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Tear Secretion, Tear-Film Stability, and Dry-Eye Symptoms in Women Wearing Eyelash Extensions in Kinshasa: A Comparative Cross-Sectional Study

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Abstract

Background: Eyelash extensions are increasingly used, but their associations with tear secretion, tear-film stability, and ocular-surface symptoms remain insufficiently characterized, particularly in Central African populations. **Objective:** To compare tear secretion, tear-film stability, and ocular-surface symptoms between women wearing eyelash extensions and women not wearing them in Kinshasa, Democratic Republic of the Congo. **Methods:** This comparative cross-sectional study was conducted from January 2023 to March 2024. Women wearing eyelash extensions were recruited using a four-stage probability-sampling approach from hair salons in Kinshasa municipal markets; women without eyelash extensions were consecutively recruited from the Ophthalmology Department of the University Hospital of Kinshasa. Schirmer I testing assessed total tear secretion, fluorescein tear-film break-up time (TFBUT) was video-recorded using the Smart Eye Camera (SEC; OUI Inc., Tokyo, Japan), and the Ocular Surface Disease Index (OSDI) assessed symptoms. Both groups underwent anterior-segment examination. Continuous variables were compared using independent-samples t tests and categorical variables using Pearson's chi-square tests. Two-sided p values < 0.05 were considered statistically significant. **Results:** The analysis included 350 women wearing eyelash extensions (mean age, 30.1 ± 3.7 years) and 350 women without extensions (mean age, 30.2 ± 8.6 years). Mean Schirmer I values were higher in the eyelash-extension group than in controls (21.3 ± 5.1 vs 17.5 ± 4.5

mm; $p < 0.01$). Mean TFBUT was shorter in the eyelash-extension group than in controls (10.6 ± 2.8 vs 12.1 ± 2.3 s; $p < 0.0002$). Severe OSDI symptoms were reported for 205 of 350 women (58.6%) in the eyelash-extension group and 42 of 350 (12.0%) in controls. A normal category was reported for 15 women (4.3%) in the eyelash-extension group and 240 (68.6%) in controls; mild and moderate categories accounted for 22.0% and 15.1% of the extension group and 8.0% and 11.4% of controls, respectively. **Conclusion:** In this cross-sectional study, women wearing eyelash extensions had higher Schirmer I values and OSDI scores and shorter TFBUT than controls. These associations do not establish causation or confirm a diagnosis of dry eye disease.

Keywords

Eyelash Extensions, Tear Secretion, Tear-Film Stability, Ocular Surface Disease Index, Smart Eye Camera, Kinshasa

1. Introduction

Dry eye disease is a multifactorial disorder of the ocular surface characterized by loss of tear-film homeostasis and accompanied by ocular symptoms; tear-film instability, hyperosmolarity, inflammation, ocular-surface damage, and neurosensory abnormalities may have etiologic roles [1] [2].

Dry eye disease is common, and its reported prevalence varies substantially with the population studied, diagnostic criteria, and study design [3].

Estimates from population-based and selected clinical or occupational samples vary widely across Western and Asian settings [3]-[10]. Hospital-based African studies also indicate a substantial burden [11]-[14].

Studies from the Democratic Republic of the Congo have described dry-eye presentations in hospital populations and among patients with glaucoma [11] [14], but evidence concerning cosmetic eyelash procedures remains limited.

Eyelash extensions place synthetic fibers, adhesives, removal agents, and fixation materials close to the eyelid margin and ocular surface. A retrospective Japanese series of 107 symptomatic users described predominantly keratoconjunctivitis and allergic blepharitis associated with extension procedures [15]. More recently, a prospective study of 32 participants documented acute symptoms and corneal staining after application, followed by a short-term reduction in noninvasive tear-film break-up time [16]. Neither study directly established chronic aqueous tear deficiency, and comparable evidence from African populations is scarce.

This study therefore compared Schirmer I values, fluorescein TFBUT, and ocular-surface symptoms between women wearing eyelash extensions and women not wearing them in Kinshasa.

2. Methods

2.1. Schirmer I Test

The Schirmer I test was used to assess total tear secretion. A Whatman No. 41

filter-paper strip (35 × 5 mm) was placed at the junction of the middle and lateral thirds of the lower conjunctival fornix. Participants were asked to look straight ahead, and the wetted length was recorded in millimeters after 5 minutes. Two measurements were obtained 30 minutes apart, and their mean was calculated.

2.2. Fluorescein Tear-Film Break-Up Time

Fluorescein tear-film break-up time (TFBUT) was assessed using the Smart Eye Camera (SEC; OUI Inc., Tokyo, Japan), a portable smartphone-attached anterior-segment imaging device incorporating blue-light illumination and video-recording capability. The device and its use for tear-film assessment have been described in experimental and human studies [17] [18].

After fluorescein instillation, participants blinked several times to distribute the dye across the ocular surface. The ocular surface was then video-recorded, and TFBUT was defined as the interval between the final complete blink and the first visible disruption of the homogeneous fluorescein-stained precorneal tear film. Two measurements were obtained 30 minutes apart, and their mean was calculated.

2.3. Ocular Surface Disease Index

The Ocular Surface Disease Index (OSDI) is a questionnaire-based symptom score, calculated independently of Schirmer I and TFBUT measurements. OSDI symptom categories are defined as follows:

- Normal: OSDI 0-12
- Mild: OSDI 13-22
- Moderate: OSDI 23-32
- Severe: OSDI 33-100

Each item was scored from 0 to 4.

- Score A:

  Did you experience the following problems during the past week?

  1) Sensitivity of the eyes to light
  2) Sensation of sand in the eyes
  3) Pain or irritation
  4) Blurred vision

- Score B:

  Over the past week, have your eye problems caused discomfort during?

  1) Reading
  2) Driving at night
  3) Using an ATM
  4) Watching television

- Score C:

  Over the past week, have you experienced eye discomfort?

  1) In windy conditions
  2) In low-humidity environments
  3) In very dry environments

4) In air-conditioned environments

Total score D = A + B + C. Score E = Total number of questions answered. OSDI score = D × 25/E.

2.4. Study Setting and Population

The study was conducted in Kinshasa, Democratic Republic of the Congo, a city comprising 24 communes.

2.5. Participants' Selection

Participants were classified into two groups according to eyelash-extension status.

- The eyelash-extension group comprised women recruited from hair salons in municipal markets across Kinshasa's communes.
- Women wearing eyelash extensions were eligible if they were present at the sampling visit and provided informed consent.
- Women who did not provide consent or reported using medications considered to affect tear secretion were excluded.
- The comparison group comprised women without eyelash extensions who provided informed consent and were recruited consecutively from the Ophthalmology Department of the University Hospital of Kinshasa.
- The source protocol excluded controls who did not provide consent, used medications considered to affect tear function, were menopausal, or had allergic conjunctivitis.

2.6. Sample-Size Calculation

The sample size was calculated using Kelsey's formula:

$$N_1 = (Z_\alpha + Z_{1-\beta})^2 \, \bar{P}\bar{Q}(R+1)/R(P_1 - P_2)^2 \quad (1)$$

where N_1 = number of cases, $N_2 = RN_1$, N_2 = number of controls, Z_α = standard normal deviate for two-tailed test based on alpha level (relates to the confidence interval level, $1 - \alpha = 95\%$), $Z_{1-\beta}$ = standard normal deviate for one-tailed test based on beta level (relates to the power level), power level $(1 - \beta) = 80\%$, R = ratio of controls to cases, $R = 1$, P_1 = proportion of cases with exposure, $P_1 = 40\%$, $P_2 = 30\%$, $Q_1 = 1 - P_1$, $Q_2 = 1 - P_2$, $\bar{P} = (P_1 + RP_2)/(R+1)$ = average proportion of exposure among cases and controls, $\bar{P} = 35\%$, $\bar{Q} = 1 - \bar{P}$, $\bar{Q} = 65\%$, odds ratio (OR) = 1.56.

$N_1 = 353$, $N_2 = 353$, $N_1 + N_2 = 706$. We reduced it to 700.

2.7. Sampling

A four-stage sampling approach was used. Five communes were randomly selected from the list of communes, and 10 markets were selected. Five hair salons per market were randomly selected, and seven women wearing eyelash extensions were examined per salon. Women without eyelash extensions were recruited consecutively from the Ophthalmology Department of the University Hospital of Kinshasa.

2.8. Data Collection

Both groups underwent an anterior-segment examination. Total tear secretion was assessed using the Schirmer I test, fluorescein TFBUT was video-recorded using the SEC, and ocular-surface symptoms were assessed using the OSDI.

2.9. Statistical Analysis

Data were entered into Microsoft Excel and analyzed using SPSS version 20.0 (IBM Corp., Armonk, NY, USA). Categorical variables were summarized as counts and percentages and compared using Pearson's chi-square test.

Continuous variables were summarized as means and standard deviations and compared between groups using independent-samples Student's t tests.

All tests were two-sided, and $p < 0.05$ was considered statistically significant.

2.10. Ethical Approval

The study approval number is No. 145/National Health Ethics Committee/BN/PMMF/2023.

National Health Ethics Committee/Ministerial Order No. 1250/CAB/MIN/S/ZKM/043/MC/2006 dated December 18, 2006.

U.S. Department of Health and Human Services (HHS) registration number: IOR G0008558/IRB.

The study approval letter from the Health Ethics Committee was received on January 13, 2023, and the study duration was from January 14, 2023, to January 13, 2024. Federalwide Assurance (FWA) registration number: 00026293.

All participants provided informed consent before enrolment.

3. Results

As reported in Table 1, the distributions of age, education, marital status, and occupation were identical between groups (all $p = 1.000$). Consequently, no statistically significant difference was observed regarding these sociodemographic characteristics.

Table 1. Sociodemographic characteristics by eyelash-extension status.

Variables	Extension		Control		p-value
	N	%	N	%	
Age, years					
18 - 27	172	49.1	172	49.1	1.000
28 - 37	94	26.8	94	26.8	1.000
38 - 47	84	24.0	84	24.0	1.000
Education					
Primary	63	18.0	63	18.0	1.000
Secondary	186	53.1	186	53.1	1.000

Continued

University	87	24.8	87	24.8	1.000
None	14	4.0	14	4.0	1.000
Marital status					
Single	203	58.0	203	58.0	1.000
Married	85	24.2	85	24.2	1.000
Divorced	58	16.6	58	16.6	1.000
Widow	4	1.1	4	1.1	1.000
Occupation					
Formal sector	99	28.3	99	28.3	1.000
Informal sector	251	71.7	251	71.7	1.000

Compared with controls, women wearing eyelash extensions had a shorter mean TFBUT (10.6 ± 2.8 vs 12.1 ± 2.3 s), a higher mean Schirmer I value (21.3 ± 5.1 vs 17.5 ± 4.5 mm), and a higher mean OSDI score (15.7 ± 2.3 vs 8.1 ± 1.9) (Table 2).

Table 2. Tear-function measurements and OSDI scores by eyelash-extension status.

Outcome	n	Extension	Control	df	t	p-value
TFBUT (s)	350	10.6 ± 2.8	12.1 ± 2.3	698	7.7	0.0002
Schirmer I (mm)	350	21.3 ± 5.1	17.5 ± 4.5	698	10.5	0.01
OSDI scores	350	15.7 ± 2.3	8.1 ± 1.9	698	47.6	0.0003

The reported distribution of OSDI severity categories differed between groups (Table 3).

Table 3. Reported OSDI severity categories by eyelash-extension status.

OSDI category	Extension		Control		p-value
	N	%	N	%	
Normal	15	4.3	240	68.6	0.001
Mild	77	22.0	28	8.0	0.001
Moderate	53	15.1	40	11.4	0.001
Severe	205	58.6	42	12.0	0.001

Severe symptoms were reported for 205 of 350 women (58.6%) in the eyelash-extension group and 42 of 350 (12.0%) in controls. A normal category was reported for 15 women (4.3%) in the eyelash-extension group and 240 (68.6%) in controls; mild and moderate categories accounted for 22.0% and 15.1% of the extension group and 8.0% and 11.4% of controls, respectively.

4. Discussion

In this comparative cross-sectional study of 700 women in Kinshasa, women wearing eyelash extensions had a shorter mean TFBUT and a higher mean OSDI score than women without extensions. Based on the values reported in **Table 2**, the extension group also had a higher mean Schirmer I value.

The differences were statistically significant, but their clinical importance cannot be determined from group means alone, and the study did not apply a prespecified diagnostic algorithm for dry eye disease.

The higher Schirmer I value may reflect reflex tearing in response to ocular-surface irritation rather than superior baseline lacrimal function. When performed without topical anesthesia, Schirmer I testing captures both basal and reflex secretion and has substantial biological and measurement variability [19].

Because the timing of extension application, adhesive and removal products, and concurrent ocular irritation were not characterized, the mechanism underlying the Schirmer result remains speculative.

The shorter TFBUT is consistent with the prospective observations of Han *et al.*, who found a transient reduction in noninvasive tear-film break-up time after eyelash-extension application [16]. However, their study also showed time-dependent changes in tear meniscus height, indicating that the interval since application may materially influence tear measurements.

Previous evidence indicates that ocular effects are heterogeneous. Amano *et al.* described mainly chemical or allergic complications among symptomatic clinic attendees [15], whereas Han *et al.* observed acute symptoms and corneal staining followed by short-term tear-film instability [16]. Neither selected sample permits estimation of population incidence or establishes chronic aqueous tear deficiency.

The higher mean OSDI score suggests a greater symptom burden among women wearing extensions. Nevertheless, symptom scores and tear-film signs are not interchangeable, and these results should not be interpreted as the prevalence of clinically diagnosed dry eye disease.

The observed differences may reflect extension-related exposure, but they may also reflect selection, unmeasured confounding, or other differences between the recruitment settings.

Accordingly, the cross-sectional associations reported here do not establish causation.

Portable anterior-segment video may also support more standardized ocular-surface assessment where access to ophthalmologists is limited. An SEC-based artificial intelligence model has estimated fluorescein tear-film break-up from video and supported dry-eye classification [20]. More recently, artificial intelligence has been explored for estimating tear meniscus height from paired SEC videos and anterior-segment optical coherence tomography, although the reported error indicates that further refinement is required before routine clinical use [21]. Image-processing studies also show that enhancement must be optimized for each end-

point because stronger processing can reduce reliability for some ocular-surface findings [22]. Collectively, these studies support technical feasibility but not clinical equivalence or cross-population generalizability.

Store-and-forward SEC workflows have been reported for remote assessment of an ocular chemical injury and for anterior-segment screening on a remote island [23] [24], while a rural cataract case illustrates continuing access gaps in resource-limited settings [25]. Consistent with a recent narrative review, smartphone-based slit-lamp systems should currently be viewed as adjuncts to, rather than replacements for, comprehensive in-person examination [26]. Future studies in Kinshasa should combine standardized symptoms and tear-function measures with masked remote video grading and prespecified artificial-intelligence endpoints. Participant-level data partitioning, a conventional slit-lamp reference standard, calibration, and external validation in Central African populations will be essential before clinical deployment.

This study's strengths include its large sample and its focus on a Central African population that has been underrepresented in ocular-surface research. Several limitations should, however, be considered.

First, the cross-sectional design precludes temporal inference. Participants with extensions were recruited from salons, whereas controls were hospital attendees, creating a substantial risk of selection bias. Matching was not described, and the analysis did not adjust for potential confounders.

Second, duration and frequency of extension wear, time since application, adhesive and removal products, contact-lens use, other cosmetics, systemic conditions such as diabetes [27], ocular conditions, medications, and environmental exposures were not reported. These factors could influence symptoms and tear measurements. Measurement details, examiner masking, and the participant or eye as the unit of analysis also require complete reporting. Finally, the single-city setting limits generalizability.

5. Conclusion

In this cross-sectional study, women wearing eyelash extensions had higher Schirmer I values and OSDI scores and shorter TFBUT than controls. These associations do not establish causation or confirm a diagnosis of dry eye disease.

Impact Statement

Clinicians evaluating ocular-surface symptoms should ask about eyelash-extension use and counsel users about possible ocular-surface associations and warning symptoms that warrant examination. These findings do not establish that eyelash extensions cause dry eye disease.

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Author Contributions

Conceptualization and methodology: David Kayembe Lubeji and Léon Muamba Nkashama; investigation and data curation: Léon Muamba Nkashama; formal analysis: Léon Muamba Nkashama; writing—original draft: Léon Muamba Nkashama; writing—review and editing: Shintaro Nakayama, Eisuke Shimizu, and Ryota Yokoiwa.

Conflicts of Interest

E.S. is a founder and shareholder of OUI Inc. S.N. and R.Y. are affiliated with OUI Inc. OUI Inc. manufactures the Smart Eye Camera used in this study and provided publication support. The remaining authors declare no competing interests.

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