Contact Lens and Anterior Eye 43 (2020) 389–394

Contents lists available at ScienceDirect

Contact Lens and Anterior Eye

journal homepage: www.elsevier.com/locate/clae

Corneal epithelial thickness and corneal curvature changes during the day: The effects of daily disposable contact lens wear

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ARTICLE INFO

Keywords:
Corneal epithelial thickness
Corneal curvatures
Daily disposable contact lenses

ABSTRACT

Purpose: To evaluate the changes in corneal epithelial thickness and corneal anterior and posterior curvatures during the day, and the effect of wearing daily disposable soft contact lenses.

Methods: Thirty-two healthy volunteers were enrolled in a randomized crossover study. At the baseline visit, corneal and epithelial thickness maps (OCT; Optovue, Inc., Fremont, CA, USA) and keratometric measurements (Pentacam, Oculus, GmbH, Germany) were performed in the morning and in the afternoon (8 hours after). Then, each subject was fitted with the following brands of daily disposable contact lenses in random order: Dailies Total 1 (Delefilcon A), Dailies Aqua Comfort (Nelfilcon A), TruEye (Narafilcon A) and Biotrue Oneday (Nesofilcon A) on different days. All fitted lenses had a power of −3.00 diopters (D). Measurements were repeated before putting the contact lens on and after an-eight-hour contact lens wear.

Results: With no lens wear, the anterior topographic indices showed significant steepening [Kflat: $p < 0.0001$; Ksteep: $p < 0.0001$ and maximum keratometry value (Kmax): $p = 0.04$] and the corneal thickness significantly decreased in the central and temporal portion of the cornea in the afternoon. There were no significant changes in the posterior topographical indices and corneal epithelial thickness. With contact lens wear, no significant change occurred in the corneal and epithelial thickness, and the anterior and posterior curvatures during the day (all p values >0.05). There was no statistically significant difference in the epithelial thickness among the groups wearing different contact lens types ($p > 0.05$).

Conclusions: Anterior corneal topographic indices steepen depending on the natural diurnal variations. Daily wear of soft contact lenses appears to mask this steepening. The corneal epithelial thickness is not affected by daily disposable soft contact lenses.

1. Introduction

Refractive errors may be managed by different means in modern ophthalmology. Currently, soft contact lenses (CLs), which provide different designs, materials, and wear schedule, seem to be very popular among them. Daily disposable contact lenses (DDCLs), designed to be worn once and then replaced with a new pair of lenses on a daily basis, offer a number of advantages compared with conventional daily wear or frequent replacement (weekly/monthly) CLs. The causes of non-compliance among the reusable lens wearers can be listed as follows: lens wearing times, procedures for lens care, lens replacement schedules, and procedures for lens case hygiene [1,2]. The advantages of DDCLs include improved comfort (dryness, redness, tiredness), improved vision quality (less blur), reduced lens deposition, and a lower rate of medical complications due to lack of need to use a lens care system or overnight storage [3–5].

CL wear induces some morphologic changes in the cornea. The wear time, lens material, design, and the frequency of use may affect those corneal parameters. However, while interpreting these findings, the diurnal changes on the corneal thickness and curvature as a result of the natural metabolism of the cornea and the tear film layer must be kept in mind [6–9].

There are studies evaluating the corneal changes induced by both rigid gas permeable [10] and soft CL wear [6,11–13]. Some studies showed that long-term soft CL (SCL) wear reduced oxygen uptake and induced cell death, and thus caused central and peripheral corneal epithelial thinning [4]. It has been shown that daily wear of different design SCLs may induce anterior corneal steepening or flattening [6,11,14]. Studies assessing corneal thickness while wearing SCLs showed some degree of corneal swelling [6,12–14]. A small number of studies evaluating posterior cornea showed slight steepening in the posterior corneal curvature [6,13].

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https://doi.org/10.1016/j.clae.2019.11.017
Received 15 July 2019; Received in revised form 29 November 2019; Accepted 30 November 2019
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There is a wide range of techniques available to help measure the corneal changes mentioned above. Non-invasive optical systems based on a rotating Dual-Scheimpflug or a Placido tomography system may help quickly analyse the anterior segment of the eye. The corneal epithelial thickness can be measured using optical coherence tomography (OCT), ultrasonography, and confocal microscopy. Recently, a software algorithm based on a Fourier-domain OCT system that prevents large variability in the point thickness was developed in order to automatically map corneal epithelial thickness [15]. It measures the average central and peripheral epithelial thickness with a single measurement. After a series of repeated measures with OCT, coherent results were reported in normal subjects, patients with keratoconus, dry eyes, and orthokeratology lens-wearing children [15,16].

Posterior corneal measures and epithelial mapping are very useful in the early detection of keratoconus, and also in the evaluation of patients who are candidates for refractive surgery. Comprehension of the effect of diurnal variations and the influence of CL wear on corneal shape gives precious information in the interpretation of results in research and everyday clinical practice. The purpose of this study was to evaluate the changes in corneal epithelial thickness and corneal anterior, and posterior curvatures induced by wearing four types of daily disposable CLs.

2. Methods

Thirty-two healthy volunteers (11 males and 21 females) who had never worn CLs were enrolled in this crossover study. This prospective randomized study was conducted within the tenets of the Declaration of Helsinki after obtaining approval from the local ethics committee. The subjects were recruited from patients attending the outpatient unit of the cornea department of Marmara University, Istanbul. Written informed consent was obtained from all patients. All subjects in the study were CL-naive healthy subjects with refractive errors. The exclusion criteria included a history of any systemic or ocular disease (refractive disorder was included), which would negatively affect the outcome of the study, a history of ocular surgery, a history of previous CL use, use of any topical or systemic drugs, pregnancy or lactation.

2.1. Contact lenses

Four different types of daily CLs were evaluated: Dailies Total 1 (Alcon Lab. Inc., TX, USA), 1 Day Acuvue TrueEye (JohnsonJohnson Vision Care, NJ, USA), Dailies Aqua Comfort (Alcon Lab. Inc., TX, USA), Biotrue Oneday (Bausch and Lomb, NY, USA). The properties of the lenses are given in Table 1. Two lenses were made of silicone hydrogel (SiHy) and other two were made of hydrogel (Hy). All subjects were fitted with -3 D lenses.

2.2. Study procedure

All patients underwent a detailed ophthalmologic examination at their first visit including keratorefractometry (NIDEK ARK-530A, NIDEK Co. Ltd., Gamagori, Japan) measurements, best corrected visual acuity (BCVA), biomicroscopic examination, intraocular pressure measurements, Scheimpflug-based anterior segment mapping (Pentacam, Oculus, GmbH, Germany), and epithelial thickness maps using anterior segment OCT (Optovue, Inc., Fremont, CA, USA). Anterior segment imaging was performed using a rotating Scheimpflug camera, which captures 50 images automatically and measures 25,000 true elevation points. This instrument outputs a ‘quality specification’ for images, which provides the reliability data of the scan (checking for poor alignment, excessive blinking, any missing or invalid data). If the image quality was not acceptable, the measurements were repeated. The keratometric measurements were recorded from the Pentacam map. Each eye was scanned 3 times during a single visit. Both anterior and posterior curvature data were obtained from the Pentacam map.

Baseline measurements were taken at approximately 10:00 AM (to avoid the peak in corneal thickness immediately after waking) and at 18:00 PM, without any CLs being worn in order to record each individual’s natural diurnal variation in corneal epithelial thickness and curvature. All measurements were repeated at 10:00 AM, before lens wear and at 18:00 PM, after 8 hours of lens wear. Each eye of the subjects was fitted with lenses of different brands, which were chosen in a random order. After a period of at least three days of non CL wear, in order to allow the cornea to restore its normal state, the other two brands that were not used on the first day were fitted to each eye and the same procedure was followed. All measurements and examinations were performed by the same physician (DDY).

2.3. Epithelial thickness map

OCT epithelial thickness mapping and pachymetry software were obtained using the RTVue Fourier-domain OCT system with a corneal adaptor module (L-Cam lens). The scan pattern (6.0 mm scan diameter, 8 radials, 1024 axial scans each, repeated 5 times) was centred on the coaxially fixating corneal light reflex identified by the central bright reflection. The epithelial thickness map was processed by an automatic algorithm and divided into 2-mm, 5-mm, and 6-mm diameter circular areas according to the centre of the cornea. The paracentral and peripheral zones were also divided into 8 sectors (Fig. 1). The minimum and maximum values were also measured and noted.

2.4. Statistical analysis

Statistical analysis was performed by using the SPSS statistical software package (SPSS version 20.0, SPSS, Inc., Chicago, IL). The Kolmogorov-Smirnov test was applied to determine the normality of

Table 1
Properties of the contact lenses.

Lens Properties	Lens Types			
Lens name	Dailies Total 1	1-Day Acuvue TrueEye	Dailies Aqua Comfort	Biotrue Oneday
Manufacturer	Alcon Laboratories, Inc.	Johnson δ Johnson Vision Care	Alcon Laboratories, Inc.	Bausch + Lomb
Material	Delefilcon A	Narafilcon A	Nelfilcon A	Nesofilcon
Power, D	−1.00 to −6.00	−1.00 to −6.00	−0.50 to −10.00	−0.25 to −9.00
Water content, %	33 (core), >80 (surface)	46	69	78
Dk/t value (−3.00 D)	156	118	26	42
Diameter, mm	14.1	14.2	14.0	14.2
BCOR, mm	8.5	8.5 and 9.0	8.7	8.6
Modulus, Mpa	0.7 (core), 0.025 (surface)	0.66	unknown	0.49
Central thickness at −3.00 D, mm	0.09	0.085	0.10	0.10

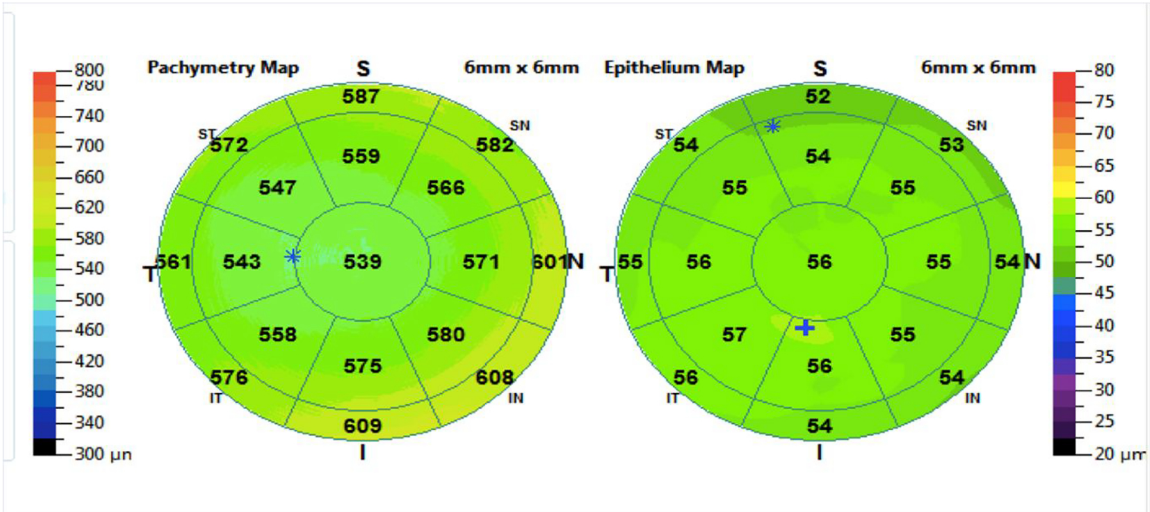

Fig. 1. Pachymetry and epithelial thickness map obtained by anterior segment OCT.

data distribution. All descriptive data are presented as mean, standard deviation (SD), median and 95% confidence interval (CI) values. Parametric tests and non-parametric tests were applied depending on the distribution of the data. The paired sample and the Wilcoxon signed-rank tests were used to check within-group differences. The Kruskal-Wallis test was performed for multiple comparisons. Analysis of variance (ANOVA) was used to evaluate the significance between differences among groups. The statistical significance value was set at $p = 0.05$

3. Results

The mean age of patients was 23.5 ± 7.0 (range, 18 to 14 years. With regard to the diurnal changes, the anterior topographic indices significantly steepened (Kflat: $p < 0.0001$; Ksteep: $p < 0.0001$; Kmax: $p = 0.04$), whereas posterior topographic indices remained unchanged ($p > 0.05$) (Table 2). The mean diurnal change in corneal thickness showed significant thinning in the central corneal region (−5.5 ± 18.7 µm, $p = 0.034$) and the temporal corneal region (−7.1 ± 18.5 µm, $p = 0.04$). There was no significant thinning in the nasal corneal region (−6.4 ± 18.4 µm, $p = 0.08$) (Table 3). Considering the corneal epithelium, which was divided into five different zones (central, nasal, temporal, inferior, and superior), no significant thinning was observed in any of the five zones between the morning and the afternoon measurements (Table 3).

Regardless of the lens type, CL wear had no effect on the corneal (Table 4) and epithelial thickness (Table 5), or the anterior (Table 6) and posterior curvature (Table 7) ($p > 0.05$). There was no significant difference in the epithelial thickness among the groups ($p > 0.05$)

Table 2
Diurnal changes in topographic indices.

Scheimpflug-based Device Anterior and Posterior Curvatures (D)				
		Morning	Afternoon	
Anterior Curvature Mean ± SD Median (CI)	Kflat	41.9 ± 1.1 42.2 (41.5 to 42.5)	42.6 ± 1.3 42.95 (41.6 to 43.6)	p < 0.0001*
	Ksteep	42.6 ± 1.2 42.65 (42.0 to 43.2)	43.5 ± 1.3 43.7 (42.7 to 44.3)	p < 0.0001*
	Kmax	44.2 ± 1.5 44.45 (43.5 to 45.1)	44.5 ± 1.0 44.6 (44.2 to 45.2)	p = 0.04*
Posterior Curvature Mean ± SD Median (CI)	Kflat	−6.2 ± 0.2 −6.2(−6.3 to −6.0)	−6.1 ± 0.2 −6.2(−6.3 to −5.9)	p = 0.07†
	Ksteep	−6.5 ± 0.2 −6.50(−6.6 to −6.4)	−6.4 ± 0.2 −6.5(−6.6 to −6.4)	p = 0.16†
	Kmax	−6.3 ± 0.2 −6.3(−6.5 to −6.2)	−6.3 ± 0.2 −6.3(−6.5 to −6.2)	p=0.06†

* Paired sample t-test.
† Wilcoxon signed-ranks test.

4. Discussion

The present study was designed to examine changes in corneal and epithelial thickness and corneal anterior/posterior curvatures in subjects wearing different types of daily disposable CLs and to determine whether these changes were regional or uniform. Moreover, the diurnal changes of the cornea were also evaluated. To exclude the possible influence of previous CL wear, all subjects were neophytes.

A software algorithm capable of automatically mapping corneal epithelial thickness based on a Fourier-domain OCT system was developed to prevent large variability in point thickness. It measures the average central and peripheral epithelium thickness with a single measurement and good repeatability has been reported in normal subjects, and patients with keratoconus, dry eye, and orthokeratology lens-wearing children [15,16].

Regardless of whether an individual wears CLs, the corneal thickness, curvature, and epithelial thickness change during the course of a day. Corneal thickness has a diurnal variability and the most dramatic changes are observed after waking [7–9,13,17–21]. The baseline measurements were made at 10:00 AM and 18:00 PM without lens fitting in this study, because it is reported that the corneal de-swelling mostly occurs after waking [7,13]. Corneal stromal collagen fibrils are the same in shape and size, but the spacing between the fibrils increases in the peripheral cornea [6]. The peripheral corneal thickness has a tendency to show a greater amount of diurnal change because of this physiologic feature. Due to this physiologic variation, the evaluation of corneal thickness should be made over an area, instead of a single point (central corneal thickness). Steepening of the anterior curvature and flattening of the posterior curvature throughout the day were reported in previous studies, and these phenomena were explained by this variation of the cornea [6,22].

The diurnal variations of the cornea and the variations induced by daily use of SCLs were studied by Del Aguila et al. [6] They noted that when subjects were not wearing any CLs, the anterior corneal curvature

Table 3
Diurnal changes on the corneal and epithelial thickness.

		Anterior Segment OCT (μm)		
		Morning	Afternoon	
Pachymetry Mean ± SD Median (CI)	Central	549.2 ± 30.5 553.5 (544.9 to 556.4)	542.7 ± 31.8 533.5 (531.2 to 554.2)	p = 0.034*
	Temporal	556.4 ± 31.9 548.0 (538.2 to 560.2)	549.3 ± 32.3 541.0 (537.2 to 560.7)	p = 0.034*
	Nasal	571.8 ± 33.2 561.0 (559.8 to 583.8)	566.3 ± 34.5 557.0 (553.8 to 578.7)	p = 0.08*
Epithelial Thickness Mean ± SD Median (CI)	Central	54.3 ± 3.4 54.0 (52.7 to 55.1)	53.9 ± 3.2 54.0 (52.7 to 55.1)	p > 0.05†
	Temporal	53.0 ± 3.6 53.0 (51.3 to 53.5)	52.4 ± 3.0 53.0 (51.3 to 53.5)	p > 0.05*
	Nasal	53.6 ± 3.6 54.0 (52.1 to 54.3)	53.3 ± 3.0 54.0 (52.1 to 54.3)	p > 0.05*
	Superior	52.2 ± 3.1 53.0 (51.1 to 53.3)	51.9 ± 3.0 53.0 (50.8 to 53.1)	p > 0.05†
	Inferior	55.1 ± 3.4 56.0 (53.6 to 56.6)	54.7 ± 4.2 55.0 (53.2 to 56.2)	p > 0.05*

* Paired sample t-test †Wilcoxon signed-ranks test.

showed a significant steepening of −0.01 ± 0.01 mm ($p = 0.047$), and the posterior corneal curvature exhibited a statistically non-significant flattening of 0.01 ± 0.02 mm ($p = 0.055$). In this study, based on the analysis of the diurnal variation measurements, although the anterior corneal curvature showed a significant steepening of 0.7 ± 0.7 D ($p < 0.0001$) in Kflat, 0.8 ± 0.9 D ($p < 0.0001$) steepening in Ksteep, and 0.4 ± 1.0 D ($p = 0.04$) in Kmax, the posterior corneal curvature showed no statistically significant difference.

In the current study, the corneal thickness significantly decreased in the central (−6.5 ± 18.4; $p = 0.034$) and temporal (−7.1 ± 18.6; $p = 0.034$) portion of the cornea. The trend of thinning observed in the nasal portion of the cornea was not statistically significant. The epithelial thickness remained unchanged. As in the present study, Del Aguila et al. also found that the corneal thickness decreased −2.0 ± 1.7 μm ($p = 0.037$) in the central corneal region and −4.6 ± 2.8 μm ($p = 0.012$) in the peripheral corneal region [6].

The changes in a well-fitted daily use SCL are rather small but they may be significant. These changes may depend on the individual characteristics of the subject and the type of lens. In this study, the anterior and posterior corneal curvatures, and corneal and epithelial thicknesses remained unchanged during lens wear. The physiologic diurnal corneal thinning was masked by lens wear. As reported in the literature by Del Aguila et al. [6] the corneal thickness showed less variation and the anterior corneal curvature showed slight flattening except for one lens (Clariti 1-Day, CooperVision, NY), which caused a slight steepening in the daily SCL wearing condition. Tyagi et al. [13] found that a small but significant swelling in the corneal thickness occurred after 8 hours of hydrogel soft toric lens wear. Three other silicone hydrogel lenses produced some amount of thinning; however, it was not statistically significant compared with the diurnal variations.

There are multiple factors that influence corneal thickness such as blinking frequency [22], low humidity [23], evaporation, and changes in tear tonicity [24]. A change in these factors during the CL wear may be the cause of this reduction in thinning of the cornea. Low oxygen transmissibility (Dk/t) thresholds of some SCLs may cause hypoxia-induced corneal swelling during open eye wear [25,26]. The critical Dk/t threshold values to avoid corneal swelling are noted as units [25] (central and peripheral respectively) and 24.1 ± 2.7 [26] during open eye daily CL wear. SiHy lenses have higher Dk/t values in comparison with Hy lenses [17,25,26]. In the present study, two SiHy and two Hy lenses were used. It may be speculated that the difference between the lenses had no significant effect on corneal thickness due to the high Dk/t values above the critical thresholds, which is important in extended wear.

It has been reported that long-term wear of SCLs results in epithelial thinning [4]. The exact mechanism of central corneal epithelial thinning in long-term daily use of SCL wearing is still unknown. It is speculated that the mechanical compression and oxygen transmissibility of CLs might play a role [[4]]. Jalbert et al. reported that the corneal epithelium was thinner in low oxygen transmissibility SCL

Table 4
Corneal thickness changes in the DDCLs wearing condition.

		Corneal Thickness (μm)			
		Dailies Total 1*	Dailies Aqua Comfort*	1-Day Acuvue TrueEye*	Biotrue Oneday*
Central Sector Mean ± SD Median (CI)	Before lens insertion	533.1 ± 28.8 531.0 (518.0 to 554.0)	536.5 ± 34.2 533.5 (521.5 to 557)	549.3 ± 36.8 557.0 (522.5 to 570.0)	543.3 ± 37.0 543.0 (517.0 to 570.0)
	After the 8-h wearing	529.4 ± 27.7 528.0 (510.0 to 552.0)	531.0 ± 29.9 532.0 (515.0 to 549.5)	543.4 ± 36.8 541.0 (517.0 to 569.0)	541.7 ± 38.1 530.5 (513.0 to 571.0)
Nasal sector Mean ± SD Median (CI)	Before lens insertion	557.8 ± 29.6 554.0 (540.5 to 570.0)	554.6 ± 36.4 555.0 (539.5 to 573.5)	573.8 ± 39.9 574.0 (548.5 to 594.0)	562.5 ± 39.1 555.5 (539.0 to 595.0)
	After the 8-h wearing	552.4 ± 28.2 548.5 (531.0 to 576.0)	547.8 ± 32.9 544.5 (534.5 to 567.9)	567.6 ± 42.0 562.5 (540 to 589.0)	559.6 ± 37.4 555.5 (537.0 to 568.0)
Temporal Sector Mean ± SD Median (CI)	Before lens insertion	537.6 ± 28.8 538.0 (522.5 to 554.0)	548.7 ± 34.2 545.0 (528.5 to 568.0)	554.3 ± 36.4 560.0 (525.5 to 583.0)	552.6 ± 37.7 554.5 (523.0 to 573.0)
	After the 8-h wearing	535.1 ± 29.6 539.0 (517.5 to 552.0)	543.1 ± 28.0 540.0 (527.5 to 558.0)	551.6 ± 36.5 554.5 (521.0 to 577.0)	553.6 ± 44.1 534.0 (520.0 to 587.0)

$p > 0.05$.
* Paired-sample t-test.

Table 5
Epithelial thickness changes in the DDCLs wearing condition.

		Epithelial Thickness (μm)			
		Dailies Total 1*	Dailies Aqua Comfort*	1-Day Acuvue TrueEye*	Biotrue Oneday*
Central Sector	Before lens insertion	54.5 ± 3.4	54.2 ± 3.0	55.0 ± 3.6	55.0 ± 3.2
Mean ± SD		54.5 (53.0 to 57.0)	5.40 (53.0 to 56.0)	55.5 (54.0 to 57.0)	55.0 (54.0 to 57.0)
Median (CI)	After the 8-h wearing	54.1 ± 3.6	53.8 ± 3.1	54.4 ± 3.8	54.6 ± 3.4
		54.0 (52.0 to 56.0)	54.0 (53.0 to 55.5)	54.5 (53.0 to 56.0)	54.5 (53.0 to 56.0)
Superior Sector	Before lens insertion	52.1 ± 2.9	52.4 ± 2.9	52.9 ± 3.3	52.6 ± 3.0
Mean ± SD		52.0 (51.0 to 55.0)	52.0 (51.0 to 54.0)	53.0 (51.0 to 55.0)	52.5 (51.0 to 55.0)
Median (CI)	After the 8-h wearing	52.5 ± 3.0	52.2 ± 3.3	52.5 ± 3.7	53.4 ± 4.1
		52.0 (51.0 to 54.0)	51.5 (50.0 to 54.0)	53.0 (50.0 to 54.0)	53.0 (52.0 to 54.0)
Nasal sector	Before lens insertion	53.8 ± 3.3	53.5 ± 3.2	54.3 ± 3.6	54.2 ± 3.3
Mean ± SD		54.0 (52.0 to 55.5)	54.0 (52.0 to 55.5)	54.0 (53.0 to 57.0)	55.0 (53.0 to 56.0)
Median (CI)	After the 8-h wearing	53.8 ± 3.7	53.7 ± 3.1	54.1 ± 3.5	54.1 ± 3.5
		53.0 (52.0 to 57.0)	54.0 (53.0 to 56.0)	54.0 (52.5 to 56.0)	54.0 (53.0 to 55.5)
Inferior Sector	Before lens insertion	55.2 ± 3.8	54.9 ± 3.5	56.1 ± 3.7	55.8 ± 3.7
Mean ± SD		56.0 (53.0 to 57.0)	55.0 (53.0 to 57.0)	56.0 (54.0 to 58.0)	56.0 (54.0 to 57.5)
Median (CI)	After the 8-h wearing	55.2 ± 3.9	55.1 ± 3.9	56.3 ± 4.0	56.3 ± 3.7
		55.0 (53.0 to 58.0)	55.0(53.0 to 57.5)	57.0 (54.0 to 59.0)	56.5 (55.0 to 58.5)
Temporal Sector	Before lens insertion	53.5 ± 3.2	52.6 ± 3.0	53.8 ± 3.5	53.6 ± 3.0
Mean ± SD		53.5 (52.0 to 56.0)	53.0 (51.0 to 55.0)	54.0 (52.0 to 55.0)	54.0 (52.0 to 56.0)
Median (CI)	After the 8-h wearing	53.3 ± 3.5	52.7 ± 3.2	53.4 ± 3.6	53.6 ± 2.8
		53.0 (52.0 to 56.0)	53.0 (51.5 to 54.0)	54.0 (52.0 to 55.0)	53.5 (53.0 to 55.0)

$p > 0.05$.
* Paired-sample t-test.

wearers than in high oxygen transmissibility wearers and in normal controls [27]. In another study conducted by Hong et al., corneal epithelial thickness was evaluated in SCL wearers who had worn SCLs for more than 2 years and them compared with 40 normal subjects who had never worn CLs. The long-term SCL wearers had significantly thinner epithelial thickness in the central and peripheral region ranging from 3 to 5 microns [28]. This was in contrast to Patel et al., who demonstrated that central epithelial thickness was similar in long-term SCL wearers and control subjects, but that the temporal epithelium was thinner in the SCL group [29]. This discordance may be caused by the differences in the method used for epithelial thickness measurement and the timing of the measurement. The measurements were performed after 12 to 24 hours in the study of Patel et al. [29] in contrast to Hong et al. [28] who took measurements at least 1 hour after lens removal on that day and used confocal microscopy to measure the epithelial thickness. In the current study, which evaluated the short-term effects of DDCLs on the corneal epithelium, no significant difference was found in epithelial thickness.

It is reported that high oxygen transmissible SCLs cause less thinning of the epithelium [27]. It may be due to the fact that the corneal epithelial metabolism, thus thickness, depends strongly on oxygen levels. Ren et al. [30] also reported that hyper-oxygen transmissible CLs caused less thinning after extended wear. Despite the differences among Dk/t values of the lenses fitted in the present study, no significant difference was observed among the lenses. This may be accounted for by the fact that the short-term effects of DDCLs were evaluated.

It is difficult to establish a comparison between the results of different studies because the subjects, the type of lenses used, and the measurement methods differ. Therefore, further clinical studies with longer follow-up and larger series would be necessary to definitely confirm these results.

In conclusion, the corneal and epithelium thickness were not affected by daily disposable SCLs, whereas corneal thickness decreased in the natural diurnal variation. The steepening of the anterior corneal surface might be masked by DDCLs despite the diurnal changes in the anterior topographic indices being significantly steepened. No significant difference was found in either diurnal changes or CL wearing in

Table 6
Anterior curvature changes in the DDCLs wearing condition.

		Scheimpflug-based Device Anterior Curvature (D)			
		Dailies Total 1*	Dailies Aqua Comfort*	1-Day Acuvue TrueEye*	Biotrue Oneday*
Kflat Mean ± SD	Before lens insertion	41.6 ± 1.2	41.7 ± 1.0	41.7 ± 1.0	41.9 ± 1.0
Median (CI)		41.7 (40.8 to 42.5)	41.9 (41.0 to 42.5)	41.6 (41.2 to 42.1)	41.8 (41.5 to 42.5)
	After the 8-h wearing	41.5 ± 1.0	41.6 ± 1.0	41.7 ± 0.9	41.8 ± 1.0
		41.5 (40.9 to 42.3)	41.6 (41.0 to 42.4)	41.7 (41.2 to 42.1)	41.6 (41.4 to 42.5)
Ksteep	Before lens insertion	42.4 ± 1.2	42.6 ± 1.2	42.4 ± 1.0	42.5 ± 1.1
Mean ± SD		42.8 (41.8 to 43.0)	42.7 (41.9 to 43.3)	42.5 (42.0 to 43.0)	42.3 (41.9 to 43.1)
Median (CI)	After the 8-h wearing	42.3 ± 1.8	42.6 ± 1.0	42.4 ± 0.9	42.5 ± 1.1
		42.6 (41.4 to 43.1)	42.6 (41.8 to 43.2)	42.4 (42.0 to 43.0)	42.3 (42.0 to 43.2)
Kmax	Before lens insertion	43.8 ± 1.4	43.9 ± 1.5	43.9 ± 1.3	43.9 ± 1.2
Mean ± SD		44.0 (43.1 to 45.1)	43.9 (42.7 to 45.1)	43.8 (43.3 to 44.6)	43.9 (43.5 to 44.5)
Median (CI)	After the 8-h wearing	43.6 ± 1.2	44.1 ± 1.3	44.2 ± 0.9	44.2 ± 1.0
		43.6 (42.9 to 44.3)	44.3 (43.3 to 45.1)	44.1 (43.8 to 44.8)	44.0 (43.5 to 44.8)

$p > 0.05$.
* Paired-sample t-test.

Table 7
Posterior curvature changes in the DDCLs wearing condition.

		Scheimpflug-based Device Posterior Curvature (D)			
		Dailies Total 1*	Dailies Aqua Comfort*	1-Day Acuvue TrueEye*	Biotrue Oneday*
Kflat	Before lens	−6.1 ± 0.3	−6.4 ± 0.2	−6.1 ± 0.2	−6.1 ± 0.2
Mean ± SD	insertion	−6.1 (−6.2 to −6.0)	−6.1 (−6.2 to −5.9)	−6.0 (−6.3 to −5.9)	−6.1 (−6.2 to −6.0)
Median (CI)	After the 8-h	−6.0 ± 0.2	−6.0 ± 0.2	−6.0 ± 0.2	−6.1 ± 0.2
	wearing	−6.0 (−6.2 to −5.9)	−6.1 (−6.2 to −6.0)	−6.0 (−6.3 to −5.9)	−6.1 (−6.3 to −6.0)
Ksteep	Before lens	± 0.2	−6.4 ± 0.1	−6.5 ± 0.2	−6.4 ± 0.2
Mean ± SD	insertion	−6.4 (−6.6 to −6.4)	−6.4 (−6.5 to −6.3)	−6.4 (−6.7 to −6.4)	−6.4 (−6.6 to −6.3)
Median (CI)	After the 8-h	−6.4 ± 0.2	−6.4 ± 0.2	−6.4 ± 0.2	−6.4 ± 0.2
	wearing	−6.4 (−6.6 to −6.3)	−6.4 (−6.5 to −6.3)	−6.4 (−6.6 to −6.3)	−6.4 (−6.6 to −6.3)
Kmax	Before lens	−6.2 ± 0.2	−6.2 ± 0.1	−6.3 ± 0.2	−6.3 ± 0.2
Mean ± SD	insertion	−6.3 (−6.4 to −6.2)	−6.2 (−6.3 to −6.1)	−6.3 (−6.5 to −6.2)	−6.2 (−6.4 to −6.1)
Median (CI)	After the 8-h	−6.2 ± 0.2	−6.2 ± 0.2	−6.3 ± 0.2	−6.3 ± 0.2
	wearing	−6.2 (−6.4 to −6.1)	−6.2 (−6.3 to −6.1)	−6.2 (−6.5 to −6.1)	−6.2 (−6.5 to −6.1)

$p > 0.05$.
* Paired-sample t-test.

posterior corneal curvature. In addition, anterior segment OCT systems seem to be an easy, repeatable, quick technique for detecting early changes in corneal epithelial thickness caused by CL wear.

Funding

The authors did not receive any financial support from any public or private sources.

The authors have no financial or proprietary interest in a product, method, or material described herein.

This work has previously been presented in 46th ECLSO (European Contact Lens And Ocular Surface Congress), September - 01 October 2016 Paris, France.

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