

Morphometric differences between normal and dry eyes

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SUMMARY

The aim of the study was to quantify the anatomic differences in central corneal thickness, anterior ocular chamber depth, lens thickness, vitreous chamber depth, and ocular axial length between normal and dry-eyes. Central corneal thickness (CCT), ocular anterior chamber depth (ACD), lens thickness (LT), vitreous chamber depth (VCD) and ocular axial length (AL) were measured in 70 normal subjects and in 58 subjects with dry-eyes. Central corneal thickness was measured with scanning-slit corneal topography while ocular anterior chamber depth, lens thickness, vitreous chamber depth and ocular axial length were measured with applanation ultrasound biometry.

Central corneal thickness was 0.558 ± 0.30 mm and 0.532 ± 0.34 mm in normal and dry-eyes, respectively ($p < 0.001$). Mean ocular anterior chamber depth was 3.17 ± 0.23 mm and 2.93 ± 0.35 mm in normal and dry-eyes, respectively ($p = 0.002$). Lens thickness was 4.49 ± 0.42 mm in the dry-eye patients and 4.71 ± 0.32 mm in the normal subjects ($p = 0.022$). Vitreous chamber depth was 16.75 ± 1.75 mm and 15.54 ± 1.34 mm in normal and dry-eyes, respectively ($p = 0.001$). Ocular axial length was 24.58 ± 1.73 in normal subjects and 23.07 ± 1.48 in dry-eye subjects ($p < 0.001$). We conclude that quantitative ocular anatomy values are lower in dry-eye subjects.

Key words: Dry-eye – Applanation Ultrasound – Orbscan pachymetry

INTRODUCTION

Currently quantitative human ocular anatomy studies can be carry out by means of applanation ultrasound biometry (AUB) (McBrien and Adams, 1997; Osuobeni, 1999; Hiagis et al., 2000; Hosny et al., 2000; Cegarra et al., 2001; Findl et al., 2003) and scanning-slit corneal topography (SSCT) (Liu and Pflugfelder, 1999; Modis et al., 2001; Suzuki et al., 2003; Rainer et al., 2004; Sanchis-Gimeno et al., 2005).

The development of technologies such as AUB and SSCT has allowed anatomists to carry out studies in order to detect anatomic differences in CCT, ACD, LT, VCD and AL between normal and pathological eyes. Thus, AUB and SSCT can be used to determine the quantitative anatomic differences between normal and dry-eyes.

Population-based studies have detected that only in the USA alone more than 3 million women aged 50 and over suffer from dry-eye syndrome (Schaumberg et al., 2003). The prevalence of dry-eye only in the USA is believed to be approximately 11 million people (Liu and Pflugfelder, 1999).

Previously, few studies have focused in the quantitative anatomic differences in CCT values between normal and dry-eyes (Pole and Batzer, 1985; Liu and Pflugfelder, 1999; Sanchis Gimeno et al., 2005). Based on a bibliographic search using MEDLINE we have not found studies that have analyzed the quantitative differences in

ACD, LT, VCD and AL between normal and dry-eyes. CCT, ACD, LT, VCD and AL values are of great clinical importance because before refractive and cataract surgery it is necessary to calculate the CCT, ACD, LT, VCD and AL. Thus, theoretically anatomic differences in CCT, ACD, LT, VCD and AL in dry-eye subjects could affect surgery.

In light of the above, the aim of the present paper was to investigate quantitative anatomic differences in CCT, ACD, LT, VCD and AL between normal and dry-eyes.

MATERIAL AND METHODS

We analyzed the CCT, ACD, LT, VCD and AL in 70 normal subjects (54.68%) and in 58 subjects with dry-eye (45.31%). All CCT, ACD, LT, VCD, and AL measurements were carried out by one experienced examiner who did not know if subjects had dry-eye. The study was approved by the institutional review board at our center, and written informed consent was obtained from all subjects. The methodology used in the study is described below.

Previous ophthalmologic examination

All subjects underwent an ophthalmologic examination that included best corrected visual acuity, cycloplegic refraction (KR 7000-P; Topcon Corp., Tokyo, Japan), slit-lamp examination (Haag Streit Biomicroscope 900; Haag Streit, Bern, Switzerland), applanation tonometry (Goldmann Applanation Tonometer; Haag Streit, Bern, Switzerland), and dilated fundus examination.

Dry-eye detection

Dry-eye was confirmed by means of the tear break-up test, fluorescein staining of the cornea, the Schirmer test, and analysis of the meibomian gland by slit-lamp. Positive signs of dry-eye were defined (Lin et al., 2003) as there being at least 2 positive results between a tear film break-up time of ≤ 10 seconds, a Schirmer basal tear secretion test score of ≤ 5 mm, a fluorescein score of ≥ 1 (grade 0, no staining; grade 1, mild staining with a few disseminated stains and limited to less than one third of the cornea; grade 2, moderate by severe staining between grades 1 and 3; and grade 3, severe staining with confluent stains occupying half or more of the cornea), and the existence of meibomian gland disease ≥ 1 (grade 0, no obstruction; grade 1, plugging with translucent serous secretion when compressing the lid margin; grade 2, plugging with a viscous or waxy white secretion when compressing the lid margin; and grade 3, plugging with no secretion when compressing the lid margin) (Lin et al., 2003). Normal subjects had tear

break-up test of ≥ 16 seconds, fluorescein score grade of 0, absence of meibomian gland disease, and a Schirmer test ≥ 15 mm.

CCT SSCT measurements

CCT measurements were performed using the Orbscan Corneal Topography System II (Orbscan Inc., Salt Lake City, UT, USA). With the Orbscan Topography System two scanning slit-lamps project beams at 45° to the right or left of the instrument axis. Forty images – 20 with slit beams projected from the left and 20 from the right – are obtained at two intervals, each lasting 0.7 seconds. Surface data points are measured on the x, y, and z axes. The system creates true 3-D maps from the anterior segment of the eye using measurements based on the Scheimpflug principle (Rabsilber et al., 2003). Corneal thickness is calculated by measuring the distance in elevation between the anterior and posterior surfaces of the cornea (Rabsilber et al., 2003). During examination, the patient's chin is positioned on the chin rest and the forehead against the forehead strap. The volunteers are asked to look at a blinking red light coaxial to the imaging system while the tracking system measures involuntary eye movements during the examination. The images of the cornea are taken using a placido disc and are shown on the screen of the instrument.

The means of five CCT readings were averaged in a 2-mm-diameter circle in the center of the cornea. The Orbscan System II was used with an acoustic equivalent factor of 0.92, as recommended by the manufacturer.

ACD, LT, VCD and AL AUB measurements

Measurements of AL, ACD, LT, and VCD were obtained using a 10-MHz A-mode ultrasound device (Compuscan; Storz, St. Louis, MO, USA). The hard-tipped, corneal contact ultrasound probe was mounted on a tonometer (Haag-Streit, Bern, Switzerland) set to the person's intraocular pressure. The mean of 16 separate readings was recorded, together with the SD of each parameter.

In order to carry out the measurements, the cornea was anesthetized with two drops of oxybuprocaine 0.4%. Two minutes after anesthesia, the probe was positioned in front of the eye and the patient was asked to fixate on the red light within the probe. Then, the investigator positioned the biometric probe on the ocular surface so as to form an angle of 90° . The probe was then brought forward to gently touch the cornea without indenting it. The biometer used had a measurement precision of ± 0.06 mm, depending on the correct positioning of the probe. For this reason, the biometer comes with an automatic alignment system that detects the acceptability or not of the echoes for ensuing calculations.

In the biometer, the ultrasonic pulse produced in the transducer penetrates the various chambers of the eye. Each time the pulse passes from one intraocular medium to another the resistance encountered by the ultrasound changes and produces a reflection of the pulse. At that moment, an echo from the ultrasound is retransmitted to the transducer. A graphic representation of this process appears on the screen of the biometer. The abscissa axis indicates the time required for the propagation of the impulse, while the axis ordinates show the amplitude of the echoes.

The ACD is measured between the anterior corneal surface and the anterior lens surface. The LT is measured between the anterior lens surface and the posterior lens surface. The VCD is measured between the posterior lens surface and the anterior surface of the retina. The AL is measured between the anterior corneal surface and the anterior surface of the retina.

Statistical analysis

In the present study we analyzed only one eye per patient with a view to eliminating the possible *intra*-subject effect that would appear if both eyes of the same patient were studied (Fisher and Van Belle, 1993). The choice of either the right or the left eye was random. The Kolmogorov-Smirnov test and the Student's t-test were applied. *P* values of less than 0.05 were considered to be statistically significant.

RESULTS

Table 1 presents the characteristics of the subjects analyzed. Figure 1 shows the CCT, ACD, LT, VCD and AL results of the study. Significant quantitative anatomic differences between normal and dry-eye subjects were found in CCT, ACD, LT, VCD and AL values.

Table 1.- Characteristics of the subjects analyzed (mean±SD).

	Normal eyes	Dry-eyes	p-value*
n	70	58	---
Age	40.15±2.23	42.10±2.81	0.459
Spherical equivalent refraction (diopters)	-3.24±1.52	-1.15±1.08	0.011
Tonometry (mmHg)	16.09±2.30	15.88±	0.551
Meibomian gland disease	---	1.36±0.45	---
Schirmer test (mm)	18.34±6.21	4.78±1.32	<0.001
Break-up time (seconds)	18.16±4.15	6.25±1.81	<0.001
Fluorescein staining	---	1.14±0.34	---

* Student's t-test

DISCUSSION

We observed reduced CCT, ACD, LT, VCD and AL values in dry-eyes as compared to normal eyes. We analyzed CCT with SSCT and ACD, LT, VCD and AL with AUB. SSCT is an optical non-contact technique while AUB is a contact ultrasound technique.

CCT is usually measured with conventional applanation ultrasound pachymetry (Sanchis-Gimeno et al., 2001, 2003). We carried out SSCT using the acoustic equivalent factor of 0.92. SSCT CCT measurements without the acoustic factor give higher readings than ultrasonic pachymetry (Modis et al., 2001); the differences between SSCT and ultrasound pachymetry disappear when SSCT measurements are carried out using the acoustic equivalent factor of 0.92 (Suzuki et al., 2003). Thus, since we used the acoustic factor, the SSCT CCT values in the present study may be similar to those that can be obtained with the most common ultrasound pachymetry (Doughty and Zaman, 2000).

Previously, corneal morphometric studies (Liu and Pflugfelder, 1999; Sanchis-Gimeno et al., 2005) reported that dry-eye can cause significant decreases in CCT values. The mean difference with normal eyes was approximately 30 microns (Liu and Pflugfelder, 1999), and 14 microns (Sanchis-Gimeno et al., 2005). Nevertheless, in another study carried out on a small sample of 16 patients (Pole and Batzer, 1985) it was detected reduced CCT values in dry-eyes but no significant differences between dry-eye and normal eyes.

The factors involved in decreased corneal thickness values in dry-eye are an increase in tear film evaporation, resulting in increased osmolarity of the tear fluid (Sanchis-Gimeno et al., 2005). This may lead to a decrease in tear film thickness, which normally ranges from 3 to 40 microns (Sanchis-Gimeno et al., 2005). In addition, decreased tear turnover could also result in an increase in osmolarity. Thus, the reduction in tear film thickness can be one cause of reduced CCT values in dry-eyes because when carrying out SSCT CCT measurements tear film thickness is measured.

The possibility of reduced CCT values in dry-eyes has been analyzed before, but to our knowledge this is the first study that has addressed the quantitative anatomical differences in ACD, LT, VCD and AL values between dry-eye subjects and subjects without dry-eye. We analyzed ACD, LT, VCD and AL with AUB the measurements being carried out by one experienced examiner because of the knowing influence of experience on the reproducibility of AUB (Findl et al., 2003). On the other hand, it is known that SSCT has a good interobserver and intraobserver reproducibility (Rainer et al., 2004).

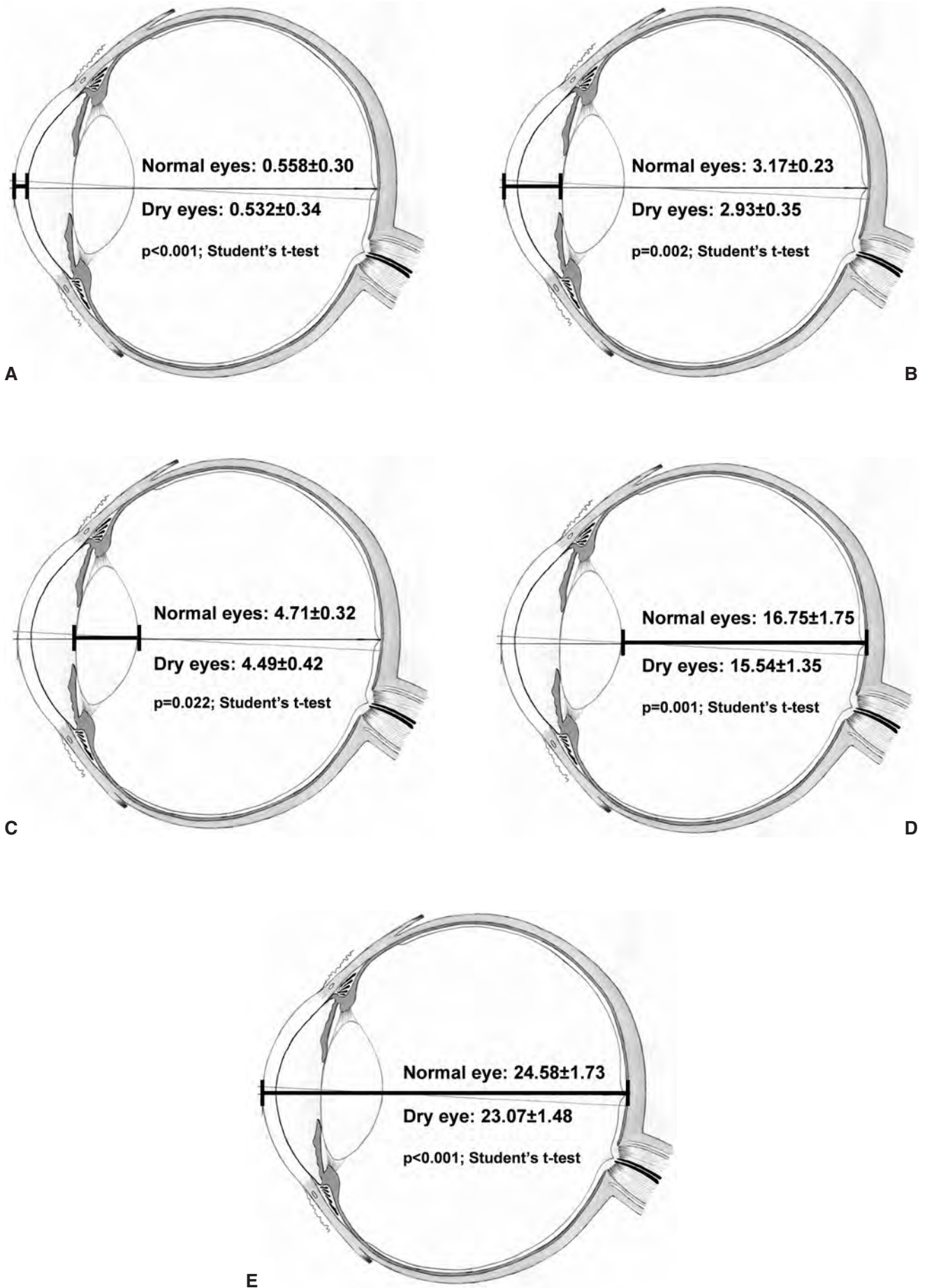


Fig. 1.- **A.** Central corneal thickness (mm). **B.** Anterior chamber depth (mm). **C.** Lens thickness (mm). **D.** Vitreous chamber depth (mm). **E.** Ocular axial length (mm).

SSCT CCT measurements were carried out before AUB because of the possibility of indentation of the ocular globe when measuring ACD, LT, VCD and AL. Nevertheless, Solomon (1999) did not observe that corneal indentation with applanation ultrasound pachymetry could affect CCT values.

Analysis of our AUB results reveals reduced ACD, LT, VCD and AL in dry-eye subjects. The SSCT and AUB anatomical differences may be of great importance for clinicians because CCT must be measured before refractive excimer laser surgery (Price et al., 1999) and ACD, LT, VCD and AL must be measured before cataract surgery in order to establish intraocular lens power (Haigis et al., 2000). The detection of quantitative anatomical differences in CCT between dry-eye and normal subjects may condition the amount of corneal tissue to be removed with the excimer laser in the dry-eye subjects. Furthermore, the reduction in the results of AUB in dry-eye subjects may affect calculations of intraocular lens power before cataract surgery. Thus, we believe that assessment of the anatomic effects of dry-eye on CCT, ACD, LT, VCD, and AL values should be accessible to clinicians before performing surgery. Attention must be given to and the indications must be considered carefully in dry-eye subjects because the values of these subjects differ from those presented by normal subjects.

We measured ACD with AUB. ACD is measured between the anterior corneal surface and the anterior lens surface with AUB. Thus, the ACD calculated with AUB includes the value of CCT. However, as we measured CCT with SSCT the *real* values of ACD must be calculated subtracting 0.558 ± 0.30 mm and 0.532 ± 0.30 mm in normal and dry-eye subjects.

Finally, it should be noted that there was a significant difference in spherical equivalent refraction between dry-eye and normal eyes being the normal subjects more myopic than the dry-eye subjects. It is generally accepted that the basis of refractive errors is the ocular anatomy itself since a number of studies have reported greater AL in myopic eyes than in hyperopic ones (McBrien and Adams, 1997; Osuobeni, 1999; Hosny et al., 2000; Cegarra et al., 2001). Previously, Price et al. (1999) did not observe any correlation between the spherical equivalent refraction and CCT in a study carried out on a large sample of eyes. Nevertheless, another study carried out by Chang et al. (2001) on myopic patients reported that the corneas were thinner in more myopic eyes, with a significant correlation between corneal thickness and the spherical equivalent. Moreover, in a study carried out on hyperopic corneas no significant differences in the mean values of the CCT between low and high hyperopic eyes were found (San-

chis-Gimeno et al., 2001). Thus, the possible influence of refraction on CCT values is not clear. Nevertheless, it could be surmised that the differences observed in ACD, LT, VCD and AL may be a consequence of the differences in refraction between dry-eyes and normal eyes. However, it also could be posited that the differences in refraction observed in our subjects could be a consequence of dry-eye, because dry-eyes have reduced AL values. This reduced AL could cause the lower myopia of the dry-eye subjects.

In sum, analysis of the ocular anatomic values shows that dry-eye subjects have lower CCT, ACD, LT, VCD and AL values than subjects without dry-eye. Nevertheless, further research is necessary to ascertain the differences in CCT, ACD, LT, VCD, and AL values between normal and dry-eye subjects with the same refraction.

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