

Evaluation of the effects of electronic cigarettes on the tear film of Smokers using Keratograph and SM Tube

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ABSTRACT

Purpose: To evaluate the effects of e-cigarettes on tear film by comparing the tear film parameters of smokers and non-smokers using Keratograph and SM Tube.

Study Design: Cross sectional study.

Place and Duration of Study: Qasim University, from Saudi Arabia.

Methods: A total of 60 males of age group 20 – 38 years were divided into three groups (Twenty non-smokers, 20 tobacco smokers and 20 vapor users). After consent, dry eye symptoms questionnaire was given to the participants. Four different test parameters through the Keratograph (5M JENVIS). Tear meniscus height, non-invasive tear break-up time, ocular redness and lipid layer thickness were measured. The new strip meniscometry tube (SM Tube) was used to test tear production. Data were analyzed using Statistical Package for Social Sciences (SPSS) with p value of less than 0.05 considered as significant.

Results: The average tear breakup time was significantly decreased in both smokers and vapors group (10.15 ± 1.92 and 10.25 ± 2.65 respectively) than in nonsmokers (13.35 ± 2.36). There was also statistically significant difference in tear meniscus height, redness and lipid layer thickness between e-smokers and non-smokers ($p > 0.05$). The difference in these parameters was statistically non-significant between smokers and e-cigarette users.

Conclusion: E-cigarettes cause low tear breakup time, less tear volume and other dry eye parameters, which leads to dry eye. There is a need for strict checks and balances on E-cigarette consumption for controlling cases of vision impairments related with e-cigarettes.

Key Words: Tobacco, Smoking, E-cigarette, Ocular surface disease index, Tear film break up time.

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INTRODUCTION

Smoking is a global problem associated with many ocular conditions. Chemicals like nitrosamines, hydrocarbons, and heavy metals are widely used in cigarettes and can cause damage to the ocular tissues.

According to the World health organization, tobacco is a silent killer of its consumers.¹ Nowadays, a new type of cigarette named E-cigarette has been introduced in market which does not contain tobacco and is considered safe.² In 2014 definition of E-cigarettes was published by the Food and Drug Administration (FDA) which defines it as a nicotine and chemical supplier which operates with batteries and is different from traditional smoking habits.³ Initially, E-cigarettes were considered safe however researchers provide strong evidence of vaping side effects on the respiratory system. Despite the hazardous effects, vaping is still popular in young adults and families having strong social status.⁴

E-cigarettes deliver nicotine, designed in an aerosolized to provide real experience of smoking to its users. Each E-cigarette contained 0 to 24 mg or more nicotine according to the user preferences. The chemical composition of E-cigarettes shows fewer toxicant levels than conventional cigarette smoke.⁵ Since 2005, the E-cigarette market has expanded to three billion dollars in global business with 466 brands and almost 8,000 different flavors. This market has opened doors to nicotine addiction among young population.

A study revealed two times high consumption of E-cigarettes in North America, European Union, and Republic of Korea from 2008 to 2012.⁶ The study of Zhang et al,⁷ found that nicotine delivery through E-cigarettes depends upon the vaping technique, particle evolution, and cloud effects. However, studies found that high E-cigarette exposure may lead to dry eye.^{8,9} E-cigarettes or vaping damage the lipid layer of the pre-corneal tear film resulting in dry eyes.⁹ However, there are not enough studies about the effect of e-cigarettes on the tear film, and none have been conducted in the Qasim region. So, we designed this research to investigate the effect of e-cigarettes on the tear film by evaluating the tear film parameters of smokers compared to non-smokers among Qasim University students and workers.

METHODS

A total of 60 males of age group 20 – 38 years were divided into three groups for this cross-sectional single visit study. Twenty non-smokers, 20 tobacco smokers and 20 vapor users were enrolled in this cross-sectional study. Ethical approval was obtained from Qasim University Ethics Committee. Subjects who use contact lenses, eye lubricants or any medications that could adversely affect eyes and passive smokers were excluded from the study. Chronic smokers and healthy individuals were included in the study. Tests were conducted during the morning and afternoon (8 am – 2 pm) and all subjects were given a written consent form prior to conducting the tests. Dry eye symptoms questionnaire was also given to the participants (Ocular surface disease index OSDI). We used Thomas¹⁰ study for calculating sample size. Sample size was calculated based on the differences of tear breakup time in nonsmokers (11.28 ± 1.27 seconds) and tobacco cigarette smokers (7.26 ± 1.86 seconds),¹⁰ which showed that four subjects in each group were sufficient to detect significant differences with 95%

confidence interval and 80% power.

All subjects underwent four different test parameters through the Keratograph (5M JENVIS). Following tests were included; tear meniscus height TMH, non-invasive tear break-up time (NITBUT), ocular redness (OR) and lipid layer thickness (LLT). TMH test was conducted by measuring the tear height at the lower lid margin three times and taking the average of the three. Subjects were asked to focus on red dot of light, height of more than 0.20 mm was considered normal TMH, and less than 0.20 mm was considered low TMH. NITBUT was also measured quantitatively through K5M. Subjects were asked to focus on the red dot of light and not to blink for about 25 seconds while recording, then the average was measured by the K5M. TUBT of 10 seconds or more was considered normal BUT and less than 10 seconds as low BUT. Degree of ocular redness (OR) was evaluated qualitatively on a scale of 1-4 (1 = normal, 2 = mild, 3 = moderate and 4 = severe). Subjects were asked to open their eyes widely and an image of the eye was captured for evaluation.

Assessment of LLT was done qualitatively in grading scale of 1 – 4, based upon the color hue of the corneal tear film layer appearing in the video recording.

1 = Yellowish-grayish hue: lipid at equilibrium (normal).

2 = Reddish to bluish hue: high lipid abundance (mild).

3 = Grayish to whitish hue: mild lipid deficit (moderate).

4 = Very pale-whitish hue: significant lipid deficit (severe).

Subject was asked to blink multiple times during recording. First two blinks were for the adjustment of focus from the rings reflected from cornea.

OSDI questionnaire score was collected for each subject. The questionnaire consists of 12 multiple choice questions related to dry eye symptoms, each question has 5 answers and each answer has a score (all the time “4 score”, most of the time “3 score”, half of the time “2 score”, some of the time “1 score”, none of the time “0 score”). OSDI questionnaire scores were collected and the average was taken for each group. The new strip menis cometry tube (SM Tube) was used in this study as a test of tear production.

Data were analyzed using Statistical Package for

Social Sciences (SPSS) with p value of less than 0.05 considered as significant. One-Way ANOVA was used which compares the means of the three groups in the study to determine whether there is statistical evidence that the associated population means are significantly different. T-test was used as a post hoc analysis if there is a difference between the groups.

RESULTS

For this study, 40 smokers were recruited. Out of these, 20 were using vapors with a mean age of 32.55 ± 9.25 .

For comparison, 20 nonsmokers were selected with a mean age of 33.85 ± 11.35 . The average tear breakup time was significantly decreased in both smokers and vapors group (10.15 ± 1.92 and 10.25 ± 2.65 respectively) than in nonsmokers (13.35 ± 2.36). A statistically significant difference was found when comparing the tear breakup time among the three groups ($p = 0.000041$). We reported a significant difference among the three groups when comparing tear volume through the strip menisometry tube (SM Tube) test ($p = 0.00001$). Table 1 reflects the detailed clinical outcomes.

Table 1: Demographic and Clinical characteristics of participants.

Variables	Non-Smokers	Smokers	Vapors	F-ratio (ANOVA)	P-value
Age	33.85 ± 11.35	34.35 ± 11.09	32.55 ± 9.25	0.1534	0.85
Ocular Surface Disease Index (OSDI)	4.25 ± 4.48	10.85 ± 5.96	10.3 ± 7.67	7.01	0.001
Tear meniscus height (TMH) mm	0.272 ± 0.04	0.255 ± 0.05	0.244 ± 0.04	1.58	0.213
Tear breakup time (TBUT)	13.35 ± 2.36	10.15 ± 1.92	10.25 ± 2.65	12.13	0.000041
Redness	1.55 ± 0.51	1.95 ± 0.75	2 ± 0.83	2.766	0.071
Lipid Layer thickness	1.45 ± 0.51	1.6 ± 0.59	1.85 ± 0.48	2.855	0.065
SM Tube	6.3 ± 1.41	3.2 ± 2.16	3.1 ± 1.91	19.13	0.00001

Table 2: Post-Hoc Analysis of Ocular Surface Disease Index, Tear breakup time (TBUT) and SM Tube.

	Pair wise Comparison	Tukey's HSD (C.I at 0.05 = 4.70)	Value for Q (C.I at 0.05 = 3.40)	P-value
Ocular Surface Disease Index	Non-smokers Vs smokers	6.60	4.77	0.00375
	Non-smokers Vs Vape user	6.05	4.38	0.00845
	Smokers Vs Vape users	0.55	0.40	0.957
	Pair wise comparison	Tukey's HSD (C.I at 0.05 = 1.7771)	Value for Q (C.I at 0.05 = 3.40)	P-value
Tear breakup time (TBUT)	Non-smokers Vs smokers	3.20	6.13	0.00018
	Non-smokers Vs vape users	3.10	5.94	0.00028
	Smokers Vs vape users	0.10	0.19	0.98
	Pair wise comparison	Tukey's HSD (C.I at 0.05 = 1.4154)	Value for Q (C.I at 0.05 = 3.40)	P-value
SM Tube	Non-smokers Vs smokers	3.10	7.45	0.00001
	Non-smokers Vs vape users	3.20	7.69	0.0000
	Smokers Vs vape users	0.10	0.24	0.98

Table 3: Logistic regression analysis of Non-Smokers Vs Smokers.

Variables	Cohen's d	Pearson Correlation	Adjusted odd ratio (95% C.I)
Age	-0.04	-0.02	-0.08 (-1.24, 1.08)
Ocular surface disease index	-1.25	-0.53	-2.27 (-3.54, -1)
Tear meniscus height (TMH) mm	0.38	0.18	0.68 (-0.49, 1.85)
Tear breakup time (TBUT)	1.49	0.6	2.7 (1.39, 4.01)
Redness	-0.62	-0.3	-1.13 (-2.32, 0.06)
Lipid Layer Thickness	-0.27	-0.13	-0.49 (-1.66, 0.67)
SM Tube	1.7	0.65	3.08 (1.73, 4.44)

Table 4: Logistic regression analysis of Non-Smokers Vs Vape users.

Variables	Cohen's d	Pearson Correlation	Adjusted Odd Ratios (95% C.I)
Age	0.13	0.06	0.23 (-0.93, 1.39)
Ocular surface disease index	-0.96	-0.43	-1.75 (-2.97, -0.52)
Tear meniscus height (TMH) mm	0.7	0.33	1.27 (0.07, 2.47)
Tear breakup time (TBUT)	1.24	0.53	2.24 (0.97, 3.51)
Redness	-0.65	-0.31	-1.18 (-2.38, 0.01)
Lipid Lt	-0.81	-0.37	-1.47 (-2.67, -0.26)
SM Tube	1.91	0.69	3.46 (2.06, 4.86)

DISCUSSION

According to the National Eye Institute, dry eye is classified into Aqueous tear deficiency (ATD) which is characterized by inadequate aqueous production by the lacrimal gland, and Evaporative tear deficiency (ETD) in which tears are evaporated easily due to insufficient lipid layer production by the Meibomian glands. ETD comprises of majority of dry eye patients.¹¹ Tear film is a critical component of anterior segment of the eye. It forms a protective shield for eye from any foreign body or bacterial infections. Tear film also functions as a nutrient source for cornea and as a lubricant for anterior ocular surface.¹² It consists of three layers; mucus, aqueous and lipid layer. Any disturbance to these layers can cause an abnormality called Dry Eye, which is a multi factorial disease of tears and ocular surface that results in symptoms of discomfort, visual disturbance, and tear film instability with potential damage to the ocular surface.¹³

Active and passive smoking has been proved to cause tear film instability. Many toxic substances are there on a single cigarette and since the start of electronic cigarettes; it has been widely used around the world, considering that it contains less nicotine and other toxic substances.¹⁴

This study was conducted to evaluate the effect of E-cigarettes on the tear film of smokers at a tertiary care center in Saudi Arabia. To our knowledge, this is the first Saudi study using SM Tube and non-Invasive Keratograph. A previous study by Althobaiti¹⁵ revealed 26.3% consumption of E-cigarettes among Saudi citizens. Their study revealed a significantly high prevalence of smoking tobacco (p value=0.002) in between 18 to 24 years age group.

Literature shows that smoking contains more than 4000 toxic minerals and matters which cause ophthalmological disorders especially dry-eye disease.¹⁶ In our study, we observed that the majority of smokers were in the mean age group of 32.55 years similar to the previous study of Agrawal.¹⁷ A meta-

analysis highlights several pathogenesis of dry eye including chronic inflammation of the ocular surface, low sensitivity of the cornea, and low production of tears and stability.¹⁸ Kjaergard and colleagues¹⁹ conducted a study on tobacco workers. They found a high degree of ocular irritation among them. In the current study, we observed that the ocular surface disease index score increases up to 40% among smokers and vape users with a significant mean difference (p-value = 0.001).

In the past, several studies have demonstrated an association between tear instability and smoking.^{10,11,12} Majority of the studies found a strong association between tear instability and smoking. A study by Satici et al,⁹ explored the effect of smoking on the ocular surface. They observed ocular surface epithelial damage in smokers groups due to direct contact of smoke with the ocular surface. Jetton's study²⁰ found that smoking interrupted the corneal wound healing process. However, Munsamy's study²¹ found no effect of vaping on the pre-corneal tear film and corneal epithelial thickness. In our study, we observed a significant reduction in tear breakup time and tear volume among smokers and vape users as compared to non-smokers. A previous study by Etter et al,²² found that e-cigarette user's vaped an average of 175 puffs. Variations in the results may occur due to several puffs and the efficacy of the nicotine delivery per day. A recent study of Nishitsuka²³ found an increase in corneal thickness among Japanese smokers. Meanwhile, the study of Du et al,²⁴ revealed that corneal epithelial thickness appeared stable during the daytime. A study by Isa et al,¹³ observed mild to moderate eye dryness (25.0 [interquartile] ranges, 14.6 to 43.7) in vape users as indicated by the ocular surface disease index. However, in our study, only 6 vape users reported mild to moderate eye dryness (Median IQ = 12.5).

Although the current study has an objective of examining the effect of vaping on the tear film, the

study has certain limitations in terms of small sample size and missing demographic information. In this study, the number of E-cigarette puffs was not mentioned, along with missing information on vaping techniques.

CONCLUSION

Vaping adversely affects tear lipid layer of users which causes low tear breakup time, less tear volume, and may cause dry eye. A strong positive alarming association has been found between tear breakup time and volume with vaping. There is a need for strict checks and balances on E-cigarette consumption for controlling cases of vision impairments related with e-cigarettes.

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Conflict of Interest

Authors declared no conflict of interest.

Ethical Approval

The study was approved by the Institutional review board/Ethical review board (21-21-09).

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Author's Designation and Contribution

Saleh Alshammeri; Assistant Professor: *Concepts, Design, Literature search, Data acquisition, Data analysis, Statistical analysis, Manuscript preparation, Manuscript editing, Manuscript review.*

