

Soft And Hard Tissue Evaluation Following Delayed Dental Implant Placement With and Without Porcine-Derived Collagen Matrix: A 4-Month Clinico-Radiological Study

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ABSTRACT

Background:

Adequate peri-implant soft tissue dimensions are essential for maintaining long-term implant health and esthetics, particularly in patients with a thin gingival phenotype. This randomized clinical study was conducted to assess the effect of a porcine-derived collagen matrix on peri-implant soft and hard tissue parameters following delayed implant placement.

Materials and Methods:

Twenty-two patients with mandibular edentulous sites and gingival thickness <2 mm were enrolled in the study. The primary outcome measures were gingival thickness and keratinized mucosal width, whereas plaque index, gingival index, and crestal bone loss were evaluated as secondary outcomes. Participants were randomly assigned to two groups: Group A (n = 11) underwent delayed implant placement alone, while Group B (n = 11) received delayed implant placement with a porcine-derived collagen matrix. Clinical parameters were recorded at baseline, 12 weeks, and 16 weeks, and crestal bone loss was assessed radiographically at 12 and 16 weeks.

Results:

Clinical improvement was observed in both groups throughout the follow-up period. However, the group treated with the porcine-derived collagen matrix demonstrated significantly greater gains in gingival thickness and keratinized mucosal width, together with a greater reduction in gingival inflammation. Crestal bone levels remained stable in both groups, with no statistically significant differences between the groups.

Conclusion:

Within the limitations of this study, the adjunctive use of a porcine-derived collagen matrix during delayed implant placement resulted in superior peri-implant soft tissue outcomes without adversely affecting crestal bone stability. Therefore, the porcine-derived collagen matrix may serve as a predictable, minimally invasive option for peri-implant soft tissue augmentation.

Keywords: Delayed implant placement; porcine-derived collagen matrix; gingival thickness; keratinized mucosal width; peri-implant soft tissue; crestal bone loss.

INTRODUCTION

The long-term success of dental implant depends on osseointegration as well as maintenance of healthy peri-implant soft and hard tissues. Inadequate gingival thickness and reduced keratinized mucosal width have been associated with elevated plaque deposition, inflammation of peri-implant tissue, recession of mucosa, and compromised aesthetic outcomes, especially in thin gingival phenotype patients.^[1-4] Clinical studies have demonstrated that adequate peri-implant soft tissue thickness and keratinized mucosa contribute to improved tissue stability, enhanced plaque control, patient comfort, and maintenance of marginal bone levels.^[5,6]

Various surgical modalities have been employed to enhance peri-implant soft tissue outcomes. Autogenous grafts, such as subepithelial connective tissue grafts and free gingival grafts, are considered predictable techniques for soft tissue augmentation.^[7] However, these procedures are associated with donor site morbidity, increased surgical time, postoperative discomfort, and limited tissue availability. To overcome these limitations, xenogeneic collagen matrices have been introduced as minimally invasive alternatives for peri-implant soft tissue augmentation.^[8]

Porcine-derived collagen matrices are resorbable biomaterials composed primarily of type I and type III collagen that function as three-dimensional scaffolds promoting angiogenesis, fibroblast proliferation,

and soft tissue regeneration.^[9] Previous studies have demonstrated favorable biocompatibility, increased gingival thickness, and gains in keratinized mucosal width associated with their use.^[10] In addition, these matrices have shown favorable esthetic integration with reduced patient morbidity compared with autogenous grafting procedures.

Delayed implant placement remains a predictable and widely accepted treatment protocol, particularly in situations requiring controlled soft tissue healing before implant insertion. The adjunctive use of a porcine-derived collagen matrix during delayed implant placement may therefore improve peri-implant soft tissue stability while maintaining crestal bone levels. However, limited evidence is available comparing peri-implant soft and hard tissue outcomes following delayed implant placement performed with collagen matrix augmented and non-augmented groups. Therefore, present randomized clinical trial intended to evaluate effect of porcine-derived collagen matrix on gingival thickness, keratinized mucosal width, peri-implant clinical parameters, and crestal bone stability during delayed implant placement.

MATERIALS AND METHODS

Study design

This study was undertaken at the Department of Periodontology of a tertiary care dental teaching hospital [redacted for peer review]. The study constitutes patients presenting with a minimum of one mandibular edentulous site requiring implant-supported rehabilitation. A total of 22 subjects with thin gingival phenotype (<2 mm) were enrolled and randomly allocated into two treatment groups between 2024 and 2025.

Inclusion criteria: Adults aged between 18 and 70 years presenting with at least a completely healed mandibular edentulous site and thin gingival thickness (<2 mm). Patients maintaining good oral hygiene with plaque index^[11] and gingival index^[13] scores ≤1, medically healthy individuals, and patients willing to comply with the treatment protocol were included in the study.

Exclusion criteria: Pregnancy or lactation, systemic diseases affecting healing, anticoagulant therapy, immunocompromised status, tobacco use, poor oral hygiene maintenance, allergy to the study material, and inability to provide informed consent.

All implant procedures were performed by a single operator. Dental implants from the ADIN implant system were utilized in all cases, and implant osteotomy preparation was performed using the ADIN surgical kit in conjunction with a physiodispenser (Osseo Set™ 200, W&H Austria).

Study protocol was approved by the Institutional Ethical Committee and Institutional Expert Committee of a tertiary care dental institution [redacted for peer review]. Before participation, written informed consent was obtained from all participants, and the study complied with the Declaration of Helsinki.

Surgical protocol

Surgical procedures were performed under local anesthesia using 2% lidocaine hydrochloride with adrenaline (1:80,000). Before implant placement, each patient completed initial periodontal treatment comprising scaling and root planing and was instructed on appropriate oral hygiene practices. Clinical reassessment was carried out three to four weeks later prior to surgery.

In Group A, the surgical procedure was performed under local anesthesia. A mid-crestal incision was made to expose the underlying alveolar ridge, followed by elevation of a full-thickness mucoperiosteal flap. The implant site was prepared using the manufacturer's prescribed drilling sequence, after which the dental implant was inserted into the prepared osteotomy. Upon completion of implant placement, the flap was repositioned and closed with interrupted 3-0 silk sutures to achieve primary wound closure (Figure 1A–L).

In Group B, a mid-crestal incision was performed followed by reflection of a partial-thickness flap. The porcine-derived collagen matrix (Mucograft®) was trimmed and adapted over the periosteum at the recipient site. The matrix was stabilized using non resorbable sutures, after which implant osteotomy and implant placement were performed. The flap was repositioned to completely cover the matrix and stabilized using interrupted sutures. Figure 2 [A–L]

Postoperative follow-up

Postoperative medications included antibiotics, analgesics, and 0.2% chlorhexidine mouth rinse for 10–15 days. Patients were recalled after 10 days for suture removal and subsequently followed at 12 weeks and 16 weeks for examining clinically and radiographically. In the event of postoperative complications, patients were re-evaluated and managed accordingly.

Outcomes: Primary and secondary

The initial objective of this study was to examine changes in gingival thickness and keratinized mucosal width following delayed implant placement with and without adjunctive use of a porcine-derived collagen matrix. Secondary outcomes included evaluation of plaque index, gingival index, and radiographic crestal bone loss.

Clinical parameters comprising plaque index, gingival index, gingival thickness, and keratinized mucosal width were noted at baseline, 12 weeks, 16 weeks. Crestal bone loss was assessed radiographically using standardized intraoral periapical radiographs obtained at baseline, 12 weeks, and 16 weeks. Standardization of gingival thickness measurements was achieved using a customized acrylic stent with reference grooves. A 2 mm-thick acrylic stent with reference grooves was fabricated, and its thickness was subtracted from the measurements obtained using the reamer to ensure accurate assessment. Digital Vernier caliper was used to measure soft-tissue thickness and keratinized mucosal width in order to maintain standardization.

STATISTICAL ANALYSIS

Collected observation were interpreted using SPSS statistical software (version 27.0; IBM Corp, Armonk, NY, USA). An overview of the study data was obtained using descriptive statistical methods. The significance of variations observed within and across the groups was determined using one-way analysis of variance (ANOVA). A p-value below 0.05 was considered indicative of statistical significance.

RESULTS

The intragroup and intergroup comparisons of keratinized mucosal width (KMW), gingival thickness (GT), and crestal bone loss (CBL) are summarized in Table 1. Non-parametric Mann–Whitney U test was employed for comparisons between the study groups. for KMW and CBL and the independent t-test for GT. Intragroup comparisons were performed using the Friedman test (KMW Group A), repeated measures ANOVA with Bonferroni post hoc test (KMW Group B and GT), and Wilcoxon matched-pair signed-rank test (CBL). Group B demonstrated a significant increase in KMW over the study period, whereas no significant difference was observed in Group A. Gingival thickness increased in both groups, with significantly greater improvement observed in Group B. No significant intragroup or intergroup differences were observed in crestal bone loss during study period.

DISCUSSION

Prolonged success of implant rehabilitation is governed not only by successful osseointegration but also on the conservation of soft tissues and stable crestal bone levels around implant. Inadequate gingival thickness and reduced keratinized mucosal width have been associated with increased plaque accumulation, mucosal inflammation, soft tissue recession, and compromised aesthetic outcomes.^[1,12] Therefore, mucosal grafting procedures around implant have increasingly gained importance in implant dentistry. Among the available biomaterials, porcine-derived collagen matrices have emerged as promising alternatives to autogenous grafts because of their favorable biocompatibility and reduced patient morbidity.^[14,15]

In the present randomized clinical trial, delayed implant placement performed in conjunction with a porcine-derived collagen matrix demonstrated superior peri-implant soft tissue outcomes compared with delayed implant placement alone. Both groups exhibited improvement in clinical parameters over the follow-up period; however, significantly greater reductions in gingival inflammation and significantly greater gains in gingival thickness and keratinized mucosal width were observed in the collagen matrix group. These findings suggest that adjunctive use of a porcine-derived collagen matrix may enhance peri-implant soft tissue stability during healing.

Gingival inflammation, assessed using the Gingival Index, decreased in study arms throughout study. However, Group B demonstrated significantly lower gingival index scores at both 12 and 16 weeks compared with Group A. Similar findings have been reported by Schmitt et al ^[20] and Maiorana et al ^[16], who observed improved soft tissue conditions following grafting procedures around implants. The reduced inflammatory response observed in the collagen matrix group may be attributed to improved tissue adaptation and enhanced soft tissue quality around the implant surface.

Gingival thickness is considered an important determinant of peri-implant tissue stability and esthetic success. In the present study, both treatment groups demonstrated increases in gingival thickness; however, significantly greater gains were observed in Group B. The enhanced gingival thickness associated with the collagen matrix may be related to its three-dimensional scaffold properties, which facilitate fibroblast proliferation, angiogenesis, and soft tissue maturation. Similar outcomes have been reported by Cairo et al ^[18] and Thoma et al ^[19] following the use of xenogeneic collagen matrices for peri-implant soft tissue grafting.

Keratinized mucosal width remained relatively unchanged in Group A, whereas Group B demonstrated a statistically significant increase throughout the follow-up period. These findings support the efficacy of porcine-derived collagen matrices in augmenting peri-implant keratinized tissue. Similar increases in keratinized mucosal width following collagen matrix application have been reported by Manfredini et al ^[17] and Sanz et al ^[14], who also emphasized the reduced morbidity associated with collagen matrices compared with autogenous grafting procedures.

Radiographic evaluation demonstrated maintenance of crestal bone levels with a tendency toward improvement across the study period in both arms, with no statistically significant changes observed either within or between the groups. The findings in the collagen matrix group suggest that the adjunctive use of a porcine-derived collagen matrix may contribute to favorable peri-implant hard tissue outcomes without inducing additional crestal bone loss. Similar findings have been reported by Thoma et al ^[21] and Cairo et al ^[18] following peri-implant soft tissue augmentation procedures using collagen matrices. Additionally, Sanz et al ^[14] highlighted the role of enhanced soft tissue volume in supporting peri-implant bone preservation. The observed hard-tissue improvement is likely related to the combined influence of postoperative tissue healing, resolution of inflammation, and the regenerative properties of the biomaterial employed.^[22]

Within shortcomings of the present research, comprising limited sample size and short-term observation, adjunctive use of a porcine-derived collagen matrix during delayed implant placement demonstrated favourable soft tissue outcomes while maintaining consistent crestal bone levels around implant.

CONCLUSION

Delayed implant therapy provides reliable clinical approach for rehabilitation of mandibular edentulous sites with satisfactory peri-implant soft and hard tissue outcomes. Although both treatment groups demonstrated favorable clinical and radiographic results, the adjunctive use of a porcine-derived collagen matrix resulted in greater gains in gingival thickness and keratinized mucosal width, along with a more pronounced reduction in gingival inflammation, without adversely affecting crestal bone stability. Moreover, the collagen matrix demonstrated favorable soft tissue integration and may serve as a minimally invasive and patient-friendly alternative to autogenous soft tissue grafting procedures. Porcine-derived collagen matrices may therefore be considered a promising adjunct to delayed implant placement for enhancing soft tissue stability as well as promoting extended peri-implant health.

ABBREVIATIONS

ANOVA- Analysis of Variance

PDCM- Porcine Derived Collagen Matrix

GT- Gingival Thickness

KMW- Keratinized Mucosal Width

CBL- Crestal Bone Loss

SD- Standard deviation

SPSS- Statistical Package for the Social Science

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Table 1- Values are presented as Mean $\pm$ SD. $p \leq 0.05$ indicates statistical significance.
CAPTIONS FOR FIGURES

Para-meter	Time Interval	Group A Mean $\pm$ SD	Group B Mean $\pm$ SD	Intergroup p-value	Intragroup p-value (Group A)	Intragroup p-value (Group B)
KMW (mm)	Baseline	2.50 $\pm$ 0.45	2.14 $\pm$ 0.71	0.243	0.070	<0.001*
	12 weeks	2.36 $\pm$ 0.50	2.50 $\pm$ 0.59	0.562		
	16 weeks	2.28 $\pm$ 0.46	2.87 $\pm$ 0.54	0.019*		
GT (mm)	Baseline	1.01 $\pm$ 0.11	1.05 $\pm$ 0.10	0.442	<0.06	<0.06
	12 weeks	1.12 $\pm$ 0.12	2.41 $\pm$ 0.16	<0.001*		
	16 weeks	1.20 $\pm$ 0.11	3.22 $\pm$ 0.17	<0.001*		
CBL (mm)	12 weeks	0.73 $\pm$ 0.41	0.59 $\pm$ 0.49	0.606	0.157	0.746
	16 weeks	0.55 $\pm$ 0.47	0.68 $\pm$ 0.41	0.562		

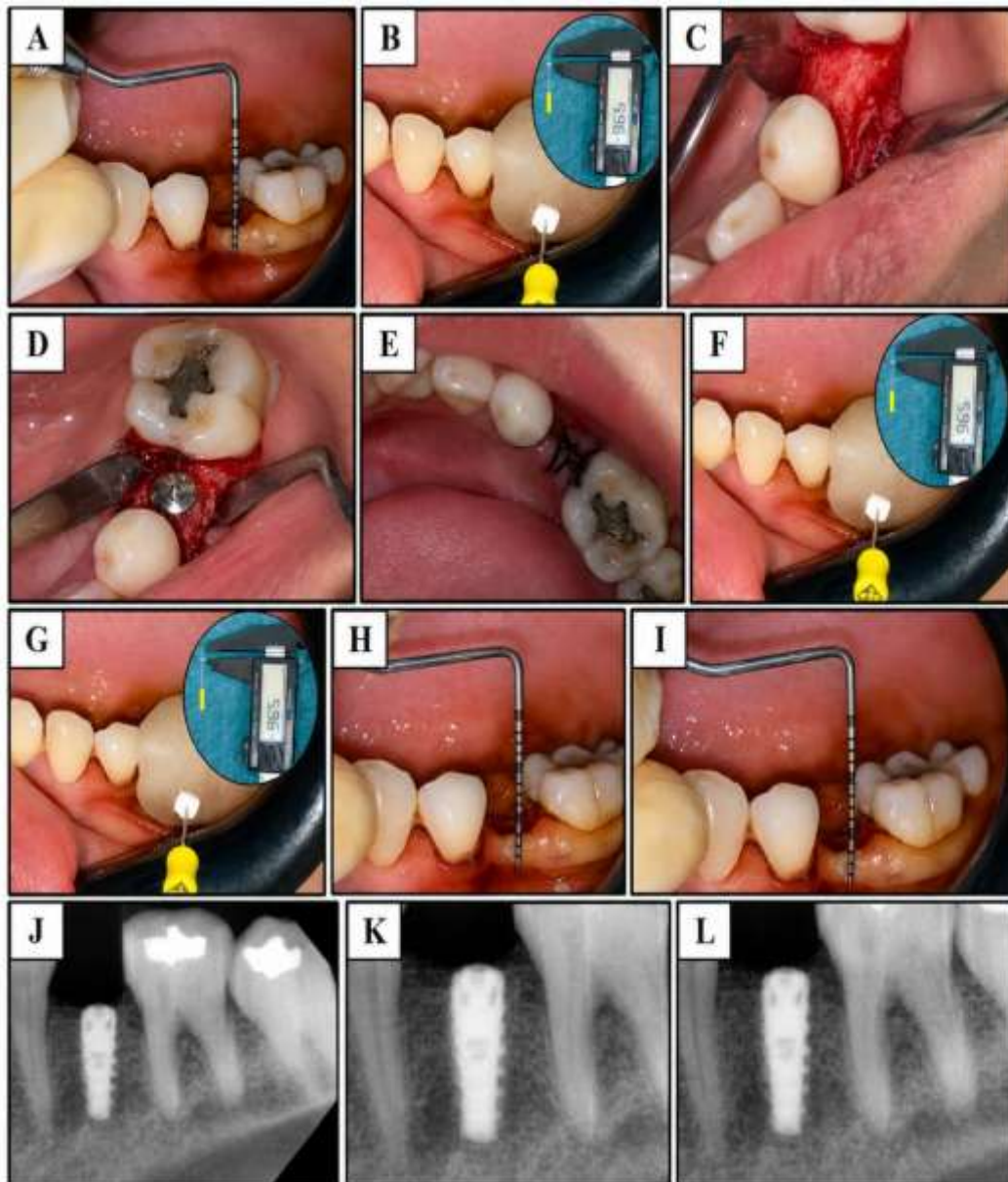


FIGURE 1:(A) Baseline measurement of keratinized mucosal width [3mm] (B) Baseline measurement of gingival thickness [2mm] (C) Muco periosteal flap elevation (D) Osteotomy site prepared & Adin implant placement done (E) Interrupted sutures given (F) Gingival thickness at 12 weeks post- operative [2 mm] (G) Gingival thickness at 16 weeks post- operative [2 mm] (H) 12 weeks post op measurement of keratinized mucosal width [3mm] (I) 16 weeks post op measurement of keratinized mucosal width [3mm] (J) Baseline Radiograph (K) 12 weeks post-operative radiograph (L) 16 weeks post-operative radiograph

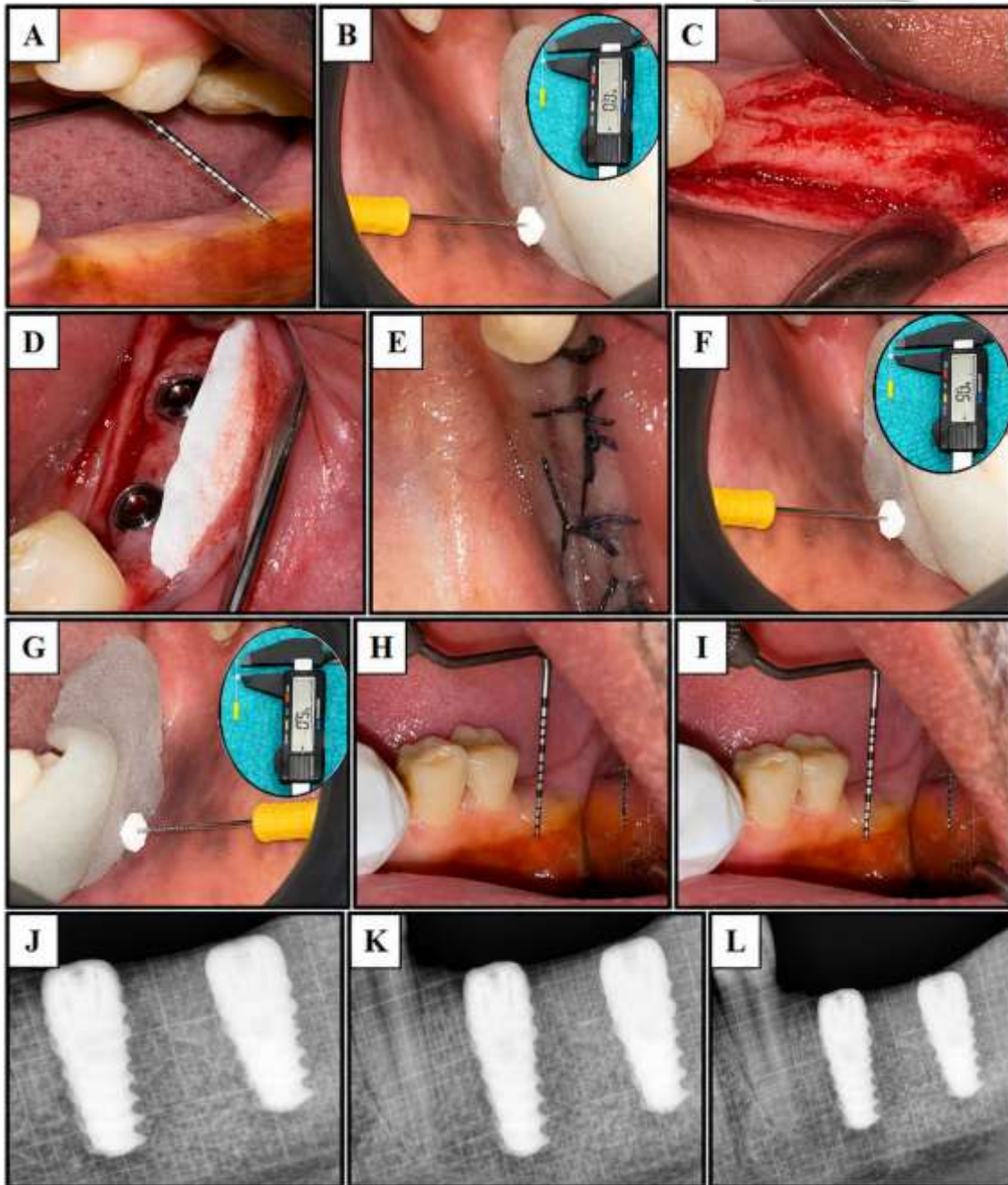


FIGURE 2: (A) Baseline measurement of keratinized mucosal width [4mm] (B) Baseline measurement of gingival thickness [2mm] (C) Muco periosteal flap elevation (D) Osteotomy site prepared & Adin implant placement done with PDCM Mucograft® (E) Interrupted sutures given (F) Gingival thickness at 12 weeks post-operative [2.8 mm] (G) Gingival thickness at 16 weeks post- operative [3.8 mm] (H) 12 weeks post op measurement of keratinized mucosal width [6mm] (I) 16 weeks post op measurement of keratinized mucosal width [7mm] (J) Baseline radiograph (K) 12 weeks post-operative radiograph (L) 16 weeks post-operative radiograph