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Original Article

Seven-Year Esthetic and Radiographic Stability of Anterior Maxillary Implants after DBBM–Collagen Matrix Ridge Preservation

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ABSTRACT

This study aimed to assess the prolonged esthetic appearance and radiographic performance of dental implants positioned in the anterior maxilla following ridge preservation using a bovine-derived graft in combination with a collagen membrane. Fifteen participants who required extraction of a single tooth because of fracture, root resorption, or extensive decay were enrolled. Each socket was filled with Deproteinized Bovine Bone Mineral (DBBM) integrated with collagen and covered by a resorbable collagen matrix (CM). Implants measuring 3.8–4.2 mm in diameter were inserted five months after grafting. All subjects were followed clinically and radiographically for more than seven years. The esthetic evaluation was performed by three independent reviewers utilizing the Pink Esthetic Score (PES) system. After more than seven years, a 100% survival rate was recorded for all 15 implants, showing minimal marginal bone reduction. The mean PES values were 11.40 (±1.44) at the initial evaluation and 11.38 (±1.63) at the later one, with no significant difference ($p = 0.978$). These data indicate that grafting extraction sockets with collagen-enriched bovine bone and sealing them with a collagen matrix helps maintain the alveolar contour and ensures durable esthetic success.

Keywords: Implants, Esthetics, Regeneration, Collagen, PES

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Introduction

Tooth extraction initiates a series of biological events involving bone modeling and remodeling during socket healing [1]. This progressive, irreversible process results in notable structural and dimensional alterations at the edentulous site, leading to approximately a 50% loss of ridge volume within six months [1–3]. Such shrinkage often decreases the width of soft tissue and keratinized mucosa, generating esthetic issues around restorations or complicating implant placement, thus requiring guided bone regeneration (GBR) [3–6]. Immediate implant insertion into a fresh socket cannot fully prevent bone contraction, particularly of the buccal plate, and may cause esthetic compromise [4, 7–10].

Over the last twenty years, numerous investigations have explored the effectiveness of alveolar ridge preservation (ARP). These typically involved minimally invasive extractions and immediate grafting of the socket with particulate substitutes and GBR techniques, either with or without additional grafts. Materials used for such procedures (ARP-SG) include xenografts, allografts, alloplasts, autogenous bone, and biologically active factors. Most meta-analyses concur that ARP-SG significantly reduces vertical and horizontal ridge resorption [11–14].

The compatibility of Deproteinized Bovine Bone Mineral (DBBM) within extraction sockets and its capacity to integrate with regenerated bone have been confirmed through many experimental and clinical trials [15–17]. These studies, which analyzed tissue composition about six months post-placement, found

slightly delayed healing yet superior ridge preservation compared to untreated sites [18]. After nine months, sufficient bone volume and density were generally reported, allowing predictable implant installation [18].

In recent years, bone grafting innovations have produced mixtures combining DBBM granules with porcine collagen (typically 90% DBBM and 10% collagen), offering better moldability and clinical handling [17]. Evidence shows that when applied alone to fresh extraction sites, these composites maintain alveolar dimensions effectively, and long-term reviews have shown stable implants and minimal bone loss even up to a decade later [19].

Soft tissue handling around extraction areas is equally vital for esthetic rehabilitation. Traditional palatal soft tissue grafting procedures often resulted in longer surgery, potential graft necrosis, and postoperative discomfort. New xenogeneic, bilayer, non-cross-linked collagen matrices (CMs) made from porcine sources have emerged, aiming to enhance soft tissue repair, reduce patient pain, and lower complication rates [19, 20].

These matrices, composed of pure type I and III collagen, are pre-formed and ready to use, particularly effective for sealing sockets during ridge preservation with an intact buccal wall [21]. The denser outer layer adheres well to oral tissue margins, while the porous inner layer facilitates integration and rapid vascularization [22, 23]. Clinical and histologic data show successful tissue regeneration, re-epithelialization, and incorporation without inflammation, producing better soft tissue thickness, width, and color match compared with natural healing [20, 21].

Despite the progress achieved in ridge preservation, variations still exist concerning augmentation needs, esthetic predictability, and implant longevity [24]. Moreover, the majority of research focuses on short-term outcomes—usually less than three years [25].

For assessing peri-implant soft tissue esthetics, the Pink Esthetic Score (PES) method was introduced, offering standardized and objective evaluation criteria for implant-supported restorations [26]. Its reliability and repeatability have been proven in several studies [27, 28].

Accordingly, this research presents a clinical approach using DBBM combined with collagen (Geistlich Bio-Oss® Collagen, Geistlich, Wolhusen, Switzerland) and a collagen seal (Mucograft® Seal, Geistlich, Wolhusen, Switzerland) for grafting fresh extraction sockets. The main goal was to examine long-term soft tissue and radiographic stability of implants placed at these sites over more than seven years. The secondary goal was to confirm the consistency and reproducibility of the Pink Esthetic Score (PES) assessment technique.

Materials and Methods

Study population

This retrospective clinical investigation involved participants who needed removal of a single tooth within the visible maxillary region because of fracture, root resorption, or deep carious destruction **(Table 1)**. Molars were intentionally excluded. All subjects presented stable periodontal conditions and lacked medical problems that could compromise healing, such as uncontrolled diabetes, chronic steroid therapy, heavy smoking, or blood-related illnesses.

Table 1. Characteristics of participants included in the analysis.

Case	Tooth Position	Reason for Extraction	Bone dehiscence	Implant Brand	Diameter/Length (mm)	Follow-Up Duration (Years)	True linear bone loss (mm)	Percentage of Bone Loss
Patient 1	21	Fracture	NO	3i Biomet	4/13	10	0.92 mm	7.7%
Patient 2	24	Fracture	NO	3i Biomet	4/13	10	0.0 mm	0%
Patient 3	12	Caries	NO	3i Biomet	4/12	10	0.37 mm	2.8%
Patient 4	12	Fracture	NO	Biohorizon	3.8/12	9	0.0 mm	0%
Patient 5	13	Fracture	NO	Biohorizon	3.8/12	7	0.0 mm	0%
Patient 6	22	Caries	NO	Biohorizon	3.0/12	8	0.46 mm	3.8%
Patient 7	21	Fracture	NO	Biohorizon	3.8/12	8	0.46 mm	3.8%
Patient 8	14	Fracture	Buccal	Biohorizon	4.2/12	7	0 mm	0%
Patient 9	22	Fracture	NO	Biohorizon	3.8/12	8	0.55 mm	4.6%

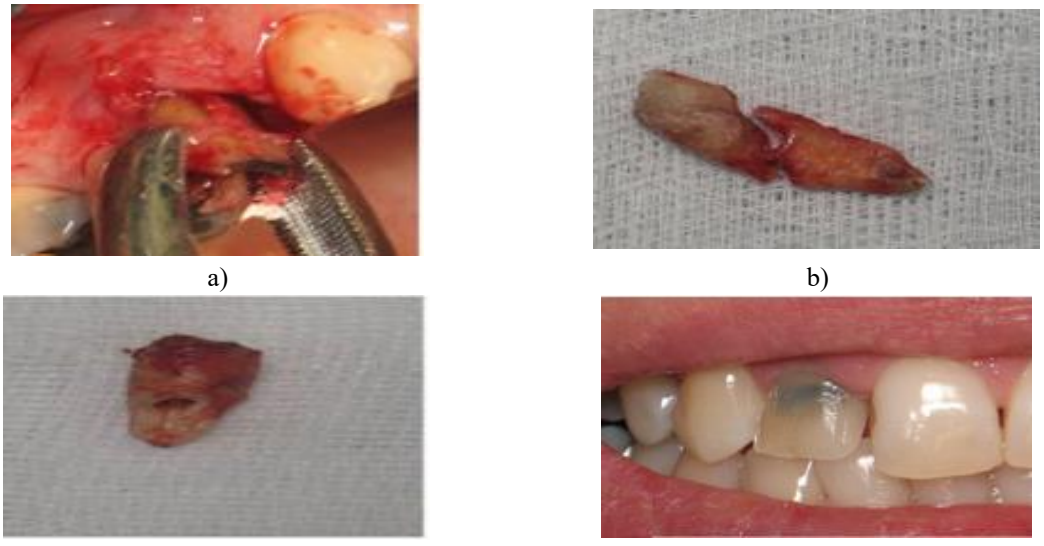
Patient 10	12	Caries	NO	Biohorizon	3.8/12	8	0 mm	0%
Patient 11	22	Resorption	Palatal	Biohorizon	3.8/12	7	0 mm	0%
Patient 12	22	Resorption	NO	Biohorizon	3.8/12	7	0.46 mm	3.8%
Patient 13	15	Fracture	Buccal	Biohorizon	3.8/12	8	0.6 mm	5%
Patient 14	11	Caries	NO	Biohorizon	3.8/12	8	0 mm	0%
Patient 15	15	Fracture	Buccal	Biohorizon	4.2/12	7	0 mm	0%

Each patient received information about several treatment approaches and voluntarily chose the plan consisting of extraction, ridge preservation, and subsequent implant therapy. Before any clinical work, participants were informed about the study and provided written consent.

Surgical approach and implant placement

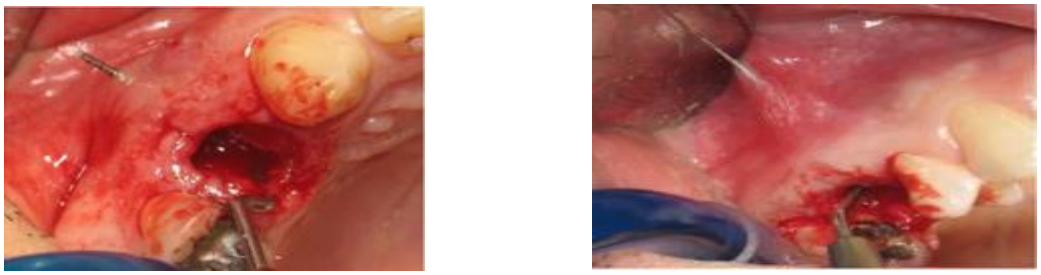
All clinical stages were conducted at the Periodontology Department, Aristotle University of Thessaloniki. Pre-operative assessment included periapical radiographs and cone-beam CT imaging. Extractions were carried out gently on the day of surgery, avoiding elevation of buccal flaps **(Figure 1)**. In some instances, parts of the buccal plate were absent or perforated—verified when a periodontal probe passed entirely through the site **(Figure 2)**.

Immediately afterward, the sockets were packed with Deproteinized Bovine Bone Mineral (DBBM) combined with collagen (Bio-Oss Collagen; Geistlich, Wolhusen, Switzerland) **(Figures 3a and 3b)**. The graft was stabilized by suturing and sealed using a resorbable collagen cover (Mucograft® Seal; Geistlich, Wolhusen, Switzerland, DMPS Biomaterials) **(Figures 3c and 3d)**.



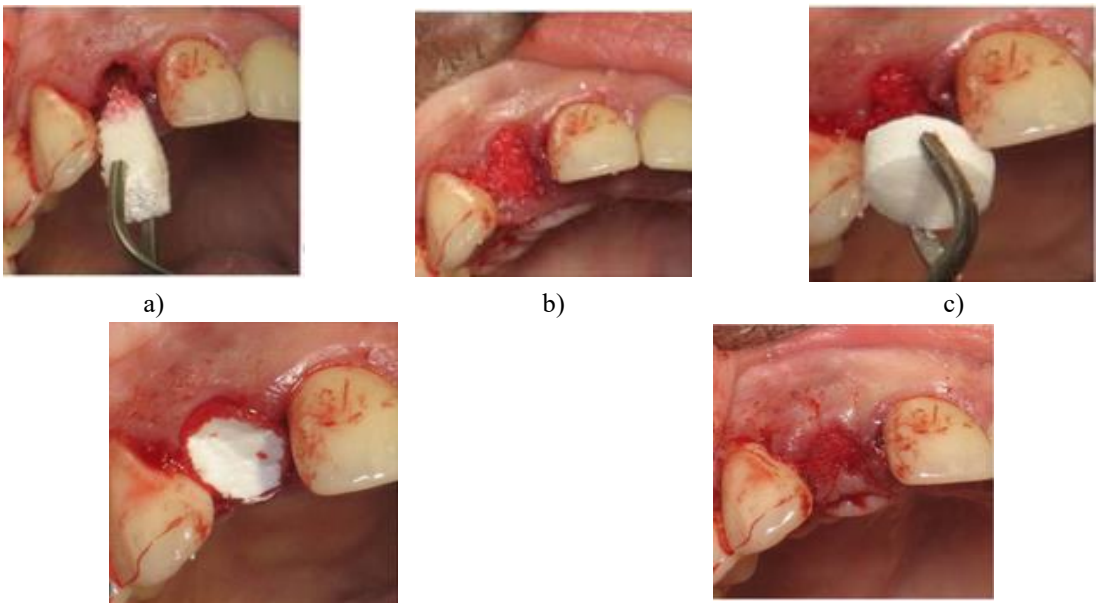
a) b) c) d)

Figure 1. (a) Atraumatic extraction; (b–d) examples of removed teeth because of fracture, resorption, or decay.



a) b)

Figure 2. Instances showing dehiscence in buccal and/or palatal plates.

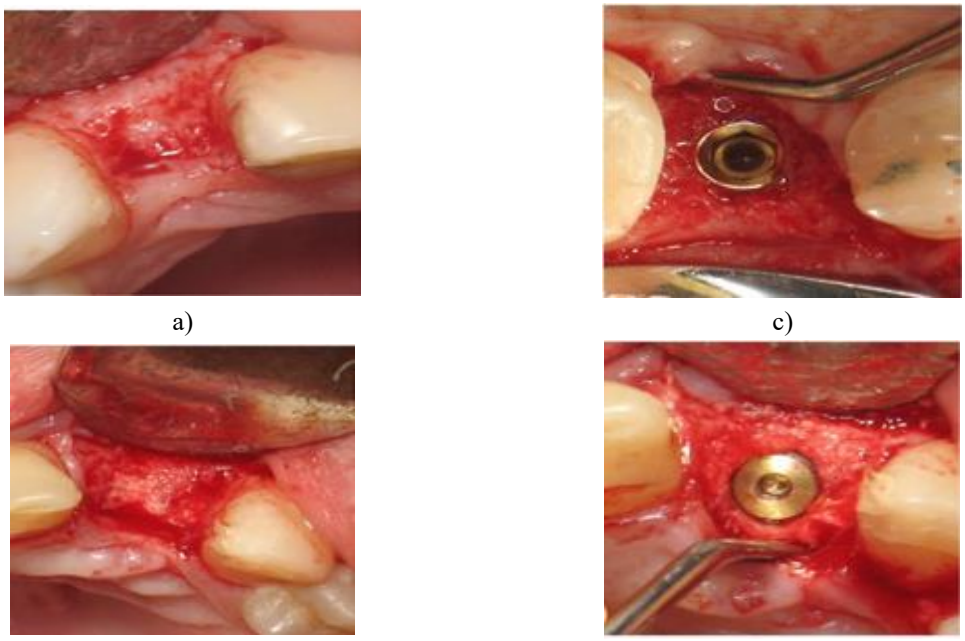


a) b) c)

d) e)

Figure 3. (a,b) Socket grafting with DBBM + collagen; (c–e) sealing using a resorbable collagen matrix.

After roughly five months, full-thickness flaps were elevated and dental implants placed in accordance with manufacturer instructions (3i Biomet, Florida, USA) **(Figure 4)**. Implant diameters varied from 3.8 mm to 4.2 mm, and all achieved immediate primary stability. Four months later, healing abutments were connected. Definitive single-unit screw-retained restorations were fabricated and delivered by the Prosthodontics Department, Aristotle University of Thessaloniki. Following completion, patients entered a scheduled maintenance phase.



a) c)

b) d)

Figure 4. (a) Condition five months post-graft, (b) flap elevation, (c,d) new bone observed and implants positioned.

Control of infection and discomfort

To minimize postoperative complications, participants received 2 g amoxicillin–clavulanic acid starting one day before surgery and continued for six days afterward (625 mg three times daily). For analgesia, ibuprofen 600 mg was prescribed three times per day.

Long-term evaluation of esthetic and radiographic parameters

Follow-up examinations—clinical and radiographic—were performed for at least seven years. These included standardized periapical radiographs (parallel technique), probing depth measurements, assessment of marginal bone changes, and photographic documentation **(Figure 5)** [22]. Marginal bone loss (BL) was calculated from the most recent radiograph using the following relation: True linear BL = (radiographic BL × actual implant length) / relative radiographic implant length **(Figure 6)**.

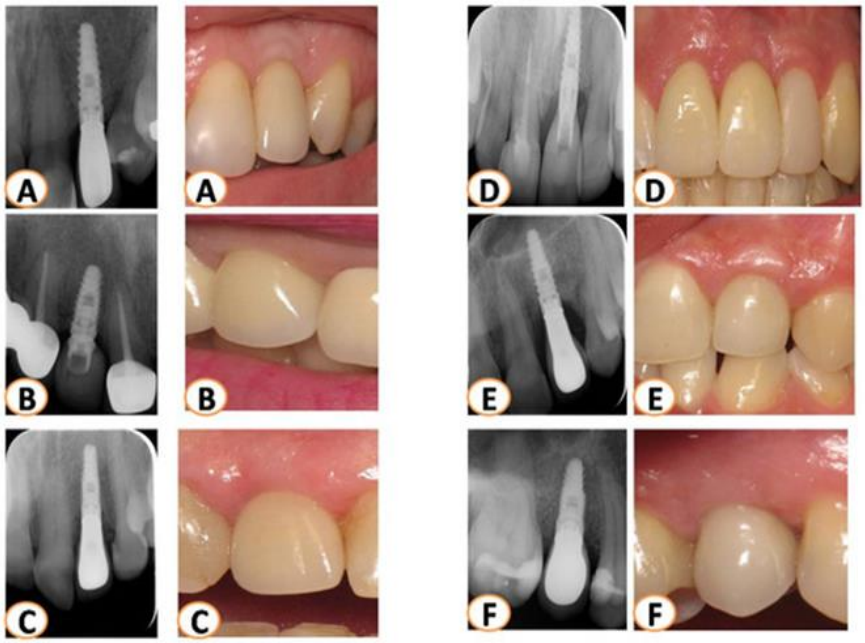


Figure 5. Representative long-term follow-ups (≥ 7 years) using radiographs and photographs (cases A–F).

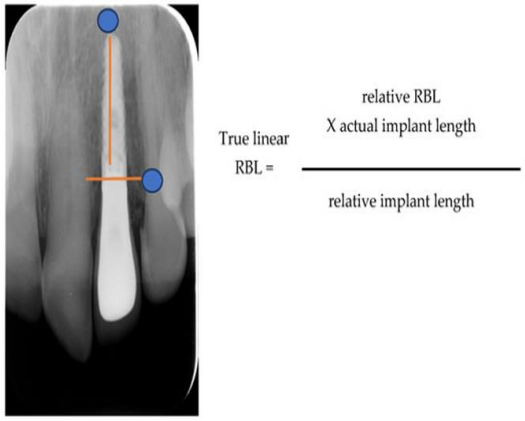


Figure 6. Diagram illustrating calculation of true linear bone loss.

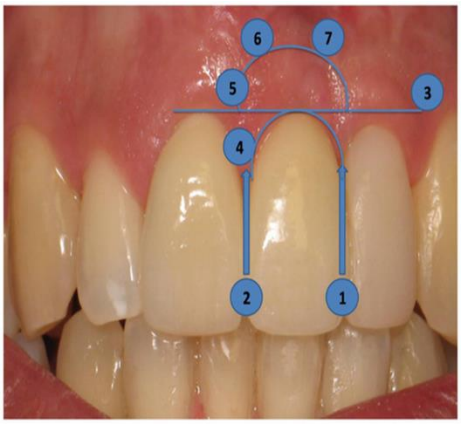


Figure 7. Variables of the PES system: (1) mesial papilla, (2) distal papilla, (3) soft-tissue margin, (4) contour, (5) ridge shape, (6) color, (7) texture.

Soft-tissue esthetics were analyzed using the Pink Esthetic Score (PES) method **(Figure 7)**. Standardized intraoral photographs were scored across seven criteria, each valued from 0 to 2, giving a total range of 0 (poor match) to 14 (perfect match). The parameters assessed were: (1) mesial papilla, (2) distal papilla, (3) height of soft-tissue margin, (4) tissue contour, (5) ridge profile, (6) color of mucosa, and (7) surface texture **(Figure 7)**.

The mesial and distal papillae were examined to determine whether they were complete, partially preserved, or missing. All remaining soft-tissue parameters were benchmarked against a reference tooth—the corresponding tooth in the anterior segment or a neighboring one in the premolar region **(Figure 6)**. To ensure consistent assessment, three postgraduate clinicians from the Periodontology Department, Aristotle University of Thessaloniki, performed two

calibration sessions spaced 15 days apart, each reviewing five cases. The findings showed strong agreement and reliability among all observers for every variable analyzed **(Table 2)**.

Table 2. Intra-examiner reliability for each observer.

Variable	1st Assessment		2nd Assessment			
	Examiner 1 ICC* (95% CI)	p Value	Examiner 2 ICC (95% CI)	p Value	Examiner 3 ICC (95% CI)	p Value
Mesial Papilla	0.576 (0.088–0.841)	0.12	0.847 (0.690–0.948)	<0.01	1.000	<0.01
Distal Papilla	0.896 (0.708–0.965)	<0.01	0.732 (0.350–0.905)	<0.01	0.930 (0.796–0.977)	<0.01
Level of the soft tissue margin	0.727 (0.345–0.904)	<0.01	0.860 (0.621–0.953)	<0.01	1.000	<0.01
Soft tissue contour	0.772 (0.428–0.921)	<0.01	1.000	<0.01	1.000	<0.01
Color	0.866 (0.634–0.955)	<0.01	0.847 (0.546–0.948)	<0.01	0.896 (0.708–0.965)	<0.01
Texture	0.778 (0.441–0.923)	<0.01	0.930 (0.796–0.977)	<0.01	0.839 (0.727–0.972)	<0.01
Overall	0.732 (0.431–0.905)	<0.01	0.920 (0.804–0.985)	<0.01	0.958 (0.975–0.986)	<0.01

ICC = Intraclass Correlation Coefficient

Statistical processing

Quantitative variables were presented as means ± standard deviation, while categorical data were summarized as counts and percentages. The Shapiro–Wilk test was applied to check normality of distribution, guiding the use of parametric or non-parametric analyses. Comparisons between paired measurements of PES components were made with the Wilcoxon signed-rank test, and Spearman's rank correlation was used to evaluate intra- and inter-examiner consistency. Statistical processing was carried out in STATA 13 (StataCorp LP, College Station, TX, USA). A p-value ≤ 0.05 was considered statistically significant.

Results and Discussion

This study included 15 individuals. Of these, three exhibited loss of the buccal plate and one displayed a palatal defect. Among extracted teeth, nine were removed following fracture, two due to root resorption, and four because of deep carious lesions. The mean observation period extended to 8.7 years.

At implant placement, clinicians found that the grafted sockets had been replaced by mature bone, and primary implant stability was achieved in every case. Postoperative swelling occurred in all participants but resolved uneventfully. Only three patients received removable temporary prostheses; the others were restored with a Maryland bridge until final rehabilitation. After a four-month healing phase, abutments were installed and definitive crowns delivered. Around all implants, 3–4 mm of keratinized mucosa and tissue thickness greater than 4 mm were observed.

Radiographic evaluation of bone changes

Following prosthetic completion, all patients were enrolled in a long-term maintenance protocol. Annual radiographs were obtained for over seven years (mean: 8.2 years) **(Table 1 and Figure 5)**. All 15 implants remained functional, giving a 100 percent survival rate. The marginal bone reduction was minimal, ranging between 0 and 0.92 mm, equivalent to an average loss of 2.25 percent.

Aesthetic evaluation using PES

During both evaluation rounds, three independent reviewers assessed 15 cases, producing 45 scores per round. Each examiner completed two separate scorings. The mean Pink Esthetic Score measured 11.40 (±1.44) in the initial assessment and 11.38 (±1.63) in the subsequent one. No meaningful difference was detected between them (p = 0.978) [23]. The alveolar ridge profile and soft-tissue outline consistently received the highest marks in both evaluations. Differences between mean values of each parameter were statistically insignificant **(Table 3)**. Both sessions exhibited excellent reproducibility among raters **(Table 4)**.

Table 3. Mean PES values and inter-session comparison of variables.

PES Variable	Mean (±SD) – 1st Assessment	Mean (±SD) – 2nd Assessment	p Value
Mesial Papilla	1.69 (±0.46)	1.71 (±0.45)	0.564
Distal Papilla	1.40 (±0.44)	1.42 (±0.63)	0.655
Level of the soft tissue margin	1.64 (±0.48)	1.61 (±0.49)	0.564
Soft tissue contour	1.83 (±0.37)	1.85 (±0.35)	0.317
Alveolar Process	1.95 (±0.21)	1.99 (±0.18)	0.157
Color	1.57 (±0.5)	1.59 (±0.54)	0.554
Texture	1.26 (±0.07)	1.06 (±0.7)	0.981

Table 4. Examiner reproducibility between assessments.

1st Evaluation		
Variable	**ICC* (95% CI)**	**p Value**
Mesial Papilla	0.925 (0.817–0.974)	<0.01
Distal Papilla	0.924 (0.815–0.974)	<0.01
Level of the soft tissue margin	0.879 (0.702–0.958)	<0.01
Soft tissue contour	0.940 (0.853–0.979)	<0.01
Alveolar Process	—	—
Color	0.834 (0.594–0.94)	<0.01
Texture	0.944 (0.843–0.984)	<0.01
Overall	0.935 (0.842–0.977)	<0.01
2nd Evaluation		
Variable	**ICC (95% CI)**	**p Value**
Mesial Papilla	0.918 (0.758–0.971)	<0.01
Distal Papilla	0.802 (0.515–0.931)	<0.01
Level of the soft tissue margin	0.877 (0.697–0.977)	<0.01
Soft tissue contour	1.000	<0.01
Color	0.829 (0.581–0.941)	<0.01
Texture	0.969 (0.924–0.989)	<0.01
Overall	0.920 (0.844–0.935)	<0.01

ICC = Intraclass Correlation Coefficient

Following tooth extraction, the alveolar ridge undergoes considerable structural and soft tissue alterations. Multiple investigations have documented these transformations, providing a deeper understanding of the biological sequence during post-extraction healing.

In a histologic investigation by Araújo *et al*., two distinct resorptive phases were identified after extraction. The process begins with bundle bone resorption inside the socket, followed by external surface resorption of the socket wall, leading collectively to a significant vertical reduction of the buccal bone plate [4].

Similarly, Cardaropoli *et al*. described a sequential pattern of socket repair. Within three days, a blood clot occupies the socket, replaced by provisional connective tissue (PCT) by day 7. By day 14, a mixture of woven bone and provisional matrix (PM) fills the area, progressing to 88% mineralized bone at day 30. Over time, bone volume declines to 15% at day 180, while bone marrow (BM) increases from 75% at day 60 to 85% at day 180 [19].

These histological findings align with clinical evidence indicating that the alveolar ridge may lose an average of 4 mm horizontally and 1 mm vertically after extraction [18]. Importantly, atraumatic or flapless techniques have not been shown to prevent such resorption in long-term follow-ups [4].

Some studies have proposed that immediate implant placement into fresh sockets may mitigate ridge

resorption [20]. Yet, other research has failed to confirm these benefits [2, 4], underscoring the complexity of post-extraction bone remodeling. To minimize these dimensional changes, various alveolar ridge preservation (ARP-SG) strategies have been explored, including autografts, xenografts, allografts, alloplasts, and growth-factor–based substitutes. Systematic reviews consistently support that ARP-SG significantly limits bone loss in both vertical and horizontal planes [6, 12, 26, 29].

A recent meta-analysis comparing xenografts with natural extraction healing showed a mean difference (MD) of −1.18 mm (95% CI: −1.82 to −0.54; $p = 0.0003$; $I^2 = 82\%$) for bucco-lingual/palatal width, and −1.35 mm (95% CI: −2.00 to −0.70; $p < 0.0001$; $I^2 = 87\%$) for ridge height [24].

In this investigation, the Pink Esthetic Score (PES) was used to assess long-term esthetic outcomes after ridge preservation using xenograft combined with collagen matrix in the anterior maxilla. Both evaluations revealed an average PES of 11.4, reflecting a highly favorable esthetic result, consistent with the literature. For example, Juodzvalys and Wang reported a PES of 11 one year after immediate implant placement with socket grafting [25], while Chen *et al*. recorded 11.1 after two years in non-augmented delayed implants [23]. Cosyn *et al*. observed mild soft-tissue recession three years postoperatively following immediate implants with limited augmentation [30].

Nevertheless, long-term data exceeding five years remain uncommon. In this study, excellent esthetics persisted for over seven years, confirming the stability of the protocol. A PES of 10–12 signifies good esthetics, while 13–14 indicates an optimal outcome; the obtained 11.4 therefore reflects a highly acceptable esthetic result.

The PES method is recognized for its accuracy and reproducibility [27, 28]. Here, assessments by three calibrated examiners, conducted twice, yielded ICC values above 0.8, confirming strong inter-rater consistency. While prior research noted variations among specialists [27], this was not evident in our data since all evaluators were trained periodontists with equivalent experience.

Findings indicate that socket grafting with Deproteinized Bovine Bone Mineral (DBBM) enriched with collagen and sealed using a resorbable collagen matrix (CM) results in predictable, reproducible, and durable outcomes. The implants demonstrated a 100% survival rate and negligible bone loss after seven years, even in sites lacking the buccal plate. This supports earlier reports validating DBBM-collagen combinations (e.g., Bio-Oss® Collagen) as effective for ridge preservation [31, 32]. The consistent use of CM further enhances soft-tissue regeneration, as evidenced by 3–4 mm keratinized mucosa and 4–5 mm tissue thickness in all subjects [33–35].

This aspect is clinically meaningful, given evidence that thicker peri-implant soft tissue protects against crestal bone remodeling, whereas thin tissues correlate with early marginal bone loss [36–38].

The distinct contribution of this study lies in its >7-year longitudinal follow-up, documenting both esthetic and radiographic stability of this ridge preservation approach. Nevertheless, direct comparison with alternative graft materials was not included. Although CBCT offers superior precision in evaluating bone formation, it was unavailable for all patients, particularly those treated more than six years prior. As a retrospective case series, this research relied on periapical radiographs and clinical evaluation, acknowledging the possibility of unmeasured buccal or palatal changes. Future controlled clinical trials with different graft compositions are required to confirm and expand upon these outcomes.

Conclusion

Within the limitations of this study, it can be concluded that the use of Deproteinized Bovine Bone Mineral (DBBM) in combination with collagen, covered by a resorbable collagen matrix (CM), effectively maintains alveolar ridge volume following extraction. The placed implants demonstrated a 100% survival rate, stable esthetic appearance, and minimal radiographic bone loss over a long-term (7+ year) period.

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Conflict of Interest: None

Financial Support: None

Ethics Statement: None

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