, South Korea). Bovine cancellous bone that forms a paste upon hydration with saline solution (S1 moldable bone, 0.2—1.0 mm particle size, MedPark, Co., Ltd, Seoul, South Korea) served as a foundational layer to stabilize particulate graft material during membrane placement and flap adaptation. Bovine cancellous bone (BOSS, particulate-type, 0.2—1.0 mm particle size, MedPark, Co., Ltd., Seoul, South Korea). Membrane: Cross-linked type I bovine collagen membrane (COLLA, MedPark).

Implant placement and reconstructive surgery

Three patients presenting with an edentulous site were prepared for the routine dental implant surgery. After local anesthesia and flap elevation, implant osteotomies were prepared using torque-reduction rotary instruments under sterile saline irrigation, following the manufacturer's guidelines. All implants were placed using an insertion device and hand ratchet according to manufacturer instructions, achieving clinically acceptable insertion torque. For the study implant exhibiting exposed buccal threads at the coronal portion, a combination of moldable bone pastes and particulate bone grafts in conjunction with a collagen barrier membrane was used for augmentation (known as DUK Technique). The moldable bone paste provided an ideal stable foundation for the particulate bone graft placed on top (Fig. 1).

The lingual or palatal aspect of the implant platform was either at the level with the osseous crest or slightly below, and the cover screw was placed (Fig. 2A). The bone paste was prepared per the manufacturer's instructions, followed by applying particulate graft material to cover exposed implant threads (Fig. 2B). A collagen membrane was placed extending from the buccal to lingual or palatal aspect to cover the graft materials and secured using internal periosteal sutures (Vicryl, Ethicon, Raritan, NJ, USA) (Fig. 2C). The flaps were adapted for tension-free wound closure with interrupted and horizontal mattress sutures (Vicryl). A periapical radiograph was taken immediately after the surgery, and the

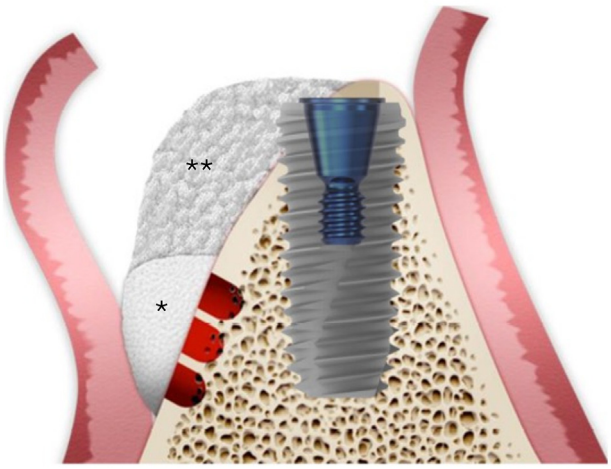

Figure 1 A diagram depicting the buccal bone augmentation techniques using both bone paste (*) and particulate bone graft (**) around non-contained and exposed buccal implant threads.

patients underwent the standard post-surgical infection and pain control with Amoxicillin 500 mg three times/day for 7 days and Ibuprofen 600 mg three times/day for 5 days. The patients came back for routine follow-up appointments until the day of the second stage surgery (six months post-augmentation).

Dental implant biopsy

Strategically placed three dental implants were biopsied using piezo surgery instruments 6 months post-implant surgery (Fig. 2D). Hard tissue augmentation using bone grafts and membranes was performed to repair biopsy sites. Recovered specimens were immediately immersed in fixative for histological preparation and evaluation.

Histological and histomorphometric analyses

The block specimens were sectioned in a mesio-distal direction and parallel to the long axis of the implant, resulting in multiple sections for evaluation. The fixed samples were dehydrated in a graded series of ethanol (60 %, 80 %, 96 %, and absolute ethanol) using a dehydration system with agitation and vacuum. The blocks were infiltrated with Kulzer Technovit 7200 VLC-resin. Infiltrated specimens were placed into embedding molds, and polymerization was performed under white- and blue light. Polymerized blocks were sectioned in a mesio-distal direction and parallel to the long axis of each implant. The slices were reduced by microgrinding and polishing using an Exakt grinding unit to an even thickness of 60—70 μm. Sections were stained with Sanderson's RBS and counter-stained with acid fuchsin and examined using both a Leica MZ16 stereomicroscope and a Leica 6000DRB light microscope. Histomorphometric measurements were performed by using software (ImageAcess, Imagic, Switzerland) to calculate the percentage of direct contact between mineralized bone and the implant surface (bone-to-implant contact).

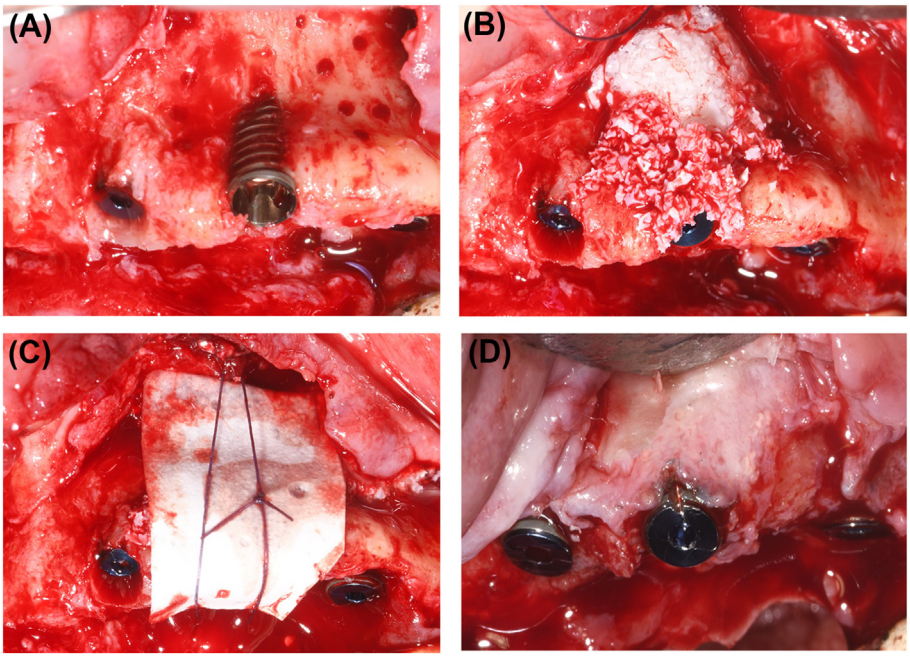

Figure 2 (A) A patient presented with non-contained and exposed buccal implant threads at the time of the implant placement. (B) A layer of paste-type bone was placed as the foundation layer before placing the particulate bone graft on top of it. (C) A collagen membrane was draped over from the buccal aspect to the palatal aspect to contain bone grafts. The membrane was secured using the internal periosteal suturing technique. (D) Six months post augmentation demonstrating what appeared to be buccal bone regeneration on exposed implant threads.

Results

Clinical outcome

Seventeen implants were placed in three patients (one maxilla, two mandibles); three designated study implants exhibiting buccal thread exposure underwent GBR using the experimental grafting protocol. During the six-month healing period, no postoperative complications were observed. All surgical sites healed uneventfully, with no cases of wound dehiscence, membrane exposure, or clinical signs of infection. At the time of the second stage surgery, 6 months post-implant placement, all implants demonstrated clinical signs of osseointegration. Previously exposed buccal implant threads were visually covered at study sites with hard, bone-like tissue, indicating a clinically successful outcome. All patients received implant-supported fixed prosthetic restoration for oral rehabilitation (Fig. 3A–C).

Histomorphometric analysis and bone-to-implant contact analysis (BIC)

Histologic evaluation of the three retrieved implants confirmed mineralized tissue in contact with the implant surface on both buccal and lingual aspects. Quantitative histomorphometric analysis revealed a mean total bone-to-implant contact (BIC) of 67.32 ± 6.27 %. The mean buccal BIC was 66.56 ± 5.52 %, and the mean lingual BIC was

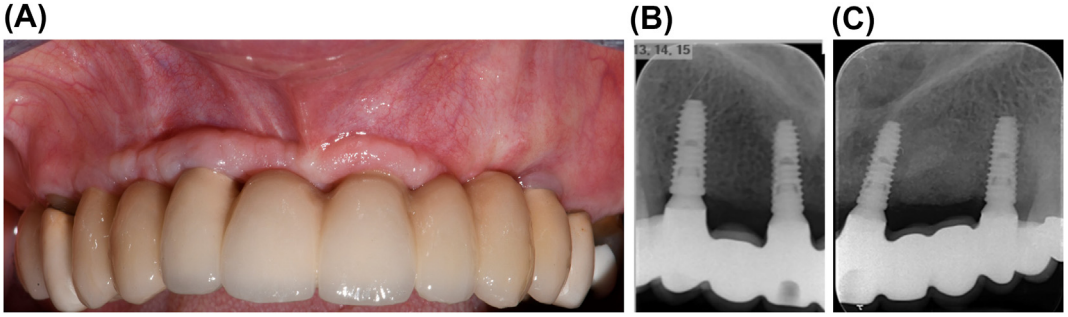

Figure 3 Restored full mouth rehabilitation case for the study participating patient. (A) Intraoral photograph showing the definitive implant-supported fixed prosthesis in the maxillary arch. (B) Periapical radiograph of the maxillary right implants immediately after prosthesis delivery. (C) Periapical radiograph of the maxillary left implants immediately after prosthesis delivery.

Table 1 Total BIC %, buccal BIC %, and lingual BIC % of three retrieved dental implants demonstrating a high percentage of BIC. BIC = bone-to-implant contact.

	Total BIC %	Buccal BIC %	Lingual BIC %
Sample #1	59.34	74.26	37.01
Sample #2	67.96	74.26	76.91
Sample #3	74.66	63.85	85.04
Mean ± SD	67.32 ± 6.27	66.56 ± 5.52	66.32 ± 20.98

66.32 ± 20.98 % (Table 1). Buccal BIC values were generally consistent across all three samples, whereas the lingual BIC showed greater variability due to one specimen exhibiting a notably lower value.

Histologic sections from each specimen were analyzed in relation to the baseline level of buccal dehiscence and the most coronal point of buccal bone-to-implant contact (Fig. 4A–C). Specimen 1 (Maxilla, Fig. 4A): Buccal bone-to-implant contact extended coronal to the baseline dehiscence level, with a thin layer of new bone on previously exposed threads. Residual graft particles were present buccally, without direct implant contact. Lingually, reduced BIC was observed, possibly due to soft tissue or marrow spaces occupying the apical third. Specimen 2 (Mandible, Fig. 4B): This specimen showed direct new bone formation on both buccal and lingual implant surfaces, extending coronally beyond the baseline buccal dehiscence. Residual graft particles were visible in the buccal area, surrounded by mineralized tissue identified histologically as new bone. BIC was high and evenly distributed, with notable bone contact near the implant shoulder. Specimen 3 (Mandible, Fig. 4C): Buccal and lingual bone contact was observed, though buccal BIC did not extend as far coronally as in Specimen 2. Residual graft particles were present in the buccal compartment, with interspersed areas of mineralized new bone, especially in regions closer to the native bone.

Discussion

Dental implants exhibit long-term clinical success; however, human histologic evidence of bone regeneration around exposed implant threads remains limited, especially in non-contained Class 3 defects.[1,4,19] Available histology largely derives from failing implants, underscoring the need for further evaluation of GBR outcomes in clinically successful implants.[3,20–25] This prospective study aimed to expand the limited histologic evidence by analyzing three implants retrieved 6 months after GBR of large buccal dehiscence defects. A novel two-layer xenograft, combining moldable bovine bone paste and particulate graft stabilized by a collagen membrane, was evaluated for its potential to achieve satisfactory BIC.

Founded in 2008 in South Korea with records of clinical success for over 10 years, the implant system used (ACH Medical's G·DIFF IB-T) features built-in platform switching for marginal bone preservation, a tapered body with hybrid double threads for enhanced primary stability, a rounded apex to protect vital structures, and a widely utilized sandblasted, large grit, acid-etched (SLA) surface with demonstrated clinical success. For GBR, the paste-type bone graft used as the foundational layer exhibited excellent handling characteristics, including adhesiveness and moldability, addressing limitations of particulate graft displacement in non-contained defects. A cross-linked type I bovine collagen membrane was selected for its long resorption period (>4 months), providing sufficient stability and containment of graft materials.

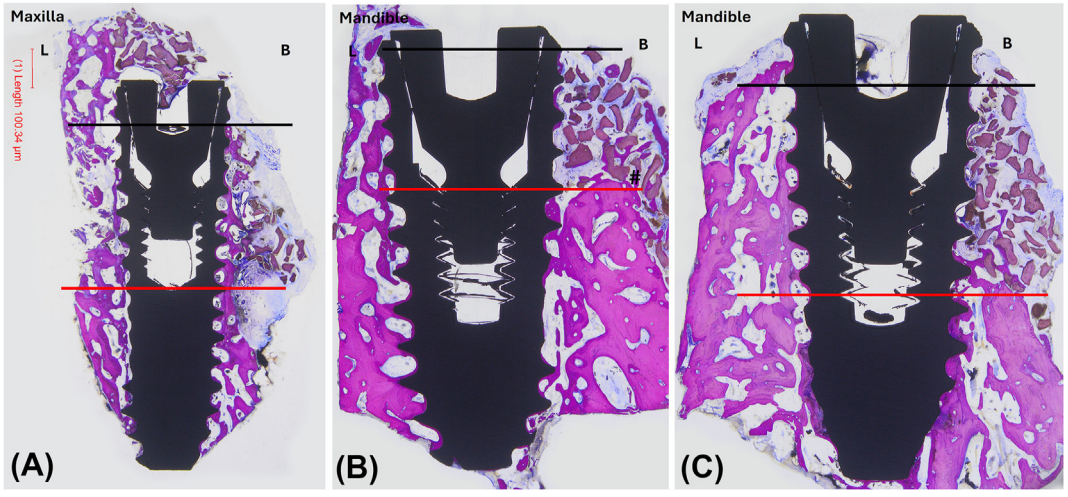

Figure 4 Histologic sections of three retrieved implants: (A) specimen 1 (maxilla), (B) specimen 2 (mandible), (C) specimen 3 (mandible), demonstrating buccal bone regeneration at six months. The black horizontal line indicates the most coronal buccal bone-to-implant contact, while the red line marks the baseline buccal dehiscence at implant placement, facilitating the assessment of new bone formation. "L" denotes the lingual/palatal side; "B" denotes the buccal side. Scale bar = 100 µm. New bone, residual graft particles, and BIC variations are evident. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Although clinical or radiographic findings often indicate "fill" around exposed implant threads, only histologic analysis can distinguish true vital bone from soft tissue or residual graft particles.[26,27] Unresorbed graft particles contacting the implant surface without bridging bone may compromise osseointegration and increase the risk of peri-implantitis.[28] Histologic studies of retrieved implants with confirmed bone formation on previously exposed surfaces are rare but provide the most definitive evidence of regeneration.[29,30]

Using a novel layered bone grafting approach, all three implants in the present study healed uneventfully and demonstrated clinically successful coverage of previously exposed threads. Histologically, total and buccal BIC values (~65 %) were consistent with prior studies.[31—33] However, detailed histologic analysis revealed a thin layer of new bone along implant surfaces, including previously exposed regions, although surrounding graft particles often showed incomplete resorption with occasional interspersed fibrous tissue. The limited volume and continuity of new bone in the buccal region may not reflect the robustness typically associated with ideal GBR outcomes.[34] Despite enhanced handling and stability provided by the paste-type xenograft, complete mineralized integration was inconsistent, with residual graft particles often adjacent to the implant surface and occasionally separated by soft tissue rather than continuous bone.

Clinically visible coverage of exposed threads via GBR is promising but does not ensure complete histologic bone regeneration. Long-term, exposed or partially covered implant surfaces may have increased risk of peri-implantitis or recession, especially if new bone is replaced by fibrous tissue.[35] The combination of paste-type and particulate xenografts simplified handling by eliminating the need for non-resorbable membranes in large defects, but incomplete bone fill highlights the need for further refinement.[19] Potential strategies include optimizing membrane properties to improve space maintenance or combining the paste-type graft with biologics to enhance early vascularization and bone in-growth.[36,37]

This study was limited by a small sample size, short follow-up (6 months), and the absence of a control group comparing conventional grafting methods. The mid-60% BIC observed may reflect stronger osseointegration apically, potentially obscuring less favorable outcomes coronally. Histologic analysis remains the gold standard for validating regenerative procedures, and future studies should involve larger controlled cohorts, longer follow-ups, and evaluation of alternative biomaterials or growth factor-enhanced grafts to optimize regenerative outcomes.

Clinically, all non-grafted implant sites achieved successful functional loading, demonstrating implant reliability. Grafted sites showed comparable bone-to-implant contact, supporting the potential of this regenerative approach despite incomplete bone fill observed histologically.

Declaration of competing interest

The authors declare that they have no competing financial interests or personal relationships that may have influenced the work reported in this study.

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