Blinking Characteristics and Corneal Staining in Different Soft Lens Materials

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Abstract*—Background* Contact lens (CL) wear can cause changes in blinking and corneal staining. *Aims and Objectives* To determine the effects of CL materials (HEMA and SiHy) on spontaneous blink rate, blinking patterns and corneal staining after 2 months of wear. *Methods* Ninety subjects in 3 groups (control, HEMA and SiHy) were assessed at baseline and 2-months. Blink rate was recorded using a video camera. Blinking patterns were assessed with digital camera and slit lamp biomicroscope. Corneal staining was graded using IER grading scale *Results* There were no significant differences in all parameters at baseline. At 2 months, CL wearers showed significant increment in average blink rate ($F_{1.626,\ 47.141}$ = 7.250, p = 0.003; $F_{2,58}$ = 6.240, p = 0.004) and corneal staining ($\chi^2_{2,\ n=30}$ = 31.921, p < 0.001; $\chi^2_{2,\ n=30}$ = 26.909, p < 0.001). *Conclusion* Blinking characteristics and corneal staining were not influence by soft CL materials.

***Keywords*—**Spontaneous blinking, cornea staining, grading, soft contact lenses.

I. Introduction

SPONTANEOUS blinking is an involuntary, transient and rapid closure of the eyelids that occurs without any deliberate or external stimulus [1], [2]. It is essential in spreading the tear film layer evenly over the corneal surface to maintain corneal integrity, wettability and cleanliness of ocular surface [3], [4].

In contact lens (CL) wearers, it helps to maintain the normal corneal function, optical quality and hydration of CL surface through interchange of tears between CL and cornea. The average spontaneous blink rate is variable between studies, ranging from approximately 10 to 26 blinks per minute [5]-[7]. Spontaneous blink rate may alter in response to different level of visual tasks, emotional states and mental activities [2], [8], [9]. Both rigid and soft CLs wear causes the spontaneous blink rate to increase. Increase blink rate in rigid lens wear is more related to reflex blinking rather than spontaneous blinking as a result of continuous irritation of lid margin caused by the lens edge [10].

A study had reported the average spontaneous blink rate increased from 12.1 blink/minute to 20.3 blink/minute in HEMA soft CL subjects despite achieving comfortable full time CL wear [11]. Reference [8] suggested that extrinsic stimulation on eyelid by soft CL is strong enough to induce the increase blink rate even in comfortable CL wear regardless of any visual tasks. It showed the average blink rate in CL subjects increased from 18.87 blink/minute to 27.03 blink/minute while listening to music whereas the average blink rate increased from 9.69 blink/minute to 22.81 blink/minute while playing a video game.

Complete blinking occurs when the upper eyelid covers more than 67% of the cornea [12] and allows a cleaner tear film layer to spread across the ocular surface by sweeping the debris into the lower tear film margin [13]. CL wear can alter the blinking pattern as it acts as a barrier to lid sensation causing lack of feedback mechanism that further leads to incomplete closure of the eyelid [14]. Reference [15] suggested that incomplete blinking may lead to a decrease in tear film distribution over the CL surface causing the deposit to be more easily precipitated on the interpalpebral region of the CL anterior surface. This condition may further increase the rate of tear evaporation and causes CL dehydration and corneal epithelium desiccation.

Corneal staining is a common clinical observation that is usually found in soft CL wearers. One-third of the hydrogel contact lens wearers showed marked corneal staining despite being asymptomatic wearers [16]. Reference [17] had reported 55.7% from 500 hydrogel lens wearers presented with corneal staining in at least on one eye. Studies had shown that corneal staining in soft CL wearers was found more at the inferior region compared to the other zones of cornea [16], [17]. This may be caused by incomplete blinking which later leads to corneal epithelium desiccation [15], [18].

Both HEMA and silicone hydrogel (SiHy) lenses are two types of soft contact lens materials that are commercially available in the market currently. HEMA soft lenses have good wettability characteristics that provide initial comfort during CL wear [19]. However, SiHy lenses provide more advantages over HEMA soft lenses and it represents a new generation of hydrogel lens material based on the technology of combining silicone rubber with hydrogel monomers [20]. Studies had shown that SiHy which has a high oxygen permeability helped to reduce signs and symptoms of corneal hypoxia and limbal hyperaemia [21], [22]. Study also showed significantly less frequency of ocular dryness, redness and lens awareness in SiHy whereas low Dk/t HEMA lenses wearers reported more dryness, limbal hyperaemia and corneal staining [23].

The aim of this study is to investigate the changes of spontaneous blink rate, blinking pattern and corneal staining in normal healthy non-contact lens wearers (control), HEMA and

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SiHy lens wearers before and after 2 months of CL delivery. Results of this study might help to increase the awareness of the CL wearers about the importance of choosing suitable soft CL material in maintaining optical quality and ocular comfort besides avoiding ocular complications during CL wear.

II. Methodology

Subjects

A total of 90 students were involved in this cohort study. Subjects were recruited by using convenient sampling method. They were divided into 3 groups i.e. HEMA soft lens wearers, SiHy lens wearers and control group (non-contact lens wearers). Each group consisted of 30 subjects. The inclusion criteria include age range within 18 to 30 years old, non-CL wearer for at least 6 months with good general and ocular health, visual acuity of 6/6 after correction with spherical correction between -1.00 DS to -6.00DS and astigmatism of less than -1.00DC for soft CL wear groups.

The study was conducted at Optometry Primary Eye Care Clinic, Universiti Kebangsaan Malaysia, Kuala Lumpur. Informed consent was obtained from all the subjects and the study was approved by Research Ethics Committee, Universiti Kebangsaan Malaysia, Kuala Lumpur (UKM 1.5.3.5/ 244/ NN-219-2011) and followed the tenets of Declaration of Helsinki.

Measurements

Comprehensive preliminary ocular examination was conducted on the subjects prior to the study. Two groups of CL subjects were fitted with HEMA (Bausch & Lomb Soflens 59) and SiHy (Ciba Vision Air Optix Aqua) lenses. All CL subjects were required to wear their lenses for 8 hours per day and 6 days per week continuously for 2 months period. They were given the same brand of solutions (Solocare Aqua Multipurpose) for contact lens maintenance. Subjects came back periodically for regular aftercare examinations. They were assessed for spontaneous blink rate, blinking patterns and corneal staining on 0, 1 and 2 months of CL wear on the right eye only.

A. Blink Rate Counting

The experimental conditions were modified from the study by [6]. Subjects were seated in an examination room with adequate room illumination (500-600 lux) and given about 5 minutes to adapt to the condition of the room. Subjects were asked to direct their gaze and maintain their fixation on a vision illusion image that was parallel to their head position at 3 metres away. Subjects were required to use their refractive correction during the whole procedure. Subjects' blink rate was recorded using a digital video camera (Canon Legria HF R26), which was placed at same level as their head at an angle of 45 degree and 1 metre away. Video recording was started spontaneously when subject was asked to look at the vision illusion for 2 minutes. Subjects were unaware about the actual purpose of video recording. Total number of blinks in 2 minutes was recorded and later counted. The average blink rate in 1 minute was then noted.

B. Blinking Patterns Observation

Using classification as in [12], two types of blinking patterns i.e. complete and incomplete blink were observed. Subjects were seated in front of the slit lamp biomicroscopy and asked to fixate on the vision illusion image at 2 metre away. They were assessed with their habitual glasses or CLs. Blinking patterns were observed under bright room illumination using a digital camera (Nikon Coolpix 4500) attached to a slit lamp (Topcon SL 3F). The number of blinks were recorded for 2 minutes and later evaluated. They were either catogorised as complete or incomplete blinks. The average number of complete and incomplete blinks for 1 minute were noted.

C. Corneal Staining Assessment

Corneal staining was graded immediately after contact lens removal. Sodium fluorescein strip was applied to the superior bulbar conjunctiva. Corneal staining was assessed under cobalt blue illumination and Wratten #12 yellow filter over the slit lamp objective lens. Photograph of corneal staining was taken with a digital camera (Nikon Coolpix 4500) attached to a slit lamp (Topcon SL 3F). For grading purpose, corneal area was divided into 5 zones (superior, inferior, nasal, temporal and central zones) as shown in Fig. 1. Each zone was graded by using Institute for Eye Research (IER) grading scale with 0.1 unit increments. The grading for average corneal staining was modified from the grading strategies suggested by [16], which was averaging the grades for all 5 zones. Corneal staining was graded by the second author who had a practice in grading corneal staining.

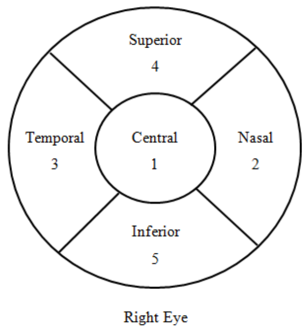

Fig. 1 Five corneal zones for the grading of corneal staining

III. Results

The distribution of subjects for each group according to gender and race was shown in Table I. The mean age of subjects was 22.40 ± 1.33 years in the HEMA group, 22.67 ± 1.18 years in the SiHy group and 22.93 ± 1.14 years in the control group. There was no significant difference in the mean age between these 3 groups of subjects (Kruskal-Wallis, $\chi^2_{2, N=90} = 2.329$, p = 0.312).

TABLE I
DEMOGRAPHIC DATA OF SUBJECTS

Group	Gender (n)			Race (n)			
	Male	Female	Total	Malay	Chinese	Indian	Total
HEMA	5	25	30	9	20	1	30
SiHy	7	23	30	5	24	1	30
Control	11	19	30	5	25	0	30
Total	23	67	90	19	69	2	90

Table II showed the mean of the average blink rate in each group within 2 months. The average blink rate showed no significant difference between HEMA, SiHy and control groups at 0 month before CL fitting (one-way ANOVA, $F_{2,87} = 0.502$, p = 0.607). However, there were significant differences in average blink rate between the 3 groups after 2 months of CL wear (one-way ANOVA, 1 month $F_{2,87} = 3.209$, p = 0.045; 2 month $F_{2,87} = 5.481$, p = 0.006). HEMA and SiHy lens wearers showed significant increment in the average blink rate after 2 months of CL wear (repeated measures ANOVA, $F_{1.626, 47.141} = 7.250$, p = 0.003; $F_{2,58} = 6.240$, p = 0.004). No significant difference was found in the average blink rate of control group within the 2 months (repeated measures ANOVA, $F_{2,58} = 0.463$, p = 0.632).

TABLE II
AVERAGE BLINK RATE OF EACH GROUP WITHIN 2 MONTHS

Group	Average of blink rate (blink/min)			p-value
	0 month	1 month	2 month	
HEMA	16.58 ± 8.88	20.58 ±10.25	22.87 ± 8.28	p = 0.003
SiHy	14.80 ± 6.94	19.25 ± 7.95	20.15 ± 9.00	p = 0.004
Control	14.98 ± 6.73	14.97 ± 8.56	15.92 ± 7.21	p = 0.632
p-value	p = 0.607	p = 0.045	p = 0.006	

Two categories of blinking patterns were classified from the average number of complete and incomplete blinking in one minute for each of the subjects. If the average number of complete blink exceeded incomplete blink, subject was classified into complete blinking pattern whereas subject was classified into incomplete blinking pattern when the average number of incomplete blink was more than complete blink. Table III showed the frequency distribution of the blinking patterns of each group within 2 months. There were no significant differences in blinking patterns among the 3 groups in 2 months (Pearson Chi-square, 0 month $\chi^2_2 = 0.424$, p = 0.809; 1 month $\chi^2_2 = 2.093$ p = 0.351; 2 month $\chi^2_2 = 0.424$, p = 0.809). Both complete and incomplete blinking patterns remain constant in both HEMA and SiHy groups before and after 2 months of CL wear (Pearson Chi-square, $\chi^2_2 = 0.000$, p = 1.000; $\chi^2_2 = 0.000$, p = 1.000). There was no significant difference in the frequency of blinking patterns for control group within the 2 months (Pearson Chi-square, $\chi^2_2 = 1.023$, p = 0.600).

TABLE III
FREQUENCY DISTRIBUTION OF BLINKING PATTERN OF EACH GROUP IN 2 MONTHS

	0 month (n)		1 month (n)		2 month (n)	
	C	I	C	I	C	I
HEMA	28	2	28	2	28	2
SiHy	28	2	28	2	28	2
Control	29	1	30	0	29	1

(C = complete, I = incomplete)

Table IV showed the mean of average corneal staining in HEMA, SiHy and control groups. No significant difference in the average corneal staining was found among the 3 groups at 0 month (Kruskal-Wallis, $\chi^2_{2,\ N=90} = 0.517$, p = 0.772). Significant differences in the average corneal staining were shown among the 3 groups after 2 months of CL wear (Kruskal-Wallis, 1 month $\chi^2_{2,\ N=90} = 39.634$, p < 0.001; 2 month $\chi^2_{2,\ N=90} = 29.908$, p < 0.001). The changes of average corneal staining for both HEMA and SiHy groups after 2 months of CL wear were statistically significant (Friedman, $\chi^2_{2,\ N=30} = 31.921$, p < 0.001; $\chi^2_{2,\ N=30} = 26.909$, p < 0.001). However, the control group showed no significant difference in the average corneal staining within the 2 months (Friedman, $\chi^2_{2,\ N=30} = 0.500$, p = 0.779).

TABLE IV
AVERAGE CORNEAL STAINING OF EACH GROUP IN 2 MONTHS

Group	Average corneal staining (units)			p-value
	0 month	1 month	2 month	
HEMA	0.007 ± 0.25	0.55 ± 0.51	0.51 ± 0.57	p < 0.001
SiHy	0.003 ± 0.02	0.38 ± 0.44	0.25 ± 0.34	p < 0.001
Control	0.003 ± 0.02	0.01 ± 0.05	0.007 ± 0.37	p = 0.779
p-value	p = 0.772	p < 0.001	p < 0.001	

IV. DISCUSSION

Average blink rates without any CL wear (0 month) for subjects in HEMA, SiHy and control groups showed an inter-subject blink rate variation, which ranged from 3 to 40 blinks/min. This can be due to different physiological and psychological conditions between individuals in this study [5]. Blink rate measurement in this study was done in primary gaze, modified from [6]. However, our study shows higher average blink rates compared to [6] who reported an average blink rate of 10.3 blinks/min despite similar experimental conditions. The initial average blink rates for the 3 groups in our study are in agreement with study [2] who reported an average blink rate ranging between 8 and 21 blinks/min for a large sample at primary gaze.

Without any soft CL wear, control group showed no significant changes in the average blink rate within 2 months under the same experimental condition. Our result suggests that there is no extrinsic stimulation on spontaneous blinking with the absence of CL wear. The two groups of soft CL wearers (HEMA and SiHy) showed a significant increment in the average blink rate during CL wear despite 2 months adaptation of full time wear. This result is consistent with previous studies regardless of different experimental conditions for blink rate measurement such as watching educational film, listening to music and playing game during blink rate measurement [8], [11]. Compared to other studies, we suggest that the increased blink rate is not influenced by the duration of adaptation to CL wear. The direct mechanical irritation caused by soft CL acts as a stimulus to increase spontaneous blinking activity although subjects had worn the CL for 3 weeks [11]. However, we believe that modern designs of soft CLs are more comfortable, thinner and have smoother edge profile compared to soft lenses manufactured 30 years ago. The higher blink rate was found in long-term adapted soft CL wearers compared to non-CL wearers [24]. The increase of blink rate after CL wear was shown in fully adapted HEMA or SiHy lens wearers for at least 1 year [8]. Our finding is contrary to [25] who suggested that the increase of blink rate is limited to the period of adaptation to the contact lenses.

Reference [26] believed that adhesion of CL to cornea and the accumulation of deposits over lens surface disrupt the tear film layer and lead to an increased blink rate during CL wear. Unstable tear film layer over a CL surface may provide surface stimulation on blinking action [8]. Some of the subjects in our study had reported ocular discomfort and dryness during CL wear. It is possible that the ocular dryness, discomfort and irritation caused the increase of blink rate among CL wearers.

SiHy lenses possess good lens dehydration properties that help to reduce dryness symptoms during CL wear [27] and the symptoms of ocular dryness induced by HEMA lenses become less after refitting with SiHy lenses [28]. It is suggested that the reduced ocular dryness in SiHy materials may result in less alteration to the blink rate. Study by [29] is contrary to other studies as it showed that there is no difference in ocular dryness and wearing comfort with SiHy and HEMA lenses over time. Our results showed that there was no significant difference in the increment of average blink rate between both HEMA and SiHy lenses. SiHy and HEMA soft lenses have similar mechanical interaction with ocular tissues and effect on tear film physiology during both types of CL wear [30]. This suggests that the extrinsic surface stimulation provided by soft CL wear is strong enough to trigger the changes in blink rate even with more advantageous and comfortable SiHy lens materials.

In our study, complete and incomplete blinks were either present on their own or in a mixed pattern among 3 groups of subjects. There was no clear distinction between complete and incomplete blinking patterns. It was found that incomplete blink was common in most of the subjects in this study. This result is similar with [31] in which incomplete blinks occurred on their own or in association with complete blinks. Our study shows that there were no significant changes in the frequency of both complete and incomplete blinking patterns in HEMA and SiHy groups after 2 months of soft CL wear. This outcome is in agreement with [11], which showed that there was no significant change in the blinking pattern after soft CL fitting. There was no significant difference in the blink completeness between soft contact lens wearers and normal subjects [24]. The frequency of complete blinks increased among soft CL wearers after blinking exercise [32]. Improved regularity of complete blinking helps to maintain the cleanliness and optical clarity of the CL surface besides reducing signs and symptoms associated with incomplete blinking among soft CL wearers [15], [32].

Our study shows that there was some degree of corneal staining present in normal control group without any contact lens wear, which is supported by previous studies [33], [34]. The prevalence of corneal staining can be as high as 79% in healthy non-contact lens wearers [33]. The mean staining grade for right eye reported in this study is much lower than that of [34], with a mean staining grading of 0.5 units for right eye. Different methods and grading scales used might contributed to these differences. Our study used one of the grading strategies suggested by [16], which is by averaging the grading in all 5 zones.

There was an increment in corneal staining after 2 months of soft CL wear in this study regardless whether HEMA or SiHy lens materials were used. It had been reported that some amount of corneal staining presents after soft CL wear [17], [35], [36]. Corneal staining is a common clinical observation in CL wearers and considered as an ocular complication after CL wear. Although there was no significant difference in the changes of corneal staining between HEMA and SiHy groups, the mean of average corneal staining for SiHy lens wearers was lower than HEMA lens wearers in this study. A study had reported 77% of hydrogel lens subjects showed less corneal staining after refitting with SiHy lens [36] and also improved significantly in dry eye CL wearers after refitting with SiHy lens (omafilcon A) [37]. It is therefore suggested that the good lens dehydration characteristics of SiHy lens materials reduces ocular dryness and subsequently reduces corneal staining after CL wear.

Since the blinking patterns were observed under different experimental condition with blink rate measurement, we expected that there would be some changes in the spontaneous blinking activity in this study. Therefore, we have made sure that every subject was in a comfortable position in front of the slit lamp and observation of blinking pattern was done without any illumination from the slit lamp to avoid too much alteration of the spontaneous blink.

We admit that there may have some degree of examiner bias in grading corneal staining since only a single examiner was involved in the grading process. There may be variability in the grading by a single examiner between visits or between subjects, which may confound the results in the study. However, we have tried to minimize this effect by using an experienced optometrist trained for this purpose.

V. Conclusion

In summary, our study shows that blink rate and corneal staining increased in HEMA and SiHy lens wear compared to the control group after 2 months of lens wear. No significant difference was found in the blink rate and corneal staining between HEMA and SiHy lens materials. Blinking completeness was not influenced by both HEMA and SiHy lens wear.

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