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Comparision Of Meibomian Gland Morphology And Function In Tobacco Smokers Versus Chewing Tobacco Users

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ABSTRACT

Background: Tobacco use, in both smoked and smokeless forms, is a recognized risk factor for systemic and ocular conditions. Meibomian gland dysfunction (MGD) is a leading cause of evaporative dry eye, yet comparative data on the effects of smoking versus chewing tobacco on meibomian gland health remain scarce.

Aim: To evaluate and compare the morphological and functional changes in meibomian glands among tobacco smokers, chewing tobacco users, and non-users.

Materials and Methods: This cross-sectional observational study enrolled 120 participants categorized into three groups: smokers (n=40), chewing tobacco users (n=40), and non-tobacco users (n=40). All subjects underwent comprehensive ocular surface evaluation, including infrared meibography, Schirmer's test, tear break-up time (TBUT), and Meibomian gland expressibility assessment. Statistical comparisons were made using ANOVA and Chi-square tests.

Results: Smokers exhibited the most pronounced meibomian gland dropout (60% severe), lowest TBUT (5.8 ± 0.9 s), and reduced Schirmer's values (7.0 ± 1.2 mm). Chewing tobacco users demonstrated moderate alterations, while controls exhibited minimal dysfunction. OSDI scores were significantly higher in tobacco users ($p < 0.001$), indicating increased symptom severity.

Conclusion: Tobacco use is associated with significant meibomian gland dysfunction, with smokers exhibiting more severe structural and functional impairment than chewing tobacco users. These findings underscore the importance of early screening and cessation counseling to prevent long-term ocular surface damage.

Keywords: *Meibomian gland dysfunction, smoking, chewing tobacco, dry eye, tear film, Schirmer's test, TBUT*

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1. INTRODUCTION

Tobacco affects multiple organ systems, including the eyes. Smoking exposes the ocular surface to toxic compounds such as nicotine, carbon monoxide, and formaldehyde, which destabilize the tear film and damage meibomian glands.[1] Chewing tobacco, although not involving direct smoke exposure, induces systemic toxicity that may similarly impair

gland function.[2]

Significance of Meibomian Gland Dysfunction
Meibomian glands secrete lipids essential for tear film stability. Dysfunction leads to evaporative dry eye, discomfort, and increased risk of ocular infections.[3,7] While smoking is an established risk factor for MGD,[3] the impact of smokeless tobacco remains under-investigated.[2]

Rationale for the Study
With rising tobacco use, understanding its ocular consequences is crucial. This study compares the effects of smoking and chewing tobacco on meibomian gland structure, function, and overall ocular surface health.[7,8]

2. MATERIALS AND METHODS

Ethics Approval: Approved by Institutional Ethics Committee Ref. No. SDUAHER/KLR/R&D/CEC/S/PG/68/2024-25, dated 21-10-2024.

This cross-sectional observational study was conducted over six months at a tertiary care hospital. Ethical clearance was obtained, and informed consent was secured from all participants. The study included participants aged 45–65 years with a history of regular smoking or chewing tobacco for at least five years, as well as non-tobacco users with no history of tobacco exposure for the control group. Individuals were excluded if they had systemic conditions such as diabetes or hypertension that could affect ocular health, a history of ocular surgery or trauma, active ocular infections, or if they were contact lens wearers or on long-term medications known to influence tear film stability.
Study Population and Sample Size

A total of 120 participants were included, categorized into three groups:
Group 1: 40 tobacco smokers
Group 2: 40 chewing tobacco users
Group 3: 40 non-tobacco users (controls)

Ocular Surface Disease Index (OSDI) Questionnaire:
The Ocular Surface Disease Index (OSDI) is a validated, standardized questionnaire used to assess the severity of symptoms related to dry eye disease (DED). It is widely employed in both clinical and research settings as a subjective measure of ocular discomfort, visual disturbance, and the impact of dry eye on daily functioning.

The total score is calculated using the formula:

$$\text{OSDI Score} = \frac{\text{Sum of scores} \times 25}{\text{Number of questions answered}}$$

The final score ranges from 0 to 100, with higher scores indicating greater symptom severity. The severity grading is typically interpreted as follows:
0–12: Normal
13–22: Mild dry eye
23–32: Moderate dry eye
33–100: Severe dry eye
The OSDI is particularly useful because it captures both the frequency and functional impact of symptoms, providing a comprehensive view of the patient's experience. It is often used alongside objective clinical tests like TBUT and Schirmer's to assess the full spectrum of dry eye disease.

Slit-Lamp Biomicroscopy:
Slit-lamp biomicroscopy was conducted as a routine part of the anterior segment evaluation. This technique enabled detailed evaluation of structural changes related to MGD and ocular surface health.

Eyelid Margin Abnormalities:
The eyelid margins were assessed for irregularities, including telangiectasia, notching, and hyperkeratinization. These findings were noted as indicators of underlying gland dysfunction.

Meibomian Gland Orifices:
The gland orifices along the lid margins were examined for plugging, capping, and structural distortion. The presence of obstructed orifices and changes in the orifice appearance were recorded.

Tear Film and Debris:
The tear film was observed for clarity, presence of debris, and signs of instability or foaming. Tear film abnormalities were documented as part of the ocular surface evaluation.

Ocular Surface Staining and Inflammation:
Using fluorescein dye and cobalt blue illumination, I assessed the cornea and conjunctiva for punctate epithelial staining and signs of surface inflammation. The staining pattern helped in correlating symptom severity and surface damage.

Meibomian Gland Expressibility:
Gentle pressure was applied to the lower eyelid to evaluate the quality and ease of Meibomian gland expression. The expressed secretions were graded based on their consistency, transparency, and amount.

This systematic approach using slit-lamp biomicroscopy allowed me to identify both functional and anatomical changes in the Meibomian glands, contributing to the clinical grading of MGD and guiding further evaluation and management.
Meibomian Gland Expressibility

Meibomian gland expressibility was evaluated to assess the functional output of the glands and the quality of the lipid layer in the tear film. This assessment provided direct insight into the secretory capacity of the Meibomian glands, which plays a critical role in maintaining tear film stability and preventing evaporative dry eye.

The evaluation was performed by applying gentle, standardized pressure to the central lower eyelid, typically across 5–8 gland orifices, using a gloved fingertip or a diagnostic paddle. The ease with which the glands expressed meibum, as well as the quantity and quality of the expressed secretions, were observed and recorded.

Expressibility was graded into the following categories:
Normal: Clear meibum was easily expressed from the majority of orifices with minimal pressure, indicating healthy gland function and adequate lipid secretion.

Mildly Reduced: Slight resistance to expression was noted, with meibum expressed from fewer glands and requiring slightly more pressure.

Moderately Reduced: Gland expression was more difficult, and secretions were minimal or appeared thicker than normal, indicating functional compromise.

Absent: No meibum could be expressed from the assessed glands, even with consistent pressure, reflecting significant gland obstruction or atrophy.

This grading provided valuable clinical information regarding gland functionality and complemented other diagnostic findings such as gland dropout (structural loss) and tear film instability.

Morphology:
The evaluation of Meibomian gland morphology and function was carried out using a combination of clinical imaging and optical devices. The examination was conducted as part of the routine ocular surface assessment in patients attending the ophthalmology department.

Meibomian gland imaging was performed using a non-contact meibography system, integrated within advanced slit-lamp biomicroscopes or dedicated meibography modules. Images of the upper and lower eyelids were captured with the patient's gaze directed appropriately to expose the tarsal plates. The morphology of the glands was assessed based on the degree of dropout, shortening, distortion, or loss of gland architecture.

To facilitate documentation, photographs of the device display screens were taken using an external smartphone camera, ensuring real-time capture of gland images for grading and analysis. Image quality was maintained through proper alignment, focus, and ambient lighting.

Tear Film Tests
To assess the functional status of the tear film, two standard clinical tests were performed: Schirmer’s Test and Tear Break-Up Time (TBUT). These tests provided objective measurements of aqueous tear production and tear film stability, which are essential for the diagnosis and classification of dry eye disease.

Schirmer's Test
Schirmer's test was used to evaluate both basal and reflex tear secretion. A standardized sterile strip of filter paper (typically Whatman No. 41) was placed in the lower fornix at the junction of the middle and lateral third of the lower eyelid, without the use of topical anesthesia. The patient was instructed to close their eyes gently, and the length of wetting on the strip was measured after 5 minutes.

Tear production was quantified in millimeters (mm).

A value of less than 10 mm was considered indicative of aqueous-deficient dry eye.

In cases requiring assessment of basal secretion alone, Schirmer's I with anesthesia could be performed to eliminate reflex tearing.

This test provided direct information about the lacrimal gland function and helped distinguish between aqueous-deficient and evaporative dry eye.

Tear Break-Up Time (TBUT)
TBUT was assessed to determine tear film stability and the rate of tear evaporation. A fluorescein strip moistened with sterile saline was applied to the inferior conjunctival sac, and the patient was instructed to blink several times to allow even distribution of the dye across the corneal surface.

Using a slit-lamp biomicroscope with cobalt blue illumination, the time interval between the last blink and the first appearance of a dry spot or disruption in the fluorescein-stained tear film was measured.

A TBUT of less than 10 seconds indicated tear film instability.

Shorter TBUT values reflected rapid tear evaporation and were typically associated with Meibomian Gland Dysfunction or lipid layer deficiency.

This test was a key indicator of evaporative dry eye and supported other clinical findings.

Statistical Analysis
Data were analyzed using SPSS version 22.0.
ANOVA was used to compare means among the three groups.
Pearson correlation was used to assess relationships between tobacco use and ocular parameters.
$p<0.05$ was considered statistically significant.

3. RESULTS

Table 1 Presents the demographic characteristics of the three study groups: Smokers, Chewing Tobacco Users (referred to as "Chewing"), and Controls. The groups were relatively comparable in terms of age, with mean ages ranging between approximately 54.8 and 56.1 years. Specifically, the mean age of the Smokers group was 55.4 years with a standard deviation (SD) of ±4.8 years, while the Chewing group had a slightly higher mean age of 56.1 ± 5.2 years. The Control group had a mean age of 54.8 ± 5.0 years. Age comparisons were analyzed using one-way ANOVA, showing no statistically significant difference between the three groups ($p > 0.05$). Gender distribution was analyzed using the Chi-square test, which also revealed no statistically significant difference ($p > 0.05$).

In terms of gender distribution, all three groups had a higher proportion of males compared to females. In the Smokers group, 80% of participants were male and 20% were female. Similarly, the Chewing group consisted of 75% males and 25% females. The Control group had the lowest male predominance, with 70% male participants and 30% female participants.

These demographic details suggest that the study population was middle-aged and predominantly male across all groups, which reflects the general trend of higher tobacco use among males in many populations. The relatively similar age distribution across groups minimizes age-related bias in outcome comparisons.

Table 2 Summarizes the comparison of key clinical parameters related to tear film stability and ocular surface health among the three study groups: Smokers, Chewing Tobacco Users, and Controls. Each group comprised 40 participants. All three continuous variables (TBUT, Schirmer's, and OSDI scores) were compared among the groups using one-way ANOVA, followed by post-hoc analysis (Tukey's HSD) to identify intergroup differences. Results showed statistically significant

differences across all three parameters ($p < 0.001$).

The Tear Break-Up Time (TBUT), a measure of tear film stability, was significantly reduced in tobacco users compared to controls. Smokers exhibited the lowest TBUT values with a mean of 5.8 ± 0.9 seconds, followed by the Chewing group with 7.1 ± 0.8 seconds, whereas the Control group had the highest stability at 10.5 ± 0.9 seconds. The difference among groups was statistically significant ($p < 0.001$), indicating that both forms of tobacco use were associated with a compromised tear film, particularly among smokers.

The Schirmer's test, which evaluates aqueous tear production, showed a similar trend. Smokers had a significantly lower mean Schirmer's value of 7.0 ± 1.2 mm, suggesting reduced tear secretion. Participants in the Chewing group demonstrated slightly better tear production (9.0 ± 1.3 mm), while the Control group maintained the highest mean values (12.0 ± 1.2 mm). The intergroup differences were statistically significant ($p < 0.001$), highlighting the adverse impact of tobacco use on lacrimal gland function.

In terms of subjective symptoms, the Ocular Surface Disease Index (OSDI) Score was markedly elevated in tobacco users, reflecting greater ocular discomfort and dry eye symptoms. Smokers reported the highest symptom burden with a mean OSDI score of 35 ± 5.3, followed by the Chewing group at 28 ± 5.2. Controls reported significantly fewer symptoms, with a mean score of 15 ± 4.8. This difference was also statistically significant ($p < 0.001$), further supporting the clinical evidence of dry eye disease in the tobacco-using cohorts.

Collectively, these findings demonstrate that both smoking and smokeless tobacco use are associated with deteriorated tear film function, reduced tear production, and increased dry eye symptoms, with the greatest impairment observed in the smoking group.

Table 3 Presents the distribution of Meibomian gland expressibility among the three study groups—Smokers, Chewing Tobacco Users, and Controls—highlighting tobacco's effect on Meibomian gland function. Categorical data on expressibility grades were analyzed using the Chi-square test, which revealed a statistically significant association between tobacco use and gland expressibility impairment ($p < 0.001$).

In the Smokers group, only 5% of participants had normal gland expressibility, indicating a significant dysfunction in lipid secretion. The majority showed pathological findings: 15% had mildly reduced expressibility, 35% had moderately reduced expressibility, and a concerning 45% demonstrated complete absence of expressibility. These findings indicate that smoking severely impairs Meibomian gland function.

In contrast, the Chewing group showed relatively better gland function, although still worse than controls. 10% of participants had normal expressibility, 25% had mildly reduced, 40% had moderately reduced, and 25% had absent expressibility. While smokeless tobacco users exhibited a substantial degree of gland dysfunction, the severity was generally less than that observed in smokers.

The Control group, comprising individuals with no tobacco exposure, had the most favorable expressibility profile. 50% of controls exhibited normal Meibomian gland expressibility, 30% had mildly reduced, 15% had moderate reduction, and only 5% had absent expressibility.

These findings indicate a clear gradient of Meibomian gland dysfunction, with the most severe impairment seen in smokers, followed by chewing tobacco users, and the least impairment in the control group. The high proportion of absent and moderately reduced expressibility in the tobacco-exposed groups supports the hypothesis that tobacco—whether smoked or chewed—negatively affects Meibomian gland function, thereby contributing to evaporative dry eye disease.

Table 4 Illustrates the distribution of Meibomian gland dropout grades among Smokers, Chewing Tobacco Users, and Controls. Gland dropout refers to the loss or atrophy of Meibomian glands, often assessed using meibography, and is a structural marker of Meibomian Gland Dysfunction (MGD). Meibomian gland dropout grades were compared across groups using the Chi-square test, which demonstrated a highly significant difference ($p < 0.001$), with smokers showing the highest frequency of severe dropout.
In the Smokers group, the dropout pattern was ma
rkedly skewed toward severe gland loss. A significant 60% of smokers demonstrated severe dropout, indicating extensive gland atrophy. Only 10% had minimal dropout, while 15% each exhibited mild and moderate dropout. This distribution reflects the profound structural damage to the Meibomian glands associated with chronic exposure to cigarette smoke, likely due to oxidative stress, inflammation, and thermal injury.

The Chewing group showed a more balanced dropout distribution. 20% had minimal, 30% had mild, another 30% showed

moderate, and 20% had severe dropout. Although this group had better outcomes than smokers, a notable proportion still exhibited moderate to severe gland loss, highlighting that even smokeless tobacco can adversely affect Meibomian gland structure.

In the Control group, the majority (60%) had minimal gland dropout, indicating preserved gland structure in the absence of tobacco exposure. Only 25% had mild, 10% had moderate, and a mere 5% showed severe dropout, supporting the role of tobacco as a significant risk factor for Meibomian gland atrophy.

Overall, these findings reveal a clear and consistent association between tobacco exposure and increased severity of Meibomian gland dropout. Smokers exhibited the most pronounced structural damage, while chewing tobacco users showed intermediate damage, and controls had the healthiest gland profiles. These results highlight the harmful effects of tobacco on ocular surface health and its relevance to dry eye management.

4. DISCUSSION

Impact of Smoking on Meibomian Gland Function

Smoking exposes the meibomian glands to oxidative stress and inflammatory mediators. The heat generated from cigarette smoke may also directly damage the delicate glandular structures. Our study confirms that smokers show significant gland dropout, leading to increased tear film instability and severe dry eye symptoms. In a study by Muhafiz et al.[3] These findings are consistent indicating that smoking causes substantial morphological alterations and functional impairment in the meibomian glands.

Furthermore, chronic smoking has been associated with increased meibomian gland atrophy and reduced tear lipid secretion. This not only compromises tear film stability but also contributes to a higher prevalence of evaporative dry eye disease in smokers as shown by Bhutia et al., 2021.[1]

Effects of Chewing Tobacco on Ocular Surface

Chewing tobacco primarily affects the body systemically, causing vasoconstriction and reduced glandular secretions. While its impact on the meibomian glands is less severe than smoking, chewing tobacco still contributes to gland atrophy and reduced lipid production. Jha et al. [2] highlighted that chewing tobacco users experience endothelial cell loss and increased inflammation, which may explain the observed reduction in tear film stability in our study.

Interestingly, the systemic effects of nicotine and other harmful chemicals from chewing tobacco have been linked to compromised vascular health, reducing blood supply to the ocular adnexa. This may accelerate glandular degeneration and dysfunction. Although the degree of gland dropout in chewing tobacco users was lower compared to smokers, it was still notably higher than in non-tobacco users.

The findings from this study suggest that tobacco users, especially smokers, should undergo regular ophthalmic screening to detect early signs of gland dysfunction. Infrared meibography and non-invasive tests enable timely diagnosis and management. Additionally, incorporating meibomian gland imaging into routine clinical practice, as advocated by Petriček et al. [5], can facilitate early intervention.

Healthcare professionals should promote cessation and tobacco control to reduce ocular damage. Counselling patients on the ocular risks can encourage behavioral changes, potentially preventing irreversible glandular damage.[7]

Further longitudinal studies are warranted to assess the progression of meibomian gland dysfunction in tobacco users over time. Studying tobacco cessation effects may reveal if gland damage is reversible. Additionally, exploring the role of adjunctive therapies, such as anti-inflammatory agents or lipid-based artificial tears, may enhance treatment outcomes for affected individuals.7,8

In conclusion, this study underscores the detrimental impact of tobacco use on meibomian gland function, with smokers experiencing the most severe damage. Chewing tobacco users also show glandular changes, albeit to a lesser degree. Early diagnosis, preventive measures, and increased awareness are crucial in mitigating the ocular consequences of tobacco use.

1. Demographics:

Group	Mean Age (years)	Male (%)	Female (%)
Smokers	55.4 ± 4.8	80%	20%
Chewing	56.1 ± 5.2	75%	25%

Controls	54.8 ± 5.0	70%	30%

Table 2. Clinical Parameters:

Parameter	Smokers (n=40)	Chewing (n=40)	Controls (n=40)	p-value
TBUT (s)	5.8 ± 0.9	7.1 ± 0.8	10.5 ± 0.9	<0.001
Schirmer's (mm)	7.0 ± 1.2	9.0 ± 1.3	12.0 ± 1.2	<0.001
OSDI Score	35 ± 5.3	28 ± 5.2	15 ± 4.8	<0.001

Table 3. Meibomian Gland Expressibility:

Expressibility	Smokers (%)	Chewing (%)	Controls (%)
Normal	5	10	50
Mildly Reduced	15	25	30
Moderately Reduced	35	40	15
Absent	45	25	5

Table 4. Meibomian Gland Dropout:

Grade	Smokers (%)	Chewing (%)	Controls (%)
Minimal	10	20	60
Mild	15	30	25
Moderate	15	30	10
Severe	60	20	5

List of Abbreviations
ANOVA: Analysis of Variance
DED: Dry Eye Disease
MGD: Meibomian Gland Dysfunction
OSDI: Ocular Surface Disease Index
SD: Standard Deviation
SPSS: Statistical Package for the Social Sciences
TBUT: Tear Break-Up Time

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MAIN POINTS

Smoking was associated with the most severe Meibomian gland damage, with a high proportion of subjects showing severe gland dropout and absent expressibility. Chewing tobacco use also resulted in significant Meibomian gland dysfunction, although the degree of structural and functional impairment was lower than in smokers. Both forms of tobacco exposure were linked to reduced tear film stability and aqueous secretion, reflected by significantly lower TBUT and Schirmer's values compared to controls. Tobacco users reported markedly higher OSDI scores, indicating greater symptomatic burden of dry eye disease. These findings highlight tobacco exposure as a major risk factor for evaporative dry eye and emphasize the need for early screening and cessation counselling to prevent irreversible ocular surface damage.

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