Original Article

Effect of Smoking on Tear Stability and Corneal Surface

Norhani Mohidin[1], Adlie B. Jaafar[1]

[1]Centre of Optometry, Faculty of Health Sciences, Universiti Teknologi MARA Selangor, Puncak Alam Campus, Selangor, Malaysia

Abstract

Purpose: To determine the effect of smoking on tear stability and ocular surface of the cornea among students aged between 19 and 25 years. This study also aimed to find a correlation between tear film stability with a score of McMonnies Dry Eye Questionnaire (MDEQ) and Ocular Surface Disease Index Questionnaire (OSDI).

Methods: This is a prospective, non-interventional, comparative study of 59 male (27 smokers and 32 non-smokers) undergraduates of a public university. Tear film stability was evaluated using non-invasive tear break-up time and fluorescein tear break-up time. Corneal staining was determined using Efron grading scale. MDEQ and OSDI Questionnaires were used to assess dry eye symptoms. Data were obtained from the right eye only and analyzed using descriptive and correlation analysis.

Results: The age range of the participants was between 19 and 25 years. The mean age for smokers and non-smokers was 22.19 ± 2.20 and 21.22 ± 1.83 years, respectively ($P = 0.07$). The smoker group had statistically significant lower tear film stability than the non-smoker group ($P < 0.0001$). Corneal staining was statistically significant higher at the nasal and temporal parts of the cornea in smokers ($P < 0.05$). There was a moderate correlation between tear film stability and scores of MDEQ and OSDI.

Conclusions: Tobacco smoke has a significant effect on the tear film stability, seen in reduced tear stability values among smokers. Corneal staining was found to be more extensive in the smokers. These findings would be useful to eye-care providers in the management of their dry eye patients related to smoking.

Keywords: Corneal staining, Dry eye, McMonnies Dry Eye questionnaire, Ocular Surface Disease Index questionnaire, Smoking, Tear film stability

Address for correspondence: Norhani Mohidin, Centre of Optometry, Faculty of Health Sciences, Universiti Teknologi MARA Selangor, Puncak Alam Campus, 42300 Selangor, Malaysia. E-mail: norhani0887@uitm.edu.my
Submitted: 18-Oct-2019; **Revised:** 09-Mar-2020; **Accepted:** 29-Mar-2020; **Published:** 04-Jul-2020

Introduction

Tobacco smoke is known to contain heavy metals and active compounds that can affect the eye.[1] Epidemiological studies have shown that cigarette smoking may be a high-risk factor for several ophthalmological disorders, including cataract, age-related macular degeneration, and dry eye disease.[2]

In a study to determine the effect of cigarette smoke on the ocular surface of the eye, several authors reported disrupted tear stability, reflected in lower tear break-up time (TBUT) values measured in smokers compared to non-smokers.[3-7] Schirmer I and II tests (using local anesthetic) carried out by the same authors, however, showed no significant difference in values between smokers and non-smokers, except for one study[6] that found that Schirmer II results were significantly lower in smokers compared to non-smokers.

Previous authors also examined damage to the epithelial surface of the cornea as results of smoking, which can be detected by corneal staining. Thomas *et al*.[5] showed that punctate staining found among smokers was significantly more than that in non-smokers. About 56.9% of smokers had superficial punctate staining on the cornea, and no punctate staining was observed in non-smokers (0%). Altinors *et al*.[3] and Matsumoto *et al*.[4] also found that fluorescein staining score in

Access this article online

Quick Response Code:

Website: www.jcurrophthalmol.org

DOI: 10.4103/JOCO.JOCO_70_20

How to cite this article: Mohidin N, Jaafar AB. Effect of smoking on tear stability and corneal surface. J Curr Ophthalmol 2020;32:232-7.

their group of participants was significantly higher in smokers compared to non-smokers. Yoon *et al*.,[8] however, found no significant difference in fluorescein staining score between the smokers and non-smokers in their study. Khalil *et al*.[6] also found no difference in corneal staining between smokers and non-smokers, but they used Rose Bengal instead of fluorescein.

Tobacco smoke was reported to contribute to dry eye among smokers. Symptoms of dry eye can be checked by using established questionnaires such as the McMonnies Dry Eye Questionnaire (MDEQ)[9] and the Ocular Surface Disease Index Questionnaire (OSDI).[10] The MDEQ consists of 12 questions related to the clinical risk factors for dry eye. It is self-administered. Respondents are asked to answer all questions, and the scores, which have a weighted scoring scale, are noted. The scores range from 0 to 45, and a score of 14.5 or above is indicative of dry eye. The OSDI questionnaire is comprised of 12 items that survey side effects, functional limitations, and environmental factors related to dry eye. It is assessed on a scale of 0–100, with higher scores representing greater disability. It is a valid and reliable instrument for measuring dry eye disease severity (normal, mild to moderate, and severe). The score can be categorized as normal (0–12), mild dry eye (13–22), moderate dry eye (23–32), or severe dry eye (33–100).[10]

A study by Tan *et al*.[11] showed no association between smoking and symptoms of dry eye using MDEQ. Similarly, Masmali *et al*.[12] also showed no significant correlation between the MDEQ score and smoking. Aktaş *et al*.,[13] however, showed a higher OSDI score among smokers compared to non-smokers.

This study aims to find information on tear stability measured using non-invasive tear break-up time (NIBUT) and TBUT among smokers and compare the results with non-smokers. It also aims to find whether the symptoms of dry eye among smokers can be differentiated from non-smokers using established questionnaire such as the MDEQ and OSDI. Besides that, it also aimed to find whether there is any correlation between tear stability values and MDEQ and OSDI scores.

Methods

Study design

Purposive sampling was used in this prospective, non-interventional, comparative study. It was approved by the research ethics committee of the university (REC 429/17) and followed the tenets of the Declaration of Helsinki. All participants signed informed consent prior to the start of the study.

There was no particular order in which the participants were examined. Because most of the participants were students, they came to the clinic at their own free time for the measurements to be done. To avoid the effect of diurnal variation on tear stability, most of the examinations were done in the morning between 9.00 a.m. and 1.00 p.m.

Participants

Participants were recruited from among students at the campus by placing advertisements around the clinic as well as by word of mouth. The inclusion criteria included male participants aged 18 and above, who had been smoking at least for the past 2 years and smoked at least one pack or more in 3–5 days, and willing to provide consent to participate in the study. The exclusion criteria included participants who had any systemic or ocular disease, history of ocular surgery or allergy, contact lens wearers, and passive smokers. All participants must not have had a history of intake of systemic or topical medications that could affect their ocular or tear physiology. The same criteria were applied in recruiting a control group of non-smokers.

Research instrument

A modified aspheric bowl with a radial pattern painted on the concave side was used in this study. This instrument has a 1-cm hole poked in the middle of the bowl to allow a near telescope (×4 magnifications) to be installed at the back and used as the observation eyepiece. The bowl was internally illuminated with a mean luminance of 50 cd/m^2. Detailed explanation of this instrument and its functions has been described by Mengher *et al*.[14]

A slit-lamp biomicroscope and fluorescein strip (Fluorescein Sodium, Rainbow Meditech, Kuala Lumpur, W.P., Malaysia) were used to evaluate NIBUT, TBUT, and corneal staining.

Procedure

The participants were first informed about the objectives and procedure of the study. They were also asked to fill out and sign a consent form before the procedure was carried out. Preliminary examination was first carried out to ensure the inclusion and exclusion criteria were met.

NIBUT was measured on the right eye by using a modified bowl perimeter with radial grid pattern painted on it together with a ×4 near telescope attached in the middle for viewing. The time taken for the mire images on the cornea to become distorted or out of focus after a complete blink while the eye remained open was timed using a stopwatch. Five consecutive readings were taken, and the mean of the best three readings closest to each other was considered for evaluation.[15]

TBUT was measured using a fluorescein strip and a slit-lamp biomicroscope. The fluorescein strip was wetted with a single drop of saline (Opticare, Excel Visions Medicals, Klang, Selangor, Malaysia), and the excess saline was shaken off. It was then applied onto the lower bulbar conjunctiva while the participant was looking up, making sure that the tip did not touch any part of the cornea to prevent reflex tearing. The participant was asked to blink a few times to spread the fluorescein. A break in the tear film was observed using a slit-lamp biomicroscope (×6) and a cobalt blue filter. The time taken for the first black patch to appear on the cornea after a complete blink while the eye remained open was timed using a stopwatch.

Three consecutive readings were taken, and the mean was considered for the evaluation of TBUT.

Corneal staining was assessed using a slit-lamp biomicroscope (×16) with the instillation of fluorescein dye and viewed under the cobalt blue filter. The cornea was arbitrarily divided into the following four sections [Figure 1] for recording purposes: S1 – superior cornea, S2 – nasal cornea, S3 – inferior cornea, and S4 – temporal cornea. The Efron Grading Scale[16] [Table 1] was used to note the extent and severity of corneal staining with Grades 0–4; Grade 0 = no staining, Grade 1 = trace staining, Grade 2 = mild staining, Grade 3 = moderate staining, and Grade 4 = severe staining.

All participants were then asked to fill up two sets of questionnaires related to dry eye, the MDEQ and OSDI questionnaires. The MDEQ consisted of 12 questions in total. A score of 14.5 was indicative of a dry eye. The OSDI consisted of 12 items graded on a scale of 0–4 whereby 0 = none of the time, 1 = some of the time, 2 = half of the time, 3 = most of the time, and 4 = all of the time. The total OSDI score was calculated by using the following formula: OSDI = ([sum of scores for all questions answered] ×25)/([total number of questions answered]). The OSDI was scored on a scale of 0–100, with higher scores representing greater dry eye severity.

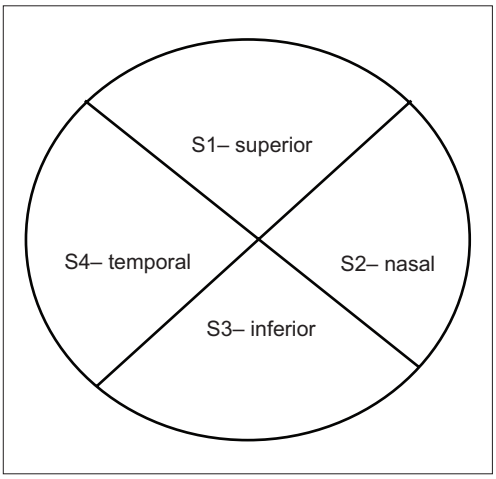

Figure 1: Sections 1 (S1) to 4 (S4) to assess the extent and severity of corneal staining using the Efron Grading Scale

Table 1: Efron Grading Scale for the evaluation of corneal staining

Grade	Extent of corneal staining
0	None: Clear cornea, no staining
1	Trace: Light punctuate staining
2	Mild: More light punctuate staining
3	Moderate: Pan-corneal punctuate staining
4	Severe: Heavy pan-corneal punctuate staining

All the measurements were done by one examiner (A.B.J.) mainly between 9.00 a.m. and 1.00 p.m. to counter the effects of diurnal variation. The intraobserver reliability was not done, but to ensure the reliability of data, A.B.J. underwent training for NIBUT measurements prior to the start of the study.

Data were analyzed using SPSS version 18 (SPSS Inc., Chicago, IL, USA). Shapiro–Wilk test was initially run to test the normality of the data collected. The test showed that the data for NIBUT were not normally distributed, hence a non-parametric test, Mann–Whitney U-test, was carried out to find the differences in tear stability (NIBUT) between the smokers and non-smokers. However, TBUT was normally distributed, so parametric test was used instead for comparison. Corneal staining observed in the different sections of the cornea of smokers and non-smokers was noted. Chi-square test was used to compare the corneal staining found in smokers and non-smokers in each of the quadrants. Spearman's correlation test was done to find any association between tear stability and MDEQ and OSDI scores. *P* value was considered statistically significant if it was <0.05.

Results

There were a total of 59 participants who took part in this study. Of the 59 participants, 27 (45.8%) were smokers and 32 (54.2%) were non-smokers. Among the 27 smokers, 15 (55.6%) smoked one pack of cigarettes per 1–2 days, 11 (40.7%) smoked one pack of cigarette per 3–5 days, and one (3.7%) participant was in the others' category. The participants comprised 100% of males and may be considered light smokers.

The mean age for the smokers was 22.19 ± 2.20 years, and the mean age for the non-smokers was 21.22 ± 1.83 years. There was no statistically significant difference between them (P = 0.07). All the 59 participants were university students.

Tear evaluation of the smokers and non-smokers is shown in Table 2. Shapiro–Wilk test was used to test the normality of all data. As the distribution of NIBUT values was not

Table 2: Evaluation of tear stability in smokers and non-smokers

	NIBUT		TBUT	
	Mean±SD (s)	Median (minimum, maximum) (s)	Mean±SD (s)	Median (minimum, maximum) (s)
Smokers	7.29±1.18	7.44 (4.87, 9.54)	3.24±1.05	3.46 (1.34, 5.46)
Non-smokers	13.26±3.72	13.29 (7.61, 21.33)	5.51±1.44	5.89 (3.00, 9.26)
P	Mann-Whitney, U=38.5, *Z*=−5.987, *P*=0.0001		*t*-test, *P*=0.0001	

P<0.05 is considered statistically significant. NIBUT: Non-invasive tear break-up time, TBUT: Tear break-up time, SD: Standard deviation

normally distributed in either smokers or non-smokers, Mann–Whitney U-test was used for comparison. The results showed that the mean values for NIBUT were significantly lower in smokers as compared to non-smokers. However, the Shapiro–Wilk test showed normally distributed data for TBUT, so the *t*-test was used to compare TBUT between smokers and non-smokers. The results also showed that the mean values for TBUT were significantly lower in smokers as compared to non-smokers.

Figure 2 shows the percentage of corneal staining in smokers and non-smokers for each quadrant. Both smokers and non-smokers had no corneal staining in the superior part (0%). A Pearson's Chi-square test was run to compare the depth and extent of corneal staining between smokers and non-smokers. Sections 2 – nasal – and 4 – temporal – showed a significant difference in corneal staining between smokers and non-smokers (Chi-square = 7.958, $P = 0.05$), while for Sections 1 – superior – and 3 – inferior –, Chi-square test did not show a statistically significant difference between smokers and non-smokers (Chi-square = 2.318, $P = 0.314$). Smokers showed more corneal staining in the nasal and temporal sections of the cornea than non-smokers.

Figure 3 shows the percentage of corneal staining in smokers and non-smokers based on the Efron grading scale. Nearly 77.8% of smokers and 94.5% of non-smokers had Grade 0 of corneal staining. While for Grade 1, corneal staining was seen in about 21.3% for smokers and 5.5% for non-smokers and for Grade 2, corneal staining was 0.9% for smokers and 0% for non-smokers. However, none of the smokers or non-smokers had Grade 3 and 4 corneal staining (0%). For analysis, the data were combined [Figure 4], and Chi-square test showed that the percentage of corneal staining was statistically significantly more in smokers than non-smokers (Pearson's Chi-square, $\chi^2 = 5.69$, $P = 0.017$).

Spearman's correlation test was run to find the association between tear film stability (NIBUT and TBUT) and MDEQ and OSDI scores. As shown in Table 3, there was significant correlation between tear stability and MDEQ score and OSDI score.

The MDEQ score and dry eye classification in smokers showed that all participants had no dry eye. The OSDI score, however, showed that only 26% of smokers were classified as not having dry eye compared to 34.4% of non-smokers [Table 4].

Table 3: Association between McMonnies Dry Eye Questionnaire and Ocular Surface Disease Index Questionnaire score and tear stability values

Score	Tear stability	*rs*	*P*
MDEQ	NIBUT	−0.423	0.001
	TBUT	−0.355	0.006
OSDI	NIBUT	−0.336	0.009
	TBUT	−0.385	0.003

P<0.05 is considered statistically significant. MDEQ: McMonnies Dry Eye Questionnaire, OSDI: Ocular Surface Disease Index Questionnaire, NIBUT: Non-invasive tear break-up time, TBUT: Tear break-up time

Discussion

The participants in this study were all university students, with a mean age of 22.19 ± 2.20 years for smokers and

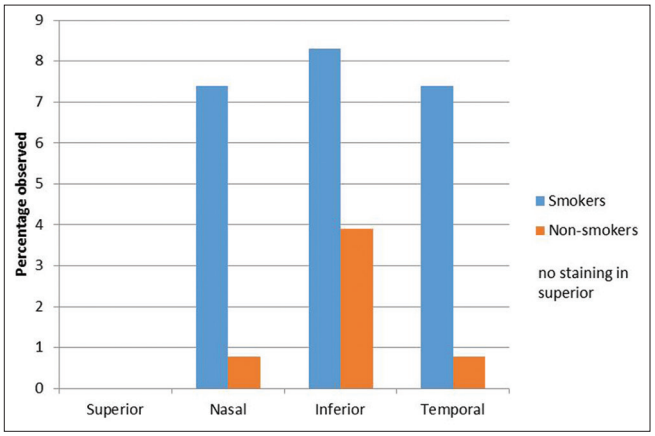

Figure 2: Corneal staining observed at different sections of the cornea between smokers and non-smokers

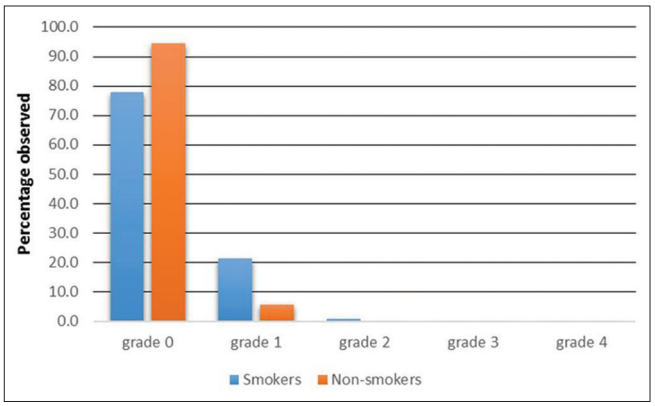

Figure 3: Grades and severity of corneal staining in smokers and non-smokers based on the Efron Grading Scale

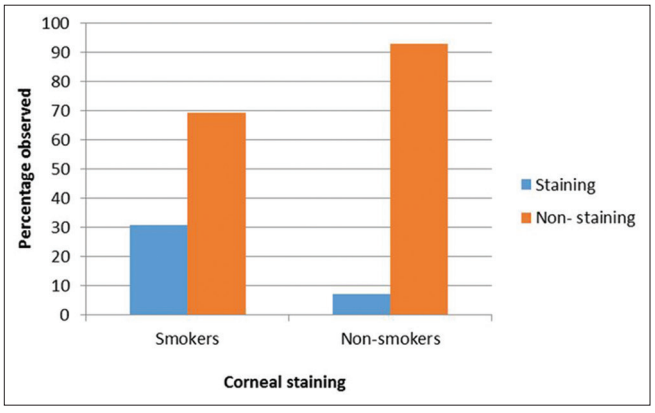

Figure 4: Corneal staining observed in smokers and non-smokers

Table 4: Dry eye classification according to McMonnies Dry Eye Questionnaire and Ocular Surface Disease Index Questionnaire scores

	Smokers (*n*=27), *n* (%)	Non-smokers (*n*=32), *n* (%)
MDEQ		
Normal (<14.5)	27 (100)	32 (100)
Dry eye (>14.5)	0 (0)	0 (0)
OSDI score		
Normal	7 (26.0)	11 (34.4)
Mild	11 (40.7)	9 (28.1)
Moderate	3 9 (11.1)	9 (28.1)
Severe	6 (22.2)	3 (9.4)

MDEQ: McMonnies Dry Eye Questionnaire, OSDI: Ocular Surface Disease Index Questionnaire

21.22 ± 1.83 years for non-smokers. They were all males because smoking is uncommon among females at the university. The mean values of TBUT measured in this study were significantly lower in smokers (3.24 ± 1.05 s) compared to that of non-smokers (5.51 ± 1.44 s). Previous studies[6,7,12] also showed that TBUT values were significantly lower in smokers compared to non-smokers. Besides TBUT, the same authors also compared Schirmer test values and found the results to be lower in smokers. Because TBUT involves an invasive procedure and is known to cause a change in tear film that may affect tear stability, we also carried out a measure of NIBUT which is now a more preferred method of measuring tear stability.[14] The results also showed a significantly lower NIBUT value among smokers (7.29 ± 1.18 s) compared to non-smokers (13.26 ± 3.72 s). A study using tear-ferning pattern[12] also showed that smokers have patterns that were consistent with those who have dry eye compared to a control group. It is of interest to note that previous studies[6,7,12] involved those who smoke more than one pack of cigarettes per day compared to the majority (55.6%) of our participants who smoke an average of one pack per 1–2 days and one packet per 3–5 days (41%), yet the results were similar. This reaffirms the findings that cigarette smoking affects tear stability as shown by the decreased values in TBUT and NIBUT among smokers, but of greater concern is that it also affects tear stability among light smokers.

In this study, the percentage of corneal staining found in smokers was more than that of non-smokers. Results of this study are in agreement with most studies reported previously.[3,5,6] Yoon *et al*.,[8] however, found no significant difference in corneal staining between smokers and non-smokers. The eye is highly sensitive to chemical borne fumes, and tobacco smoke contains heavy metals and toxic compounds that are known to cause grittiness, foreign body sensation, excess tearing, redness, and dryness.[7] This dryness is probably reflected in diminished tear volume, increment of water evaporation, and dysfunction of lipids or mucus of the tear layer, which can be measured by noting fluorescein stain on the cornea.

Various scoring systems can be used to compare corneal staining on the cornea between smokers and non-smokers. In this study, we used the Efron Grading Scale for comparison. Overall, this study showed significantly more corneal staining in smokers although most of it occurred in the nasal and temporal sections of the cornea. There is no significant difference in staining between the superior and inferior sections of the cornea between smokers and non-smokers, partly because these areas are covered by eyelids in most Asian eyes and therefore unexposed to the smoke and fumes in the atmosphere.

Based on the grades and severity of staining, the results showed that the majority of smokers (77.8%) and non-smokers (94.5%) had no staining on the cornea in this study. Grade 1 staining was found in 21.3% of smokers and 5.5% of non-smokers. Although significantly different from each other, relatively, Grade 1 staining can be considered mild. Smokers in this study only consumed one pack of cigarettes for 1–2 days (56%), and some (41%) consumed one pack per 3–5 days. It has been reported that the extent and severity of corneal staining among smokers were associated with longer duration of being smokers and smoking more than one pack per day.[7]

This study showed a significant correlation between NIBUT and MDEQ scores and TBUT and MDEQ scores. It is in contrast to the results found by Tan *et al*.[11] and Masmali *et al*.,[12] who found an insignificant correlation between TBUT values and MDEQ score. With regard to OSDI, the result also showed a significant correlation between NIBUT values and OSDI score and TBUT values and OSDI score. Wang *et al*.[17] found an insignificant correlation between TBUT values and OSDI score in their group of participants, whereas Ozcura *et al*.[18] reported a significant correlation between OSDI score and TBUT values. Furthermore, Fuller *et al*.[19] reported a significant correlation between NIBUT values and OSDI score. In summary, it appears that there is no consensus on the associations between tear stability and MDEQ and OSDI scores, and this warrants further investigation.

The MDEQ score attained by the participants in both the smoker and non-smoker groups was <14.5. According to McMonnies and Ho, participants who have MDEQ score of >14.5 only are considered to have a dry eye. Because all our participants' scores were <14.5, they fall under the "normal" category by classification. In this study, the number of participants was quite small, and MDEQ was reported not to have the ability to distinguish more than two strata (present or absent) of patients' symptoms.[20] The OSDI fared slightly better as it was able to identify some of those with dry eye. The OSDI has been claimed to be able to discriminate between the different stages of severity of dry eye from mild to severe.[10]

There were some limitations in this study. A larger number of participants will probably yield more reliable results. There may also be observational bias by the researcher when taking the measurement. A blind study will probably give a more reliable result. In conclusion, the results of this study showed that tear stability values in light smokers measured using NIBUT and TBUT were lower compared to that of non-

smokers. Corneal staining was also found more extensively in smokers than non-smokers. Tear stability (NIBUT and TBUT) was moderately correlated with MDEQ and OSDI scores. The findings of this study will help eye-care providers in the management of their patients who present with dry eye that may be related to cigarette smoking.

Acknowledgment

We thank the staff at the clinic for technical assistance during data collection.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Reijula K, Digert CS. Assessment of indoor air problems at work with a questionnaire. Occup Environ Med 2004;61:33-8.
2. Solberg Y, Rosner M, Belkin M. The association between cigarette smoking and ocular diseases. Surv Ophthalmol 1998;42:535-47.
3. Altinors DD, Akça S, Akova YA, Bilezikçi B, Goto E, Dogru M, *et al*. Smoking associated with damage to the lipid layer of the ocular surface. Am J Ophthalmol 2006;141:1016-21.
4. Matsumoto Y, Dogru M, Goto E, Sasaki Y, Inoue H, Saito I, *et al*. Alterations of the tear film and ocular surface health in chronic smokers. Eye (Lond) 2008;22:961-8.
5. Thomas J, Jacob GP, Abraham L, Noushad B. The effect of smoking on the ocular surface and the precorneal tear film. Australas Med J 2012;5:221-6.
6. Khalil HE, Aboud SA, Azzab MA. Comparative study between smokers and nonsmokers regarding dry eye. Delta J Ophthamol 2018;19:9-13.
7. Agrawal N, Jharawal MK, Paharia N, Bansal K. Effect of smoking on ocular surface and tear film: A clinic – Pathological study. Adv Ophthalmol Vis Syst 2018;8:241-4.
8. Yoon KC, Song BY, Seo MS. Effects of smoking on tear film and ocular surface. Korean J Ophthalmol 2005;19:18-22.
9. McMonnies CW, Ho A. Response to a dry eye questionnaire from a normal population. J Am Optom Assoc 1987;58:588-91.
10. Schiffman RM, Christianson MD, Jacobsen G, Hirsch JD, Reis BL. Reliability and validity of the ocular surface disease index. Arch Ophthalmol 2000;118:615-21.
11. Tan LL, Morgan P, Cai ZQ, Straughan RA. Prevalence of and risk factors for symptomatic dry eye disease in Singapore. Clin Exp Optom 2015;98:45-53.
12. Masmali AM, Al-Shehri A, Alanazi SA, Abusharaha A, Fagehi R, El-Hiti GA. Assessment of tear film quality among smokers using tear ferning patterns. J Ophthalmol 2016;2016:8154315.
13. Aktaş S, Tetikoğlu M, Koçak A, Kocacan M, Aktaş H, Sağdık HM, *et al*. Impact of smoking on the ocular surface, tear function, and tear osmolarity. Curr Eye Res 2017;42:1585-9.
14. Mengher LS, Bron AJ, Tonge SR, Gilbert DJ. A non-invasive instrument for clinical assessment of the pre-corneal tear film stability. Curr Eye Res 1985;4:1-7.
15. Cho P. Reliability of a portable non-invasive tear break-up time test on Hong Kong-Chinese. Optom Vis Sci 1993;12:1049-54.
16. Efron N. Efron Grading Scales for Contact Lens Complications, (Millennium Edition), Butterworth-Heinemann. Available from: http://eprints.qut.edu.au. [Last update on 2010 Jun 9; Last accessed on 2008 Jan 14].
17. Wang S, Zhao H, Huang C, Li Z, Li W, Zhang X, *et al*. Impact of chronic smoking on Meibomian gland dysfunction. PLoS One 2016;11:e0168763.
18. Ozcura F, Aydin S, Helvaci MR. Ocular surface disease index for the diagnosis of dry eye syndrome. Ocul Immunol Inflamm 2007;15:389-93.
19. Fuller DG, Potts K, Kim J. Non-invasive tear break-up times and ocular surface disease. Optom Vis Sci 2013;90:1086-91.
20. Gothwal VK, Pesudovs K, Wright TA, McMonnies CW. McMonnies questionnaire: Enhancing screening for dry eye syndromes with Rasch analysis. Invest Ophthalmol Vis Sci 2010;51:1401-7.