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EXPLORING THE IMPACT OF COLLAGEN MEMBRANE ON HEALING IN ORAL CANCER AND PRECANCER SURGERY

Oncology

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ABSTRACT

Background: Oral cancer represents a significant health burden in the North-Eastern India, with surgical resection being the primary treatment modality. Postoperative wound complications including infection, delayed epithelialization, and pain substantially impact patient morbidity and quality of life. **Objective:** To assess the effectiveness of collagen membrane in promoting wound healing, reducing postoperative complications, and minimizing pain following oral cancer and precancer surgery. **Methods:** Prospective cohort study of 89 patients with oral cancer/precancerous lesions receiving collagen membrane application during surgical defect closure (January 2024–April 2025). Primary outcomes measured were epithelialization time, infection rates, postoperative pain, and complication profiles. **Results:** Complete epithelialization achieved in 91.0% patients within 21–28 days (mean 23.4 ± 4.2 days). Surgical site infection rate was 6.7% (n=6), significantly lower than historical controls (15–26%). Pain intensity reduced from mean 6.8 ± 1.1 on postoperative day 1 to 1.2 ± 0.8 by day 14 ($p<0.001$). Collagen membrane integration was successful in 94.4% cases with minimal adverse effects. **Conclusion:** Collagen membrane application significantly enhances wound healing, reduces postoperative complications, and improves pain control following oral cancer and precancer surgery, representing an evidence-based reconstruction option in oral oncologic practice.

KEYWORDS

Oral cancer, collagen membrane, wound healing, surgical site infection, precancerous lesions

INTRODUCTION

Oral squamous cell carcinoma (OSCC) constitutes approximately 30% of all cancers in India, with North-Eastern states including Assam showing particularly high incidence rates.[1] Surgical resection with adequate margins remains the gold standard treatment for early and intermediate-stage disease. However, wide surgical excision creates significant soft tissue defects resulting in substantial postoperative morbidity.[2]

The challenge in oral cancer reconstruction lies not only in achieving adequate tumor margins but also in minimizing postoperative complications. Historical studies document surgical site infection (SSI) rates ranging from 15–26% following oral cancer surgery, with infection significantly impacting tumor recurrence rates and overall survival.[3] Additionally, patients experience substantial postoperative pain, delayed wound healing, and functional impairment.

Collagen-based biomaterials have emerged as promising adjuncts for managing surgical defects in oral oncology. These biocompatible materials facilitate orderly tissue repair, reduce infection risk through selective barrier functions, and promote rapid epithelialization without requiring autologous tissue harvest.[4] Despite growing clinical experience, prospective institutional data from India evaluating collagen membrane efficacy specifically in oral cancer populations remain limited.

This study was conducted to systematically evaluate collagen membrane application in our institutional cohort of oral cancer and precancer patients, documenting healing trajectories, complication profiles, and clinical outcomes over a 16-month prospective period.

METHODS

Study Design and Setting

Prospective observational cohort study conducted at the Department of Head and Neck Oncology, State Cancer Institute, Assam, India (January 2024–April 2025).

Study Population

Total Enrolled Patients: 89

Inclusion Criteria:- Histologically confirmed oral cancer or precancerous conditions (oral leukoplakia, oral submucous fibrosis, dysplastic lesions) requiring surgical intervention - Surgical procedures involving oral cavity resection with secondary defects - Age 18–80 years - Willing to provide informed consent and comply with follow-up protocol - Adequate performance status (ECOG 0–2)

Exclusion Criteria:- Uncontrolled systemic diseases affecting wound healing (poorly controlled diabetes HbA1c >9%, uncontrolled hypertension) - Patients unable to provide informed consent - Active immunosuppression or on immunosuppressive therapy - Previous surgery for same lesion with active recurrent disease - Refusal to participate in follow-up assessments

Collagen Membrane Application Protocol

All patients received bovine-derived collagen membrane (commercially available, biocompatible, cross-linked) applied intraoperatively following tumor resection and hemostasis. Membrane was trimmed to match exact defect dimensions and secured using 3-0 absorbable vicryl sutures.

Outcome Measures

Primary Outcomes: 1. Time to complete epithelialization (days) 2. Surgical site infection rate 3. Postoperative pain trajectory

Secondary Outcomes: 1. Complication profile (dehiscence, seroma, delayed healing) 2. Patient-reported functional outcomes 3. Membrane integration success rate

Follow-up Protocol

Clinical assessment at: postoperative day 7, day 14, day 21, day 28, and 3-month follow-up. Pain assessed using Visual Analog Scale (VAS: 0–10). Epithelialization assessed using standardized photography and clinical documentation.

Statistical Analysis

Descriptive statistics used for demographic and clinical characteristics. Continuous variables reported as mean ± standard deviation (SD). Chi-square test for categorical variables; paired t-test for pain trajectory analysis. p-value <0.05 considered statistically significant. SPSS version 25.0 used for analysis.

RESULTS

Demographic and Clinical Characteristics

Table 1: Patient Demographics And Clinical Characteristics (n=89)

Characteristic	n (%)	Mean ± SD
Age (years)		54.2 ± 11.3
Gender		
Male	58 (65.2%)	
Female	31 (34.8%)	
Risk Factors		
Tobacco use	71 (79.8%)	
Alcohol use	48 (53.9%)	
Areca nut use	62 (69.7%)	
Comorbidities		
Diabetes mellitus	18 (20.2%)	
Hypertension	22 (24.7%)	
None	49 (55.1%)	

Lesion Characteristics

Table 2: Lesion Site and Histopathology Distribution (n=89)

Characteristic	Oral Cancer (n=58)	Precancer (n=31)	Total
Lesion Site			
Buccal mucosa	42 (72.4%)	14 (45.2%)	56 (62.9%)
Tongue	8 (13.8%)	8 (25.8%)	16 (18.0%)
Palate	4 (6.9%)	6 (19.4%)	10 (11.2%)
Floor of mouth	4 (6.9%)	3 (9.7%)	7 (7.9%)
Precancer Type			
Oral leukoplakia	—	19 (61.3%)	19
Oral submucous fibrosis	—	9 (29.0%)	9
Dysplastic lesions	—	3 (9.7%)	3
OSCC Stage			
Stage I–II	—	18 (31.0%)	18
Stage III–IV	—	40 (69.0%)	40
Differentiation			
Well differentiated	34 (58.6%)	—	34
Moderately differentiated	18 (31.0%)	—	18
Poorly differentiated	6 (10.3%)	—	6

Primary Outcomes

Epithelialization Time

Table 3: Time to Complete Epithelialization

Epithelialization Status	Day 7	Day 14	Day 21	Day 28
Complete (%)	8 (9.0%)	34 (38.2%)	81 (91.0%)	88 (98.9%)
Partial (%)	67 (75.3%)	52 (58.4%)	7 (7.9%)	1 (1.1%)
Minimal (%)	14 (15.7%)	3 (3.4%)	1 (1.1%)	0

Mean epithelialization time: 23.4 ± 4.2 days (range 16–32 days)

Comparison with historical controls (traditional dressings): 38–42 days, representing **44% reduction in healing time** ($p<0.001$).

Surgical Site Infection (SSI)

Overall SSI Rate: 6.7% (6/89 patients)

SSI Status	n	%
No infection	83	93.3%
Surface infection (treated conservatively)	4	4.5%
Deep space infection (required drainage)	2	2.2%
Total SSI	**6**	**6.7%**

Risk Factor Analysis For SSI:

Risk Factor	SSI (+) (n=6)	SSI (–) (n=83)	p-value
Diabetes mellitus	2 (33.3%)	16 (19.3%)	0.35
Age >60 years	3 (50.0%)	28 (33.7%)	0.41
Stage III–IV OSCC	4 (66.7%)	36 (43.4%)	0.23
Oral–neck communication	3 (50.0%)	12 (14.5%)	0.034*

*Statistically significant

Comparison With Literature: Collagen membrane group (6.7%) vs. historical controls without biologic dressings (15–26%), representing **73% relative reduction in SSI** ($p<0.001$).[5]

Postoperative Pain Assessment

Table 4: Visual Analog Scale (VAS) Pain Scores Over Time

Time Point	Mean VAS ± SD	95% CI	Change from Baseline
POD 1	6.8 ± 1.1	6.5–7.1	—
POD 3	5.2 ± 1.4	4.8–5.6	–1.6 (23.5% reduction)
POD 7	3.1 ± 1.3	2.8–3.5	–3.7 (54.4% reduction)
POD 14	1.2 ± 0.8	1.0–1.4	–5.6 (82.4% reduction)*

*$p<0.001$ compared to POD 1 (paired t-test)

Mean Pain Reduction Trajectory: –0.36 VAS units per day (linear regression, $R^2=0.94$)

SECONDARY OUTCOMES

Complication Profile

Table 5: Postoperative Complications (n=89)

Complication	n	%	Management
Infection	6	6.7%	Antibiotics ± drainage
Wound dehiscence	2	2.2%	Conservative
Seroma formation	1	1.1%	Observation
Delayed epithelialization	1	1.1%	Topical growth factors
Any complication	**10**	**11.2%**	
No complications	**79**	**88.8%**	

Overall complication rate: 11.2%, significantly lower than historical series documenting 20–30% complication rates.[6]

Membrane Integration Success

Successful membrane integration (complete integration with no premature sloughing): **94.4% (84/89)** - Membrane sloughing <POD 7: 4 cases (4.5%) - Partial membrane separation POD 14: 1 case (1.1%)
Mean time to complete membrane integration: 14.2 ± 3.1 days

Patient-Reported Functional Outcomes At 3-Month Follow-up

Functional Domain	Excellent (%)	Good (%)	Fair (%)	Poor (%)
Oral function recovery	72 (80.9%)	14 (15.7%)	3 (3.4%)	0
Speech clarity	78 (87.6%)	9 (10.1%)	2 (2.2%)	0
Swallowing difficulty	81 (91.0%)	6 (6.7%)	2 (2.2%)	0
Aesthetic satisfaction	**68 (76.4%)**	**19 (21.3%)**	**2 (2.2%)**	**0**

Stratified Analysis

Outcomes by Lesion Type

Table 6: Comparison of Outcomes: Oral Cancer vs. Precancer (n=89)

Outcome	Oral Cancer (n=58)	Precancer (n=31)	p-value
Mean epithelialization (days)	24.1 ± 4.5	22.0 ± 3.6	0.062
SSI rate	8.6% (5/58)	3.2% (1/31)	0.28
Complication rate	12.1% (7/58)	9.7% (3/31)	0.71
Pain reduction by POD 14	82.1%	82.9%	0.91
Membrane integration success	93.1%	96.8%	0.40

Outcomes By Primary Lesion Site

Site	Epithelialization (days)	SSI (%)	Complications (%)
Buccal mucosa (n=56)	23.1 ± 4.0	5.4%	8.9%
Tongue (n=16)	23.9 ± 4.5	6.3%	12.5%
Palate (n=10)	23.8 ± 4.1	10.0%	20.0%
Floor of mouth (n=7)	24.2 ± 4.8	14.3%	14.3%

DISCUSSION

This prospective institutional study demonstrates that collagen membrane application significantly enhances wound healing trajectories and reduces postoperative morbidity following oral cancer and precancer surgery. Key findings warrant discussion:

Accelerated Epithelialization: Mean epithelialization time of 23.4 days represents 44% reduction compared to secondary intention healing (38–42 days) and aligns with published series in collagen-treated wounds.[7] The mechanism underlying accelerated healing involves enhanced fibroblast recruitment, organized granulation tissue formation, and selective barrier function preventing premature epithelialization-mechanisms well-characterized in biocompatibility studies.[8]

Dramatic Infection Reduction: SSI rate of 6.7% is substantially lower than historical oral cancer surgery cohorts (15–26%), representing 73% relative risk reduction.[9] This reduction likely reflects collagen's inherent antimicrobial properties through selective barrier function and creation of microenvironment conducive to organized healing rather than chronic inflammation.[10]

Pain Control: Progressive pain reduction from mean VAS 6.8 to 1.2 (82.4% reduction by POD 14) demonstrates significant quality-of-life improvement. Collagen's protective barrier over exposed nerve endings and prevention of secondary inflammation likely explains superior pain control compared to non-biological dressings.

Clinical Safety: 94.4% successful membrane integration with minimal adverse effects confirms excellent biocompatibility in our patient cohort. Only 5 cases (5.6%) experienced premature membrane sloughing or separation, well within acceptable tolerance ranges.

Stratified Outcomes: Palate and floor-of-mouth lesions showed marginally higher SSI rates (10–14.3%), possibly reflecting these sites' lower blood supply and increased bacterial colonization risk-factors requiring attention in patient selection and perioperative care.

CONCLUSION

This 16-month prospective institutional study provides compelling evidence that collagen membrane application is an effective, safe, and biocompatible approach for managing surgical defects following oral cancer and precancer surgery. The demonstrated acceleration of epithelialization, substantial reduction in surgical site infection, superior pain control, and excellent functional outcomes position collagen membranes as a first-line reconstruction option for secondary oral surgical defects in oncologic populations.

Integration of collagen membranes into our institutional practice has resulted in meaningful improvements in patient morbidity profiles and quality-of-life outcomes. Future randomized controlled trials comparing collagen membranes to alternative reconstruction strategies in larger cohorts are warranted to establish definitive clinical hierarchies and optimize patient selection algorithms.

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