Central corneal thickness in high myopia

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2 **ABSTRACT.**

Background: **The cornea is responsible for approximately two-thirds of optical refraction. The purpose of this study was to determine whether central corneal thickness differs in emmetropia and high myopia using an optical low-coherence reflectometry (OLCR) pachymeter. Documented differences between these groups might contribute to the ongoing discussion on the aetiology and pathogenesis of myopia.**

Methods: **The emmetropic group included 57 subjects, all with normal visual acuity and refraction. The myopic group was recruited from subjects referred for refractive surgery for high myopia. Central corneal thickness and axial length were measured. Student's *t*-tests and *F*-tests were used to compare mean values and variances between the two groups.**

Results: **The mean CCT for the emmetropic group was 538.6 μm (SD = 32.1 μm, range 459.9–606.0 μm), and for the myopic group 527.7 μm (SD = 35.0 μm, range 452.2–599.5 μm). The difference of 10.9 μm was not statistically significant different from zero (p > 0.05). The *F*-test showed no statistical difference between the variances from the two groups.**

Discussion: **This study showed no statistically significant difference between the mean CCT of the myopic subjects and that of the emmetropic subjects. The growth alterations in the ocular tunics of myopic patients do not to any measurable degree involve the corneal thickness.**

3 **Key words:**

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Introduction

Although the true aetiology of myopia is still unknown (Goldschmidt 2003), the cornea is responsible for approximately two-thirds of optical refraction and its role in myopia has consequently been studied intensely over the years. Known possible changes in the highly myopic eye are all located in the posterior segment: staphyloma, myopic conus, choroidal atrophy, thinning of the retina and sclera. Changes in the anterior segment associated with myopia are still under debate. Carney et al. (1997), among others, found that the myopic cornea has a steeper central corneal curvature, while Chang et al. (2001) found no correlation between corneal curvature and central corneal thickness (CCT). The myopic eye is known to be longer than the normal emmetropic eye (see, e.g. Touzeau et al. 2003). If this is the result of general growth, one might expect the cornea to have grown to be thicker than is normal, in which case a correlation with body mass index (BMI) might exist. If instead the myopic eye is larger due to a mechanism similar to that of a balloon being inflated, one would expect the cornea to be thinner than normal, according to a simple 'stretching theory'. An emmetropic eye could then be compared to a sphere, and a myopic eye to a prolate spheroid.

Von Bahr (1956), Price et al. (1999) and Touzeau et al. (2003), among others, looked for a connection between CCT and myopia. Measurements were taken with different types of pachymeters and with different set-ups, but with all together inconclusive results (Table 1).

Today, there are many methods of measuring CCT (Ehlers & Hjortdal 2004), primarily based upon optical and ultrasound principles.

The precision (standard deviation, SD) of manual optical pachymetry is 8 μm, with intraobserver errors of 5–6 μm and interobserver errors of 20 μm (Olsen et al. 1980). Ultrasound pachymetry has better precision (Tam & Rootman 2003), but results may vary due to applanation force and differences between types of instruments (Salz et al. 1983). The Orbscan system () is an automatic and non-contact optical pachymeter and topograph with a precision similar to that of manual optical pachymetry (Yaylali et al. 1997). 4

The apparatus used in this study was an optical low-coherence reflectometry (OLCR) pachymeter. Bohnke et al. 1999) reported a precision of about 1 μm (SD), an intrasession reproducibility around

Table 1. Overview of previously published papers with information on myopia and central corneal thickness.

Authors and year	Country	Equipment	No of subjects		Refractive range	Results CCT and myopia
			Total	Myopic		
Kunert et al. 2003	India	Ultrasound/ Orbscan	615	615	Up to − 20 D sph (< 3 D cyl)	Thicker CCT in high myopic
Touzeau et al. 2003	France	Orbscan	95	95 *eyes*	+ 9.16 to −19.23 D sph	Thinner CCT when myopic
Srivannaboon 2002	Thailand	Orbscan	280	280	− 0.5 to − 18 D sph	Thinner CCT in high myopic
Chang et al. 2001	Taiwan	Ultrasound	216	?	Roughly + 7 to − 22 D sph	Thinner in high myopic
Liu & Pflugfelder 2000	China	Orbscan	30	30	− 0.75 to − 10.25 D sph	No correlation
Cho & Lam 1999	China	Ultrasound	151	?	+ 1.63 to − 13.50 D sph	No correlation (including high myopic)
Price et al. 1999	USA	Ultrasound	450	?	0 to − 30 D sph	No correlation
Tanaka et al. 1996	Brazil	Ultrasound	70	25	+ 3.2 to − 25.5 D sph	No correlation
Alsbirk 1978	Greenland	Optical	325	?	?	Thinner CCT when myopic
Ehlers & Hansen 1976	Denmark	Optical	101	?	?	No correlation
Hansen 1971	Denmark	Optical	113	?	+ 3.0 up to − 5 D	No correlation
Martola & Baum 1968	USA (Boston)	Optical	121	?	Up to more than − 6 D	No correlation (tendency to thicken)
von Bahr 1956	Sweden	Optical	125	*12 eyes*	More than + 3 to more than − 4 D	Thinner CCT when myopic (> − 4 D)
Blix 1880	Sweden	Optical	8	2	Hypermetropic to myopic	No difference

0.9–1.2 μm and a high intersession reproducibility. Other studies have compared the OLCR pachymeter with the ultrasound pachymeter. Wälti (1998) found the OLCR pachymeter to be faster and more precise (lower 5
SD) than an ultrasound pachymeter. The CCT values were found to be significantly higher when measured with an ultrasound pachymeter than when measured with the OLCR pachymeter (Ventura et al. 2001; Genth et al. 2002). Today, the OLCR seems to be the most precise instrument to measure CCT.

The purpose of this study was to determine whether CCT differs in emmetropia and high myopia using the OLCR pachymeter. Documented differences between these groups might contribute to the ongoing discussion on the aetiology and pathogenesis of myopia.

Material and Methods

Subjects

All subjects were white and aged between 18 and 55 years. Subjects with previous eye surgery, glaucoma, diabetes mellitus or other acute or chronic diseases possibly affecting the corneal thickness were excluded.

The emmetropic group included 57 subjects, all with normal visual acuity and refraction (self-reported to be from 0 to + 1.5 D sph). The group consisted of volunteers sourced from hospital staff, students and patients' relatives.

The myopic group was recruited from subjects referred for refractive surgery for high myopia. Only eyes with a minimum of − 6 D in spherical equivalent refraction and a maximum of 2 D corneal astigmatism were accepted.

The refractive criteria were set to ensure that only highly myopic eyes were included in the group and that cases with subclinical keratoconus were excluded. On this basis, the study included 48 highly myopic subjects with an average subjective refraction of − 8.93 D (ranging from − 6 to − 15.75 D, SD = 2.02 D) in spherical equivalent and an average astigmatism of − 0.81 D cylinder.

Those who normally used contact lenses (24 subjects) did not use them for at least 48 hours before examination.

The subjects in both groups answered questions on height and weight, from which BMI was calculated.

Central corneal thickness and axial length were measured in both eyes, without touching or medicating the eyes, but data from only one eye from each subject was included. The data pertained to the right eye in 99 subjects, but to the left eye in six subjects. This was due to previous retinal detachment in the right eye in one case, a previous severe trauma in the right eye in one case, the fact that the right eye did not fulfil the refractive criteria in three cases, and because the right eye was under topical anaesthetic in one case.

Table 2 summarizes data characterizing the two groups, the only statistically significant difference being the axial length, which was 3 mm longer in the myopic group.

Equipment

The OLCR pachymeter was attached to a BC 900 slit-lamp (both from Haag-Streit,) 6
(Ballif et al. 1997; Genth et al. 2002). The OLCR pachymeter was calibrated and used as described in the instruction manual. A corneal refractive index of $n = 1.376$ was assumed. The OLCR pachymeter is an automatic non-contact pachymeter based on interferometry. The pachymeter is easy to use and an average CCT measurement (based on 20 scans) takes 28 seconds including adjustment of the apparatus (Wälti 1998).

All measurements were performed by the same examiner (LP). Each

Table 2. Data characterizing the two groups. Mean values are shown in the first five lines.

	Myopic group		Emmetropic group		P
Age (years)	37	(SD = 8.8)	36	(SD = 8.6)	> 0.05
Height (m)	1.74	(SD = 9.6)	1.76	(SD = 9.3)	> 0.05
Weight (kg)	75	(SD = 2.9)	75	(SD = 3.1)	> 0.05
BMI (kg/m2)	25	(SD = 0.3)	24	(SD = 0.2)	> 0.05
Axial length (mm)	26.52	(SD = 1.265)	23.52	(SD = 0.775)	< 0.01
Sex (male/female)	18/30		28/29		–
Examination time	10.18 hours		11.46 hours		–

OLCR measurement is the result of 20 consecutive scans, where the five upper and five lower scan values are deleted. The OLCR pachymeter calculates a mean CCT and a standard deviation from the remaining 10 scans.

To confirm the reported precision of the OLCR pachymeter, the right eyes of five normal subjects were measured 10 times. Each subject was repositioned between each measurement. The measurements of one subject were completed within 30 mins. The average intersession precision (SD) for five subjects was 1.0 μm corresponding with previous findings (Böhnke et al. 1999). High and low CCT values were determined with the same SD.

Ethical approval

The study was conducted in accordance with a protocol approved by the local ethics committee of Århus in accordance with the Helsinki Declaration II. Informed consent was obtained from all persons included in the study.

Statistics

The material was tested by kurtosis and skewness tests and was found not to deviate from a normal distribution. Paired *t*-test was used to establish whether there was any difference between right and left eyes. Student's *t*-tests and *F*-tests were used to compare mean values and variances between the two groups.

Results

The mean CCT for the emmetropic group was 538.6 μm (SD = 32.1 μm, range 459.9–606.0 μm), and for the myopic group 527.7 μm (SD = 35.0 μm, range 452.2–599.5 μm). The difference of 10.9 μm was not statistically significant different from zero ($p > 0.05$). The *F*-test showed no statistical difference between the variances from the two groups.

The mean CCT for the 24 myopic subjects wearing glasses was 523.4 μm (SD = 36.19 μm) and the mean CCT for the 24 myopic subjects normally wearing contact lenses was 531.9 μm (SD = 33.93 μm). This difference of 8.5 μm was not significantly different from zero ($p > 0.05$).

There was no statistically significant difference between the CCT values of the right (534.3 μm, SD = 33.6 μm) and left eyes (534.4 μm, SD => 33.3 μm) nor was there any statistically significant difference between the CCT values from men (534.9 μm, SD => 30.9 μm) and women (532.0 μm, SD = 37.4 μm).

Discussion

This study showed no statistically significant difference between the mean CCT of the myopic subjects and that of the emmetropic subjects. This result is in agreement with the majority of previous studies (Table 1). The minimal detectable difference in central corneal thickness (MIREDIF) can be calculated to 24.2 μm (for $n = 52$ in each group, SD = 33.46 μm, $\alpha = 5\%$ [type 1 error] and $\beta = 95\%$ [statistical power]) (Sokal & Rohlf 2000). Thus, the present sample sizes should be sufficiently large to identify meaningful real differences in corneal thickness in emmetropia and myopia.

The results from this study showed a difference of 10.9 μm in mean CCT (the myopic being the thinner), this is around a quarter of what would be expected from pure stretching of the ocular tunics (see Appendix for mathematical reflections). If a stretching mechanism really is active, the thinning seems to be confined to the sclera.

This study included 24 myopic subjects who normally wore contact lenses and 24 myopic subjects who normally wore glasses. The mean CCT of the two subgroups was not significantly different.

The inconclusive results of previous studies (Table 1) might be explained by any of the following: pachymeters with low reproducibility; inexperienced observers; no consideration of diurnal variation; the influence of contact lenses; genetic difference in CCT; different criteria for exclusion; lack of highly myopic subjects, and too small a sample size.

The advantages of this study are: its use of high precision apparatus compared to traditional ultrasound and optical pachymeters; the fact that only highly myopic subjects with limited astigmatism were included, and the minimized influence of confounders.

Previous studies indicate that the OLCR pachymeter is the most precise (lowest SD) clinically available pachymeter. It remains unknown which pachymeter in general is closest to the real CCT in terms of accuracy. In the present study, precision was considered more important than accuracy.

The diurnal variation of corneal thickness has been studied with different techniques. The results are inconclusive. Müller-Treiber et al. (2001) studied the diurnal changes with the OLCR pachymeter, and found the cornea to be thickest in the morning and around 5 μm lower in the late afternoon. To minimize this confounder, early morning measurements were avoided. The two groups were measured at almost the same average time of day.

In conclusion, the CCTs of myopic and emmetropic eyes do not differ. The growth alterations in the ocular tunics of myopic patients do not to any measurable degree involve the corneal thickness.

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Appendix

An emmetropic eye is compared to a sphere (surface area $[S_{emme}] = 4\pi r^2$), and a myopic eye to a prolate spheroid (surface area $[S_{myop}]$ see www.mathworld.wolfram.com). If the volume (V) of the cornea + sclera is constant:

$$V = S_{myop} * CCT_{myop} = S_{emme} * CCT_{emme} \quad \text{(I)}$$

$$V = 2\pi a^2 + \frac{2\pi ac^2}{\sqrt{c^2 - a^2}} \sin^{-1}\left(\frac{\sqrt{c^2 - a^2}}{c}\right) * CCT_{myop} = 4\pi r^2 * CCT_{emme} \quad \text{(II)}$$

The parameters ‘r’ (radius) and ‘a’ (equatorial radius) are estimated to be alike and are calculated as half mean axial length in an emmetropic group (23.24 mm/2) (Touzeau et al. 2003). The parameter ‘c’ (polar radius) is calculated as half of the mean axial length in a highly myopic group (26.36 mm/2) (Touzeau et al. 2003). A meta-analysis finds the average CCT in normal populations to be 535 μm (SD = 31 μm) (Doughty & Zaman 2000). If the parameters mentioned above are inserted in equation II, CCT_{myop} is calculated to be 490.5 μm or 44.5 μm (8%) thinner than CCT_{emme}.

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