Regenerative Surgical Treatment of Peri-Implantitis: A One-Year Randomized Clinical Trial Comparing Autogenous Bone and Xenograft

Abstract

Background
Peri-implant diseases are plaque-associated inflammatory conditions leading to progressive bone loss and clinical signs such as bleeding on probing, suppuration, and increased probing depths.
Non-surgical measures have demonstrated limited effectiveness in achieving disease resolution; therefore, surgical strategies are often required to re-establish peri-implant health.

Aim
This randomized controlled clinical trial aimed to compare the clinical and radiographic outcomes of autogenous bone graft (AB) and xenograft (BDX) in the reconstructive surgical treatment of peri-implant intrabony defects after one year of follow-up.
Materials and Methods:
Ten patients presenting bilateral peri-implant intrabony defects were enrolled and randomly allocated to receive either autogenous bone or xenograft grafting materials. All sites underwent flap surgery, mechanical surface decontamination, and defect reconstruction under a non-submerged healing protocol. Cone beam computed tomography (CBCT) and intraoral radiographs were used to assess changes in marginal bone level. Clinical parameters (PD, BOP, SUP, MR), linear radiographic bone level changes, and CBCT-based bone mineral density (HU) were evaluated at baseline, 6, and 12 months.

Results
Both groups showed significant clinical improvement after one year. Linear radiographic evaluation demonstrated a mean bone gain of 0.2 mm in the AB group and 1.6 mm in the BDX group. CBCT measurements showed significantly higher bone density in xenograft-treated sites (314 HU) compared with autogenous bone (298 HU; $P < 0.05$).

Conclusions
Within the limitations of this study, both autogenous and xenograft bone grafts were effective for the reconstructive treatment of peri-implant intrabony defects. However, xenografts exhibited greater bone density, suggesting superior space-maintenance properties over time.

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Keywords

Peri-implantitis, dental implants, regenerative surgery, xenograft, autogenous bone, marginal bone level, bone density, cone-beam computed tomography (CBCT)

INTRODUCTION

Periimplantitis (PI) is a biofilm-induced inflammatory disease affecting the supporting tissues around osseointegrated implants, characterized by bleeding and/or suppuration on probing, increased probing depths, and progressive bone loss (1). According to the 2018 Classification of Periodontal and Peri-Implant Diseases, PI is defined as a plaque-associated pathological condition involving inflammation of the peri-implant mucosa and progressive loss of supporting bone, diagnosed through bleeding/suppuration on probing together with radiographic bone loss beyond initial physiological remodeling (2). Given the widespread use of dental implants, PI has emerged as a major clinical concern, with reported prevalence ranging from 15–57% at the patient level and 8–28% at the implant level (2,3). Untreated PI lesions follow an accelerating and non-linear progression pattern, often culminating in implant failure (4).

The clinical relevance of peri-implantitis is further emphasized by recent hospital-based retrospective evidence indicating that peri-implantitis represents one of the leading causes of implant failure and subsequent implant removal in routine clinical practice, particularly in complex cases managed in a tertiary care setting (5)

Various therapeutic strategies have been proposed for PI, including non-surgical and surgical interventions. Non-surgical protocols, although beneficial in reducing bleeding on probing and pocket depth, are limited by insufficient access to the contaminated implant surface (6). Surgical approaches, particularly open-flap debridement, provide improved decontamination and visibility, resulting in enhanced peri-implant tissue health (7) . However, these techniques often lead to soft-tissue recession and may fail to achieve long-term bone stability (1,8).

In contrast, reconstructive or regenerative surgical therapies have shown superior outcomes, particularly for contained intrabony defects (three- or four-wall configurations) (9,10). Bone substitutes (autogenous or xenogeneic) have demonstrated potential to enhance bone fill and re-osseointegration, yet the superiority of one material over another remains controversial (3). While autogenous grafts provide osteoinductive and osteogenic potential, xenografts offer better volumetric stability and slower resorption rates, making them attractive alternatives for defect reconstruction.

Radiographic assessment included both standardized periapical radiographs and CBCT imaging. Periapical radiographs were used to evaluate changes in crestal bone levels, while CBCT enabled three-dimensional assessment of peri-implant bone morphology. Periapical permitted linear measurements of defect fill (mm) while CBCT the bone density evaluation through grey-value analysis, serving as an indirect indicator of bone mineralization (11).

Therefore, this randomized controlled clinical trial aimed to compare the clinical and radiographic outcomes of autogenous bone versus xenograft in the reconstructive treatment of peri-implant intrabony defects. The null hypothesis (H0) was that there would be no significant difference between the two grafting materials in terms of marginal bone level, bone density, and clinical parameters after one year of healing. Conversely, the alternative hypothesis (H1) was that autogenous bone grafts would result in superior outcomes over a one-year maintenance period, improving marginal bone levels and bone characteristics compared to xenograft.

MATERIAL AND METHODS

Study design and ethical approval

This randomized controlled split-mouth clinical trial was conducted at the Department of Periodontology, Faculty of Dentistry, South Valley University (Qena, Egypt) between 2022 and 2023. The protocol was approved by the Regional Ethics Committee of the Faculty of Dentistry, and all participants provided written informed consent. The study followed the Declaration of Helsinki and was reported in accordance with CONSORT guidelines.

Study population

Ten systemically healthy patients presenting with at least two implants diagnosed with peri-implantitis and exhibiting radiographic intrabony defects were enrolled. All participants adhered to a supportive periodontal care program at 3-month intervals throughout the 12-month follow-up.

Inclusion criteria

- Be able and willing to provide and sign the informed consent form and to comply with study procedures and follow-up appointments required by the protocol.
- Age ⩾18 years
- Presence of at least one implant affected with peri-implantitis, defined as the following condition: at least one site presenting PPD ⩾6mm and simultaneous presence of profuse BoP/SUP, and a radiographically documented change in bone loss greater than initial bone remodeling (0.5 mm within the first year of loading). In the likely event that a baseline radiographic image was absent, the bone level was estimated based on its expected position at the time of implant insertion, and a difference of ⩾3mm from that level was considered a sign of peri-implantitis
- Implants in function (i.e. loaded) for at least 1 year.

Exclusion criteria

- Compromised systemic health, which contraindicated the study procedures.
- Pregnant or nursing women.
- Cigarette smoking >20 per day
- Implants with >60% of bone loss on at least one aspect of the implant, or clinical mobility.
- Implants already treated previously (with surgical or non-surgical therapy) for peri-implantitis.
- Uncontrolled diabetes (HbA1c >46 mmol/mol).
- Current corticosteroid or anti-inflammatory therapy or systemic anti-resorptive medications.
- Systemic antibiotic use within the preceding 3 months.

Sample size considerations

This pilot split-mouth trial did not include a formal sample size calculation. Ten patients were enrolled to provide preliminary estimates of variability and treatment effect for both linear bone gain and bone density outcomes. The split-mouth design increased internal validity by reducing inter-patient variability. While the small sample limits generalizability, the data obtained serve as a basis for powering future larger randomized trials.

Randomization and blinding

An independent researcher generated a computer-based randomization sequence. Allocation was concealed using sealed opaque envelopes. For each patient, one defect was assigned to the autogenous bone graft group (AB) and the contralateral defect to the xenograft group (BDX).

All clinical and radiographic measurements were performed by the same calibrated examiner, blinded to group allocation. Intra-examiner reproducibility exceeded 90% agreement for probing measurements and radiographic assessments.

Treatment protocol

Pre-treatment procedures

All patients received full-mouth periodontal therapy 6 weeks prior to surgery, including supra- and subgingival debridement of natural teeth and nonsurgical peri-implant debridement using titanium curettes (Hu-Friedy, Mfg. Co, LLC., Titanium implant Scalers). Oral hygiene was reinforced until adequate plaque control (FMPS and FMBS <20%) was achieved.

During the baseline (T0) appointment, clinical parameters were recorded, followed by the surgical intervention.

Surgical procedures

All surgical interventions were performed under local anesthesia using 2% lidocaine with epinephrine (1:100,000). Intrasulcular incisions were made around the affected implant, extending mesially and distally as needed to expose the defect. Full-thickness flap was elevated on the buccal and lingual aspects to provide complete access to the peri-implant defect and implant surface.

Granulation tissue was meticulously removed using titanium curettes, followed by mechanical debridement of the implant surface with titanium brushes (NiTibrush, Hans Korea Co Ltd) under copious sterile saline irrigation. Particular attention was given to ensuring complete removal of contaminated tissue and biofilm from all exposed implant threads.

Surface decontamination was standardized and performed in a sequential manner:

1. Irrigation with 0.2% chlorhexidine digluconate to reduce the bacterial load.
2. Application of citric acid gel (pH 1) for 1 minute using sterile microbrushes to condition the implant surface.
3. Rinsing with hydrogen peroxide to enhance decontamination.
4. Final irrigation with sterile saline to remove all chemical residues.

Defect morphology was assessed clinically to ensure adequate containment prior to grafting.

Autogenous grafts were harvested either from the adjacent alveolar ridge, the retromolar area, or the symphyseal chin region using bone scrapers. The particulate graft was gently condensed into the intrabony defect in the autogenous bone group (AB). In the xenograft group (BDX), the defect was filled with deproteinized bovine bone mineral block (DBBM), packed without excessive compression to maintain porosity and volume stability.

Flap closure followed the same standardized protocol in all cases. Closure was completed using horizontal mattress sutures combined with interrupted sutures, both placed with 4-0 or 5-0 non-resorbable monofilament material (e.g., polypropylene), ensuring primary closure over the grafted area. Special care was taken to eliminate dead space and create secure flap stability throughout the early healing phase.

Postoperative care and maintenance

Postoperative measures included prescription of analgesics as needed and individualized systemic antibiotics based on susceptibility testing. All patients were instructed to avoid brushing in the operated area for the first 2 week and to rinse with 0.12% chlorhexidine digluconate twice daily until suture removal at 14 days. Regular follow-up during the first month (every 2 weeks) and throughout the 12-month maintenance period ensured adequate plaque control, early identification of complications, and professional supragingival debridement.

Radiographic Outcomes

Primary outcomes

- Marginal Bone Level (BL): distance between a known reference point and the mesial and distal aspects of the implant (mm)
- Bone mineral density (HU): Bone mineral density (BMD) was recorded at the first two implant threads on mesial, distal, buccal and lingual aspects and expressed in Hounsfield Units (HU)

Clinical Outcomes

All clinical examinations were performed at baseline, 6 and 12 months, and were recorded at six sites per implant: mesio-buccal, mid-buccal, disto-buccal, mesio-lingual, mid-lingual, and disto-lingual, using a periodontal probe.

Secondary outcomes

- Plaque Index.
- Probing pocket depth (PPD).
- Bleeding on probing (BOP).
- Suppuration on probing (SUP).
- Mucosal recession (MR).

Statistical analysis

Normality was assessed using the Shapiro–Wilk test. Intragroup comparisons were performed using paired t-tests; intergroup comparisons using independent t-tests. For non-parametric distributions, Wilcoxon and Mann–Whitney tests were applied. Significance was set at $p < 0.05$. Statistical analyses were performed using SPSS v26.0 (IBM Corp.).

RESULTS

A total of 10 patients (mean age 61.7 years; 4 males and 6 females) with 20 peri-implant intrabony defects were included in the analysis (Table 1). Four patients were smokers, and six were non-smokers. Implants were located in the maxilla (n = 4) and mandible (n = 6), with a mean time in function of 7.1 ± 2.0 years at the time of peri-implantitis diagnosis (Table 1). All participants completed the 12-month follow-up period. No intraoperative or postoperative complications were recorded, and all implants remained in function throughout the observation period.

Variable	Value
Age (years), mean	61.7
Sex (M/F)	4 / 6
Smoking status	Smokers: 4 • Non-smokers: 6
Implant location	Maxilla: 4 • Mandible: 6
Time in function (years), mean ± SD	7.1 ± 2.0
Baseline PPD (mm)	AB: 7.0 ± 1.8 • BDX: 7.1 ± 1.2
Baseline BOP (% sites)	100% in both groups
Baseline SUP (% sites)	AB: 79.5% • BDX: 86.5%
Baseline BL (mm)	AB: 5.3 ± 1.2 • BDX: 4.9 ±1.1
Baseline IDD (mm)	AB: 4.9 ± 0.9 • BDX: 5.9 ±1.8
Baseline bone density (HU)	AB: 297.8 • BDX: 314.3
Defect morphology	Predominantly 3-wall defects

Tab. 1 Demografic and clinical parameters.

Primary outcomes (Table 2)

Linear bone gain (mm)

Radiographic assessment demonstrated improvements in defect fill in both treatment groups. Mean linear bone gain between baseline and 12 months was:

- Autogenous bone (AB): 0.2 mm
- Xenograft (BDX): 1.6 mm

Outcome	Autogenous Bone (AB)	Xenograft (BDX)
PRIMARY OUTCOMES		
Linear bone gain (mm)	0.2 mm	1.6 mm
Bone density (HU)	297.8 HU	314.3 HU
SECONDARY OUTCOMES		
PPD (mm)	Baseline: 7.0 ± 1.8	Baseline: 7.1 ± 1.2
	12 months: 3.4 ± 0.6	12 months: 3.4 ± 0.5
BOP (% sites)	Baseline: 100%	Baseline: 100%
	12 months: 45.5%	12 months: 50.0%
SUP (% sites)	Baseline: 79.5%	Baseline: 86.5%
	12 months: 0%	12 months: 1.9%

Tab. 1 Demografic and clinical parameters.

Evidence of radiographic bone fill was observed in 5 implants in the AB group and 7 implants in the BDX group (Table 2).

Bone mineral density (HU)
CBCT analysis demonstrated an increase in bone mineral density across both groups:
- AB: 297.8 HU
- BDX: 314.3 HU

The mean difference in density values was statistically significant (p = 0.039). Thread-level analysis showed significant HU increases at:
- First thread: buccal (p = 0.006), mesial (p = 0.043), distal (p = 0.033)
- Second thread: buccal (p = 0.002), distal (p = 0.001) No significant changes were detected at deeper implant threads.

Secondary outcomes (Table 2)

Probing depth (PPD)
A marked reduction in PPD was observed in both groups:
- AB: 7.0 ± 1.8 mm at baseline —> 3.4 ± 0.6 mm at 12 months
- BDX: 7.1 ± 1.2 mm at baseline —> 3.4 ± 0.5 mm at 12 months

Bleeding on probing (BOP)
Bleeding decreased substantially:
- AB: 100% —> 45.5%
- BDX: 100% —> 50.0%

Suppuration
Suppuration was nearly eliminated:
- AB: 79.5% —> 0%
- BDX: 86.5% —> 1.9%

Plaque index (PPI)
Plaque levels decreased in both groups:
- AB: 31.7% —> 17.5%
- BDX: 29.4% —> 14.0%

Mucosal recession (MR)
A postoperative increase in recession was noted:
- AB: 1.31 ± 0.47 mm
- BDX: similar trend (non-quantified)

Intrabony defect depth (IDD)
The intrabony component decreased as follows:
- AB: 4.9 ± 0.9 mm —> 2.4 ± 0.6 mm
- BDX: 5.9 ± 1.8 mm —> 2.9 ± 1.3 mm

Both treatment modalities demonstrated favorable clinical and radiographic improvements over 12 months, with the xenograft group showing greater linear bone gain and higher bone density, while clinical outcomes (PPD, BOP, SUP, PI) improved similarly in both groups. No implants were lost and healing was uneventful.

DISCUSSION

The present randomized controlled clinical trial evaluated the clinical and radiographic outcomes of reconstructive surgical treatment of peri-implantitis using autogenous bone or xenograft. The findings of the present study should be interpreted in the context of previously published randomized clinical trials and systematic reviews comparing these grafting materials in peri-implant intrabony defects.
In the present study, both treatment groups showed improvements in clinical parameters and radiographic outcomes; however, xenograft-treated sites demonstrated more stable marginal bone levels and more consistent radiographic defect fill over the one-year follow-up. These findings are in line with long-term clinical data reporting superior treatment success rates for xenograft compared with autogenous bone. In particular, a five-year analysis reported a probability of treatment success of 78% for xenograft-treated implants versus 36% for those treated with autogenous bone, with a mean marginal bone gain of approximately 1.6 mm in the xenograft group, whereas autogenous grafts were associated with progressive bone loss over time (9). Similarly, in the present study, autogenous bone did not demonstrate superior marginal bone stability compared with xenograft.
Short-term clinical trials with a 12-month follow-up have also reported greater radiographic bone fill and improved clinical parameters following regenerative surgery using xenograft materials compared with autogenous bone (12). These outcomes are consistent with the results of the present study, in which xenograft-treated sites exhibited a more predictable radiographic pattern, while autogenous bone showed greater variability in bone fill. This variability may be related to the rapid resorption and limited space-maintaining capacity of autogenous bone, particularly in peri-implant intrabony defects.
Network meta-analyses have further demonstrated that xenogenic bone substitutes outperform autogenous bone in terms of reduction of bleeding on probing, probing pocket depth, and radiographic bone level changes (13). These findings support the clinical trends observed in the present study, where improvements in inflammatory parameters were achieved in both groups, but with a more favorable overall outcome in the xenograft group.
CBCT analysis in the present study provided additional information on bone characteristics. Xenograft-treated sites showed a more stable pattern of bone density over time, which is consistent with previous reports indicating that xenografts maintain defect

volume due to their low resorption rate (14). In contrast, although autogenous bone is traditionally regarded as the reference graft material due to its osteogenic potential, studies have consistently reported less predictable outcomes in peri-implantitis reconstruction (12,9). The present findings are in agreement with these observations, as autogenous bone did not result in superior radiographic outcomes. Regarding safety, no significant differences in adverse events or postoperative complications were observed in the present study, which is consistent with previous clinical reports indicating comparable complication rates between autogenous bone and xenograft materials. Furthermore, published evidence suggests that the adjunctive use of barrier membranes in combination with xenografts does not provide additional clinical or radiographic benefits (15,13), a finding that aligns with the outcomes observed in the present study.

Taken together, the results of the present trial are largely consistent with previously published randomized clinical trials and systematic reviews, indicating that xenograft materials provide more predictable and stable clinical and radiographic outcomes than autogenous bone in the reconstructive surgical management of peri-implantitis

Limitations

The present study has some limitations that should be considered when interpreting the results. The sample size was relatively limited, and the follow-up period was restricted to one year, which does not allow conclusions to be drawn regarding long-term stability of the regenerated peri-implant bone. In addition, bone density assessment based on CBCT grey values represents an indirect measure of bone quality and lacks full standardization. Finally, although standardized surgical and maintenance protocols were applied, complete blinding was not feasible due to the nature of the interventions

CONCLUSION

Within the limitations of the present study, reconstructive surgical treatment of peri-implantitis resulted in significant clinical and radiographic improvements. The outcomes observed with xenograft materials are consistent with those reported in previous randomized clinical trials and systematic reviews, demonstrating superior predictability and marginal bone stability compared with autogenous bone grafts.

The present findings further support the use of xenograft materials as a reliable option for peri-implant regenerative surgery, particularly in severe intrabony defects where long-term stability is a primary clinical objective. The choice of grafting material should therefore be guided by defect morphology, expected volumetric stability, and long-term treatment predictability rather than by theoretical biological properties alone.

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