Anterior segment changes following short-term reading and its correlation with corneal biomechanical characteristics

Hamed Niyazmand¹, Hadi Ostadi Moghaddam¹,², Mohammad Reza Sedaghat³, Seyed Mahdi Ahmadi Hosseini¹ and Fereshteh Abolbashari¹

¹Refractive Errors Research Center, School of Paramedical Sciences, Mashhad University of Medical Sciences, Mashhad, ²Department of Optometry, School of Paramedical Sciences, Mashhad University of Medical Sciences, Mashhad, and ³Department of Ophthalmology, Mashhad University of Medical Sciences, Mashhad, Iran


Keywords: anterior segment, corneal hysteresis, corneal resistance factor, myopia, short-term reading

Abstract

Purpose: To investigate the changes in anterior segment following short-term reading and evaluate the correlation of such changes with corneal biomechanical characteristics (CBC).

Methods: Thirty-six right eyes of 36 healthy subjects were examined. Anterior segment parameters were measured using the Pentacam before and after 30 min of reading. Ocular Response Analyzer was used to record CBC after reading. The following were recorded: central corneal thickness (CCT), central corneal power (CCP), superior corneal power (SCP), inferior corneal power (ICP), anterior chamber depth (ACD), anterior chamber volume (ACV), anterior chamber angle (ACA), corneal hysteresis (CH) and corneal resistance factor (CRF). Statistical analysis was performed with the paired student t-test and Pearson correlation test in SPSS 16.

Results: There were statistically significant decreases in CCP, SCP, ACD and ACV values following reading (p < 0.05). Our results showed a statistically significant negative correlation between CH and changes in ICP (r = 0.36, p = 0.02). Significant negative correlations were also found between CRF and changes in ICP (r = 0.41, p = 0.01) and SCP (r = 0.34, p = 0.04). On the other hand, statistical analysis indicated no correlation between CBC and other studied parameters (p > 0.05).

Conclusion: This study demonstrated significant changes in some anterior segment parameters after reading. Being knowledgeable about these changes may have important implications in high accuracy examinations such as pre-operative assessment of corneal refractive surgery candidates. This could also help researchers have a better understanding of the factors that may influence near work related development of refractive errors.

Introduction

Although the corneal contour is considered to be regular and stable, external forces applied through orthokeratology contact lenses,¹ digital pressure² or a modified tonometer probe,³ as well as diurnal variations⁴ have been shown to alter the shape of the corneal surface. Furthermore, some ocular diseases such as ptosis,⁵ palpebral hemangioma⁶ and chalazion⁷ result in changes in corneal refractive power or astigmatism. In paediatrics, eyelid pressure on the cornea is a factor that may cause with-the-rule astigmatism that could be altered with ageing.⁸ Eyelids have been also proposed to be responsible for alterations in corneal aberrations and refractive power following reading.⁹ The amounts of these lids-induced changes depend on the type of task (computer, microscopy or reading book) and position of the eyelids.¹⁰
The sharp increase in the prevalence of myopia in recent decades suggests that genetic predisposition is not the only factor implicated in the development of myopia. Previous studies established the effect of environmental factors such as reading and other near tasks in the development of myopia for the subjects at school and higher education level. The fundamental mechanism for the development of myopia during near work is still unknown. However, it is believed that the interaction between some factors such as the magnitude and duration of accommodation during near work leads to axial elongation and myopia progression. The cornea is the most powerful refractive component of the eye that could influence the quality of the retinal image. Changes in central corneal topography after reading have been reported in previous studies. These changes that are supposed to be directly related to the force of the eyelids during reading could significantly alter the corneal aberration and consequently degradation of the retinal image.

Recently, the role of the cornea in the development or progression of myopia has come to the attention of researchers. It was reported that the likelihood of lid-induced changes in higher order aberration during reading is more in myopic eyes than emmetropic eyes. However, the role of corneal biomechanical characteristics (CBC) in changes following reading has not yet been documented. In this experiment we evaluated the changes in anterior segment parameters following short-term reading and the correlation of these induced changes with CBC.

**Methods**

**Participants**

Thirty-six volunteers from the students of Mashhad university of Medical Sciences (MUMS) enrolled in this study. Consent was obtained from all subjects after explaining the purpose and procedures of the study. Ethical approval was granted by MUMS and all investigations were conducted in accordance with the Declaration of Helsinki in 1975. All subjects underwent a comprehensive ophthalmic examination including retinoscopy, best corrected visual acuity, slit lamp biomicroscopy and fundus evaluation. Those with irregular corneal astigmatism (bow tie pattern or localized steepening) in topographic examination, history of dry eye, trauma, eyelid abnormality, corneal surgery, best corrected visual acuity of worse than 0.0 logMAR (Snellen 6/6 or 20/20) and a history of contact lens wear were excluded from this study.

**Procedures**

Participants were asked not to read on the examination day to eliminate the possible effects of other visual tasks on the cornea. The right eyes of all subjects were assessed using a Pentacam HR (www.pentacam.com) to record anterior segment parameters including central corneal thickness (CCT), anterior chamber depth (ACD), anterior chamber volume (ACV) and anterior chamber angle (ACA). Central corneal power (CCP), superior corneal power at 3 mm paracentrally (SCP) and inferior corneal power at 3 mm paracentrally (ICP) were also recorded. These points were analysed automatically by the Pentacam true elevation. For Pentacam measurements patients were asked to fix on the blue fixation target inside the instrument. Once the alignment with the corneal apex was achieved, the instrument imaged the eye automatically. Only one Pentacam measurement was taken before and after reading and if the Quality Specification window was not the white ‘OK’, the examination was repeated.

High repeatability and reproducibility of the Pentacam has been documented previously in the measurement of anterior segment parameters. Since the corneal distortions decrease rapidly following the cessation of the reading task, the post-reading measurements were taken within 2 min of reading cessation.

During the reading task, subjects wore their spectacle correction in a trial frame and read N8 (1.0 m) size print from a textbook binocularly at 40 cm distance, at a 40 degree downward gaze angle from horizontal eye level. In order to fix the eyelid position during reading, only the two middle lines of the textbook were visible and the rest of the text was covered. The textbook comprised several pages with two middle lines visible that were turned over by an examiner. The position of the book was stable in the special rack in order to form a 40-degree angle with horizontal eye level.

During reading they were asked to blink naturally and read continuously for 30 min. The examination room had artificial and stable light. A table with a chin and forehead rest was designed to stabilise each subject at the mentioned angle during reading. In addition, the headrest of this table provided constant head and eye position.

To assess the corneal biomechanical characteristics, defined as CH and CRF, measurements were obtained using Reichert’s Ocular Response Analyzer (ORA; www.reichert.com/ora) following the reading. Three consecutive ORA measurements were performed on the right eye of all participants and the results were averaged.

For the ORA measurements subjects sat on a chair and placed their foreheads on the headrest of the instrument. They were told to focus on a blinking red light within the machine and the measurement was automatically obtained. During an ORA measurement an air jet is emitted in to the centre of the cornea and makes the corneal surface concave. Subsequently, when the air power is shut down, milliseconds later, the corneal surface returns to its primary convex
position. Corneal hysteresis (CH) is defined as the difference between the inward and outward applanation pressures that mainly reflects the viscosity of corneal tissues. In addition, corneal resistance factor (CRF) that shows the elastic properties of the cornea is calculated by using a proprietary algorithm.

In this experiment, we accepted only ORA measurements with a waveform score (WS) of 5 or higher, and all the Pentacam and ORA measurements were taken between 10 am to 12 am to eliminate the effect of diurnal variation.

Statistical analysis
The data for anterior segment parameters obtained by the Pentacam as well as CH and CRF measured by the ORA were extracted for statistical analysis with SPSS 16. The normality of all data was examined by the Shapiro-Wilk test. The paired student t-test was used to compare the anterior segment parameters before and after reading. In addition, the correlation of CH and CRF with the magnitude of the induced change in anterior segment parameters following reading was evaluated using Pearson’s correlation test. The Bonferroni correction was used to control type I error.

Results
Subjects
In this study, 36 right eyes of 36 healthy subjects including 24 males and 12 females with a mean age of 22.8 ± 3.8 years (range 20 to 30 years) were examined. All subjects had total astigmatism ≤ −0.25 D and the mean spherical equivalent was −0.45 D (range −4.75 to +2.00 D). The mean corneal astigmatism was 0.13 ± 0.11 D. In order to evaluate the difference in corneal changes between the emmetropic, hyperopic and myopic groups, subjects were classified into three groups according to spherical component of the refractive error (RE): myopia (RE < −0.25 D), emmetropia (−0.25 ≤ RE ≤ 0.25) and hyperopia (RE > 0.25). There were 12 myopic, 11 emmetropic and 13 hyperopic participants.

Comparison of anterior segment parameters before and after reading
CCP, SCP, ACD and ACV values significantly decreased after reading (p < 0.05). On the other hand, there were no statistical significant differences in ICP, ACA and CCT (p > 0.05). Table 1 shows the mean and standard deviation (S.D) of anterior segment parameters before and after reading along with the change in each parameter.

The SCP and CCP had the highest changes in myopic group and the lowest changes in emmetropic group. The

Table 1. Mean and standard deviation and comparison between anterior segment parameters before and after reading

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Before reading (mean ± S.D)</th>
<th>After reading (mean ± S.D)</th>
<th>Induced changes (After reading - before reading)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCT (µm)</td>
<td>523.7 ± 31</td>
<td>523.9 ± 30</td>
<td>0.2</td>
<td>0.87</td>
</tr>
<tr>
<td>CCP (D)</td>
<td>43.50 ± 1.50</td>
<td>43.39 ± 1.45</td>
<td>−0.11</td>
<td>0.03*</td>
</tr>
<tr>
<td>SCP (D)</td>
<td>42.67 ± 1.56</td>
<td>42.31 ± 1.50</td>
<td>−0.36</td>
<td>0.000*</td>
</tr>
<tr>
<td>ICP (D)</td>
<td>42.48 ± 1.34</td>
<td>42.45 ± 1.36</td>
<td>−0.03</td>
<td>0.23</td>
</tr>
<tr>
<td>ACD (mm)</td>
<td>3.21 ± 0.23</td>
<td>3.18 ± 0.24</td>
<td>−0.03</td>
<td>0.001*</td>
</tr>
<tr>
<td>ACV (mm³)</td>
<td>201.6 ± 31</td>
<td>191.1 ± 30</td>
<td>−10.5</td>
<td>0.000*</td>
</tr>
<tr>
<td>ACA (degrees)</td>
<td>41.1 ± 4.7</td>
<td>40.7 ± 4.9</td>
<td>−0.4</td>
<td>0.34</td>
</tr>
</tbody>
</table>

ACD, anterior chamber depth; ACV, anterior chamber volume; ACA, anterior chamber angle; CCT, central corneal thickness; ICP, inferior corneal power; SCP, superior corneal power; CCP, central corneal power.

Table 2. Pearson correlation analysis between corneal hysteresis and induced changes in the anterior segment parameters by reading

<table>
<thead>
<tr>
<th>Parameters</th>
<th>CCT</th>
<th>CCP</th>
<th>SCP</th>
<th>ICP</th>
<th>ACD</th>
<th>ACV</th>
<th>ACA</th>
</tr>
</thead>
<tbody>
<tr>
<td>r value</td>
<td>−0.17</td>
<td>−0.20</td>
<td>0.18</td>
<td>−0.36</td>
<td>0.17</td>
<td>0.11</td>
<td>0.08</td>
</tr>
<tr>
<td>p value</td>
<td>0.30</td>
<td>0.24</td>
<td>0.29</td>
<td>0.02*</td>
<td>0.30</td>
<td>0.51</td>
<td>0.61</td>
</tr>
</tbody>
</table>

CCT, central corneal thickness; CCP, central corneal power; SCP, superior corneal power; ICP, inferior corneal power; ACD, anterior chamber depth; ACV, anterior chamber volume; ACA, anterior chamber angle.

The correlation between CBC and change in the anterior segment parameters following reading
The mean CH was 10.07 ± 1.52 mmHg. Our results showed a statistically significant negative correlation between CH and change in the ICP (r = 0.36, p = 0.02). In contrast, correlations between CH and the changes in ACV, CCT, SCP, ACD, ACA and CCP were statistically insignificant. Table 2 presents levels of significance and correlation coefficients for measured parameters.

The mean CRF was 9.67 ± 1.53 mmHg. While there were statistically significant negative correlations between CRF and the change in ICP (r = 0.41, p = 0.01) and SCP (r = 0.34, p = 0.04), no significant correlations were found for other factors. Table 3 presents the correlation coefficients for the different parameters and the level of significance.
CH and CRF had the highest value in the emmetropic group (10.71 and 10.00 mmHg, respectively) and lowest value in myopia group (9.34 and 9.07 mmHg, respectively). But the difference between these two groups was only significant for CH ($p = 0.03$).

**Discussion**

In the current study we evaluated the change in anterior segment parameters due to short-term reading (30 min) at 40-degree downward gaze. The findings indicated that SCP, CCP, ACD and ACV changed significantly after a short period of reading.

Concerning the changes in the cornea, short-term reading leads to a considerable decline in CCP and SCP. The changes found in the corneal power following reading are most likely the consequence of displacement of corneal epithelial tissue, although this theory required corroboration by pachymetry of the epithelium. The magnitude of the changes in corneal power after reading were 0.11 D and 0.36 D, which indicated that only a few epithelial cells has been displaced as these changes occurred.\(^9\)

We found a larger change in superior corneal power than the central part (0.36 D vs 0.11 D) ($p = 0.007$). This could be linked to the position of the eyelid and the area of the cornea that is covered by lids. Collins *et al.*\(^10\) showed that microscopy and reading imposed larger and more centrally located changes compared with a computer task. The authors stated that during reading and microscopy, the eyelids form a smaller palpebral fissure and cover a larger area of the cornea than during a computer task, so greater changes are expected.

In the present study, the amount of induced change in superior corneal power is similar to the results of Shaw *et al.*\(^21\) (0.36 vs 0.33 D). These colleagues evaluated the left eye of 18 young adults with a Medmont E300 Corneal Topographer. Although their study was conducted under similar experimental conditions (15 min duration, 20 and 40 degree downward gaze) to our protocol, they averaged the corneal refractive power over a 4 mm central diameter. On the other hand, Buehren *et al.*\(^9\) reported as much as 1.34 D change in superior power of the cornea in one subject following a 60 min reading task. However, they did not present the mean of the changes for all subjects. Findings of the current study showed that short-term reading induced changes in CCP and SCP at 3 mm paracentrally; however, because the eyelid-induced corneal changes are wave-like, further studies are required to investigate the corneal power changes in an area instead of at a point.

Emmetropisation is a vision dependent process influenced by the quality of the retinal image. It is believed that failure of this coordinated eye growth leads not only to myopia but also to other types of refractive errors. Our hypothesis about the possible role of changes in corneal power during reading in refractive error development, require a mechanism that alters the retinal image. The cornea is the most powerful refractive component of the eye and therefore it has the potential to affect the quality of the retinal image. In our study, myopic eyes presented with higher magnitude of changes in CCP and SCP following reading compared to hyperopic and emmetropic eyes. As a result, this might indicate the possible role of reading in progression of myopia and help researchers in better understanding the factors involved in the development and progression of the myopia, as it has been known to be a multifactorial disorder.

The significant changes in CCP and SCP measured in this study could impose some changes in the retinal image and that could result in refractive error development.

In this study, 30 min of reading induced significant decrease in ACD and ACV. One likely possible explanation for this finding could be the loosening of zonules and an increase in lens thickness during accommodation.

To the best of our knowledge, this is the first study that has documented the correlation between CBC and induced changes in anterior segment parameters following reading. However, our results did not show significant correlations for numerous parameters. The only parameters that correlated weakly and negatively with CBC were ICP and SCP. This weak association might indicate the relatively insignificant role of corneal elasticity and viscosity against the induced changes by short-term reading. On the other hand, some previous reports indicated a significant correlation between CH\(^22\) and CRF\(^23\) with CCT, and a weak correlation between CH and corneal curvature, diameter and astigmatism.\(^24\) However, it should be noted that in the aforementioned studies the authors investigated the corneal parameters that affect the CBC, while we assessed the correlation of CBC with the induced changes in anterior segment parameters by reading.

The reason why these corneal changes only correlated weakly with CBC could be due to this fact that the changes occurred in the cornea following reading were probably limited to the epithelium, while the CBC mostly reflected the characteristics of the corneal stroma.
Our theory about the possible role of CBC in development of myopia could also be explained by lower valued CH and CRF in myopic eyes compared to emmetropic. The biggest changes in corneal power were observed in myopic eyes that showed the lowest values of CH and CRF. In contrast, emmetropic eyes had the highest valued CH and CRF and the smallest corneal power change following reading.

In summary, our results demonstrated significant changes in some anterior segment parameters following reading. These changes may have important implications in examinations requiring highly accurate measurements such as pre-operative assessment of refractive surgery candidates. It is suggested that patients be instructed not to perform any near task that involves downward gaze at least 45 min prior to topographic examinations in order to obtain valid results. In addition, being knowledgeable about this could help researchers have a better understanding of the emmetropisation process and the development of refractive errors.

Acknowledgements

We thank the research vice chancellor of Mashhad University of Medical Sciences for supporting this study (grant code: 87801). The results described in this paper were part of a thesis for a masters degree in optometry.

Reference