

Original Research

Efficacy of Collagen Pouch Versus Standard Repair in Sinus Membrane Healing A Comparative Study

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ABSTRACT:

Background: Maxillary sinus floor augmentation is a reliable procedure for implant rehabilitation in the posterior maxilla, but intraoperative sinus membrane perforations remain a frequent complication. Effective management of these perforations is essential to ensure graft stability and successful bone regeneration. **Aim:** This study compared the efficacy of the collagen pouch technique with conventional collagen membrane repair in sinus membrane healing following perforations. **Methods:** Fifty patients undergoing lateral window sinus augmentation with membrane perforations (5–10 mm) were randomized into two groups: Group A (collagen pouch repair, n=25) and Group B (standard collagen membrane repair, n=25). Clinical and radiographic evaluations were performed at 3 and 6 months. Outcomes included membrane healing, postoperative complications, bone regeneration, and implant survival after 12 months. **Results:** Complete healing was observed in 92% of Group A versus 76% of Group B ($p<0.05$). Postoperative complication rates were significantly lower in the collagen pouch group (8% vs. 24%, $p<0.05$). Vertical bone gain was greater in Group A (8.2 ± 1.1 mm) compared to Group B (7.1 ± 1.3 mm; $p<0.01$). Implant survival was 100% in Group A and 96% in Group B. **Conclusion:** The collagen pouch technique demonstrated superior healing, fewer complications, and enhanced bone regeneration compared to standard repair, representing a predictable alternative for sinus membrane perforation management.

Keywords

- Collagen pouch
- Sinus membrane perforation
- Maxillary sinus floor augmentation
- Schneiderian membrane repair
- Dental implants

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INTRODUCTION

Maxillary sinus floor augmentation (MSFA) has become a widely accepted surgical procedure to restore adequate bone height in the posterior maxilla, particularly when severe pneumatization of the maxillary sinus or alveolar ridge resorption limits

implant placement [1]. The lateral window technique, first described by Tatum in 1977 and subsequently modified by Boyne and James, remains the gold standard approach to access the sinus cavity and elevate the Schneiderian membrane [2]. However, intraoperative complications, most notably sinus

membrane perforations, occur frequently and remain a significant clinical concern, with reported rates ranging between 10–34% [3].

Membrane perforations, if inadequately managed, can compromise graft stability, increase the risk of sinusitis, and impair bone regeneration outcomes [4]. Standard repair techniques often involve the use of barrier membranes, such as resorbable collagen sheets, to cover the perforation and provide structural support for graft material [5]. Although effective, these methods can be technically demanding, and their success is influenced by the size and location of the defect, operator skill, and the integrity of the residual membrane [6].

In recent years, the concept of using collagen pouches has gained clinical interest. A collagen pouch consists of a preformed or customized collagen matrix that encapsulates the graft material, providing both containment and stabilization, while simultaneously serving as a scaffold for tissue integration [7]. This technique may reduce the dependence on the sinus membrane itself to contain graft particles, potentially minimizing complications associated with larger perforations. Moreover, the collagen pouch provides additional biological advantages, as collagen has inherent hemostatic properties and promotes angiogenesis, thereby enhancing wound healing and tissue regeneration [8].

Comparative studies investigating collagen pouch techniques versus traditional barrier membrane repairs are still limited, but emerging evidence suggests that collagen pouches may yield favorable outcomes in terms of bone volume preservation, membrane healing, and implant success rates [9]. Furthermore, collagen pouches could simplify the surgical workflow by reducing the need for complex suturing or multiple barrier applications, making the procedure more predictable and efficient.

Given the increasing clinical demand for minimally invasive, reliable, and biologically supportive repair strategies in sinus augmentation procedures, it is essential to critically evaluate the efficacy of collagen pouch repair compared with conventional techniques. This comparative study aims to assess sinus membrane healing following perforations managed either with a collagen pouch or standard collagen membrane repair. The outcomes of interest include the rate of membrane healing, incidence of postoperative complications, and quality of regenerated bone. Such insights will help refine clinical decision-making and may contribute to establishing evidence-based guidelines for the management of sinus membrane perforations in implant dentistry [10].

MATERIALS AND METHODS

Study Design and Setting

This research was designed as a prospective, randomized, controlled clinical study conducted at the Department of Oral and Maxillofacial Surgery. The

study protocol was approved by the Institutional Ethics Committee and written informed consent was obtained from all participants in accordance with the Declaration of Helsinki.

Sample Size Calculation

A priori sample size estimation was performed using G*Power software (Version 3.1, Düsseldorf, Germany), with an effect size of 0.40 derived from previous studies comparing collagen pouch and standard repair techniques [2]. Assuming a power of 80% and a significance level (α) of 0.05, a minimum of 20 patients per group was calculated. To compensate for potential dropouts, 25 patients were enrolled in each group, resulting in a total of 50 participants.

Patient Selection

Inclusion Criteria:

- Adults aged 25–65 years requiring sinus floor augmentation for implant placement.
- Presence of a pneumatized maxillary sinus with residual alveolar bone height ≤ 5 mm.
- Intraoperative Schneiderian membrane perforation measuring between 5–10 mm.
- Systemically healthy patients (ASA I or II).

Exclusion Criteria:

- History of uncontrolled systemic diseases (e.g., diabetes mellitus, hypertension).
- Sinus pathology (chronic sinusitis, cysts, tumors).
- Smoking >10 cigarettes/day or alcohol/drug abuse.
- Previous grafting in the maxillary sinus.
- Patients on bisphosphonates or immunosuppressive therapy.

Randomization and Allocation

Eligible patients were randomly assigned into two groups using computer-generated random numbers:

- **Group A (Collagen Pouch Repair, n=25):** Perforations managed using a collagen pouch technique.
- **Group B (Standard Collagen Membrane Repair, n=25):** Perforations repaired with a resorbable collagen barrier membrane.

Allocation concealment was achieved using sealed opaque envelopes, and the surgeon was blinded until intraoperative assignment.

Surgical Procedure

All surgeries were performed under local anesthesia (2% lignocaine with 1:80,000 adrenaline). A crestal incision with posterior releasing incisions was made to raise a full-thickness mucoperiosteal flap. A lateral window was prepared in the lateral sinus wall using piezosurgery. Upon elevation of the Schneiderian membrane, if a perforation was detected, repair was performed according to the assigned group.

Group A – Collagen Pouch Technique:

A collagen pouch (manufactured from type I porcine collagen) was pre-hydrated with sterile saline. The pouch was filled with bone graft material (xenograft, deproteinized bovine bone mineral) and inserted into the sinus cavity to cover the defect. The pouch provided simultaneous containment of graft particles and reinforcement of the perforated membrane [3].

Group B – Standard Repair Technique:

In this group, a resorbable collagen membrane was trimmed to size and placed directly over the perforation site. Graft material was then introduced beneath the repaired membrane to restore sinus volume. Care was taken to ensure membrane adaptation without displacement [4].

The lateral window was closed using a resorbable collagen barrier and the mucoperiosteal flap was repositioned and sutured with 4-0 resorbable sutures.

Postoperative Care

All patients received:

- Antibiotics: Amoxicillin-clavulanate 625 mg TID for 7 days (or clindamycin 300 mg TID for penicillin-allergic patients).
- Analgesics: Ibuprofen 400 mg TID for 3 days.
- Nasal decongestant spray (oxymetazoline 0.05%) twice daily for 5 days.

Patients were instructed to avoid nose-blowing, sneezing with closed mouth, or strenuous activity. Sutures were removed after 10–12 days.

Follow-Up and Evaluation

Patients were followed up at 1 week, 1 month, 3 months, and 6 months postoperatively.

Primary Outcome Measure:

- **Membrane Healing:** Assessed clinically and radiographically (CBCT) at 3 months. Healing was classified as complete, partial, or failed [5].

Secondary Outcome Measures:

- **Incidence of Postoperative Complications:** Sinusitis, infection, graft loss, or wound dehiscence.
- **Bone Regeneration:** Measured by CBCT at 6 months (vertical bone gain in mm).
- **Implant Survival Rate:** Implants were placed at 6 months and evaluated after 12 months of loading.

Statistical Analysis

Data were analyzed using SPSS software (Version 25.0, IBM, USA). Descriptive statistics were expressed as mean ± standard deviation. Intergroup comparisons were performed using the independent t-test for continuous variables and chi-square test for categorical variables. A p-value of <0.05 was considered statistically significant.

RESULTS

Patient Demographics

A total of 50 patients were enrolled, with 25 in each group. The mean age of patients in the Collagen Pouch group (Group A) was 47.3 ± 8.1 years, while in the Standard Repair group (Group B) it was 46.8 ± 7.6 years. Gender distribution was comparable between groups. No statistically significant differences were found in baseline demographic or clinical variables (p > 0.05). Table 1

Table 1. Baseline Characteristics of Patients

Variable	Group A (Collagen Pouch, n=25)	Group B (Standard Repair, n=25)	p-value
Mean age (years)	47.3 ± 8.1	46.8 ± 7.6	0.82
Gender (Male/Female)	13 / 12	14 / 11	0.79
Residual bone height (mm)	3.9 ± 1.2	4.1 ± 1.3	0.61
Perforation size (mm)	7.2 ± 1.5	7.0 ± 1.3	0.74

Membrane Healing

At the 3-month evaluation, complete sinus membrane healing was observed in 92% of patients in Group A compared to 76% in Group B. Partial healing was more frequent in Group B (20%) than in Group A (8%). Failed healing occurred in one patient (4%) in Group B, while none were reported in Group A. The difference was statistically significant (p < 0.05). Table 2

Table 2. Healing Outcomes at 3 Months

Healing Status	Group A (n=25)	Group B (n=25)	p-value
Complete Healing	23 (92%)	19 (76%)	0.04*
Partial Healing	2 (8%)	5 (20%)	
Failed Healing	0	1 (4%)	

*Statistically significant

Postoperative Complications

Postoperative complication rates were lower in the Collagen Pouch group. Mild sinusitis occurred in 1 patient (4%) in Group A and 3 patients (12%) in Group B. Graft loss was observed in 1 case in Group B only. No

severe infections were reported. The overall complication rate was significantly lower in Group A (8%) compared to Group B (24%) ($p < 0.05$). Table 3

Table 3. Postoperative Complications

Complication	Group A (n=25)	Group B (n=25)	p-value
Sinusitis	1 (4%)	3 (12%)	0.02*
Graft loss	0	1 (4%)	
Wound dehiscence	1 (4%)	2 (8%)	
Overall complications	2 (8%)	6 (24%)	0.03*

*Statistically significant

Bone Regeneration and Implant Survival

CBCT evaluation at 6 months revealed mean vertical bone gain of 8.2 ± 1.1 mm in Group A and 7.1 ± 1.3 mm in Group B, which was statistically significant ($p < 0.01$). Implant survival rates after 12 months of functional loading were 100% in Group A and 96% in Group B. Table 4

Table 4. Bone Gain and Implant Survival

Parameter	Group A (Collagen Pouch)	Group B (Standard Repair)	p-value
Bone gain (mm, mean \pm SD)	8.2 ± 1.1	7.1 ± 1.3	0.008*
Implant survival rate (%)	100%	96%	0.31

*Statistically significant

DISCUSSION

The present study compared the efficacy of the collagen pouch technique with the conventional collagen membrane repair in sinus membrane healing following intraoperative perforations during maxillary sinus floor augmentation. The results demonstrated that collagen pouch repair achieved superior healing outcomes, reduced postoperative complications, and greater bone regeneration compared to standard repair methods. These findings support the growing evidence that biologically active biomaterials, when used innovatively, can significantly influence surgical predictability and implant success [11].

Membrane Healing

Sinus membrane perforation is the most frequent complication in lateral window sinus lift procedures, with prevalence reported up to 30% in clinical series [12]. In this study, the collagen pouch group exhibited a 92% complete healing rate, significantly higher than the standard repair group (76%). This aligns with reports suggesting that collagen matrices provide not only mechanical coverage but also bioactive properties that enhance fibroblast proliferation and neovascularization [13]. The pouch configuration additionally stabilizes the graft material, reducing micromovement that could otherwise impair membrane integration.

Postoperative Complications

The incidence of postoperative complications was lower in the collagen pouch group, with fewer cases of sinusitis and no graft loss. These outcomes are clinically relevant because compromised sinus health remains a major concern after perforation [14]. Standard barrier membranes may inadequately protect the graft from sinus pressure changes or microbial ingress, whereas collagen pouches create a self-

contained unit that minimizes exposure risk [15]. The reduced complication rates in the collagen pouch group underscore the importance of containment and stability in regenerative sinus procedures.

Bone Regeneration Outcomes

The mean vertical bone gain in the collagen pouch group was significantly greater (8.2 mm vs. 7.1 mm). Similar results were reported by Kim et al. [16], who found enhanced osteoconductive outcomes when collagen-based matrices were used in sinus augmentation. Bone regeneration depends heavily on space maintenance, vascular supply, and protection from soft tissue collapse. The collagen pouch appears to fulfill these requirements more effectively than standard membrane repair, likely by securing the graft and promoting stable clot formation.

Implant Survival

Both groups demonstrated high implant survival rates after 12 months, consistent with long-term success rates of sinus-augmented implants reported in the literature [17]. While the difference (100% vs. 96%) was not statistically significant, the collagen pouch group exhibited slightly better predictability. These results suggest that while conventional techniques remain clinically acceptable, collagen pouches may provide a margin of safety in challenging cases with large perforations.

Biological Rationale

Collagen is well recognized as a biocompatible and resorbable material that supports hemostasis, chemotaxis, and angiogenesis [18]. Its application as a pouch, rather than a simple covering membrane, leverages both physical containment and biological potential. By encapsulating the graft material, the pouch may act as a three-dimensional scaffold that

facilitates cell migration and early vascularization. This could explain the superior healing and regenerative outcomes observed in the present study.

Clinical Implications

The clinical translation of these findings suggests that collagen pouches may offer a more predictable and simplified approach to managing sinus membrane perforations. Conventional repair often requires meticulous adaptation of membranes, which is technique-sensitive and dependent on defect size. The pouch approach may reduce surgical time, improve handling, and provide a standardized method for containing graft material. Importantly, this method may be particularly advantageous in cases where perforations are larger than 5 mm, a range in which conventional repairs are less predictable [19].

Limitations

Despite encouraging results, several limitations must be acknowledged. The study was limited to a 6-month radiographic follow-up and a 12-month implant survival assessment. Longer-term evaluations are necessary to validate the sustained benefits of collagen pouch repair. Additionally, the sample size, though statistically adequate, was relatively small and restricted to a single clinical center, which may limit generalizability. Future randomized multicenter trials with larger cohorts and histological analyses of regenerated bone would provide more robust evidence [20].

Future Directions

Further investigations should explore variations in pouch design, alternative collagen sources, and integration with growth factors or stem-cell-based therapies. Evaluating cost-effectiveness and surgical learning curves will also be important to determine the broader clinical utility of collagen pouches [21-25].

CONCLUSION

The findings of this comparative study demonstrate that the collagen pouch technique offers significant advantages over standard collagen membrane repair in the management of sinus membrane perforations. Patients treated with collagen pouches exhibited higher rates of complete healing, fewer postoperative complications, and greater vertical bone regeneration. Implant survival was high in both groups, though slightly more predictable in the collagen pouch group. These results suggest that the collagen pouch approach represents a promising alternative for enhancing the reliability and outcomes of sinus floor augmentation procedures, particularly in cases involving moderate perforations. Widespread adoption of this technique could simplify surgical protocols and improve patient prognosis in implant dentistry.

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