Morphometric study of the hyperopic central cornea

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SUMMARY

Refractive surgery by means of excimer laser results in thinner postoperative corneas following corneal photoablation. This implies the need to previously measure the central corneal thickness in order to avoid the risk of keratectasia.

In recent years and after the introduction of excimer laser refractive surgery, several studies have focused on corneal morphometry in myopic eyes. However, we have not found any references to hyperopic eyes. Following on from this, we have studied central corneal thickness in 100 healthy hyperopic eyes by using ultrasonic pachymetry.

Patients were subdivided by refractive errors into group 1 (manifesting spherical equivalent refraction ≤ +4.00 diopters) and group 2 (manifesting spherical equivalent refraction > +4.00 diopters).

In group 1, central corneal thickness was 555.20±33.31 µm (mean ± standard deviation) and in group 2 it was 548.95±31.87. No significant differences were found between group 1 and group 2 (p= 0.346).

In group 1 there were significant differences in mean central corneal thickness between females and males (p= 0.012) but not in group 2 (p= 0.947).

No significant differences in the mean values of central corneal thickness as a function of age for the members of group 1 and group 2 were noted (p= 0.198 and p= 0.628, respectively).

Central corneal anatomy in healthy hyperopic eyes is similar to that seen in myopic eyes.

Key Words : Cornea – Ultrasonic pachymetry – Hyperopia

INTRODUCTION

Currently, the hyperopic excimer laser *in situ* keratomileusis technique is used to correct hyperopia. Modification of corneal anatomy is the basis of this technique.

In this refractive technique, the paracentral cornea is ablated and sculptured to modify its refractive properties. However, it has been observed that after paracentral photoablation, the central cornea tends to thin out (Roberts, 2000). The corneal thinning out after excimer laser photoablation requires that there be a previous measurement of central corneal thickness in order to have an acceptable safety margin after surgical practice (Price et al., 1999).

The recent publication of results obtained with the hyperopic laser in situ keratomileusis technique (Göker et al., 1998; Esquenazi and Mendoza, 1999; Arbelaez and Knorz, 1999) has conferred top priority to the anatomical study of central corneal thickness in hyperopic patients.

Currently, for the study of central corneal thickness *in vivo* optical pachymetry (Herse and Yao, 1993; Foster et al., 1998), specular microscopy (Bovelle et al., 1999) and orbscan pachymetry (Liu and Pflugfelder, 1999) are used.

However, ultrasonic pachymetry is a technique that offers very high precision; its variability is estimated to range between 6 and 14 µm for the study of corneal thickness (Böhnke et al., 1998). Furthermore, ultrasonic pachymetry has the advantage of rapid and easy use (Longanesi et al., 1996). However, despite being a high-precision technique, it has some disadvantages such as the necessary contact with the corneal surface. This contact with the corneal surface can lead to the transmission of infections. To avoid this risk, in recent years some

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techniques without contact have been proposed (Bovelle et al., 1999).

There are different studies of corneal thickness with ultrasonic pachymetry in myopic patients (Terry and Ousley, 1996; Colin et al., 1996; Faucher et al., 1997; Cennano et al., 1997; Mardelli et al., 1997; Copt et al., 1999; Price et al., 1999). Currently, however, we have failed to find any references to study of the central corneal anatomy in hyperopic patients. This is the reason why it is not possible to know whether the central corneal thickness of hyperopic patients is different to that seen in myopic patients.

In the light of above, the aim of the present work was to study the central corneal thickness of healthy hyperopic subjects before laser in situ keratomileusis using an ultrasonic pachymeter.

Materials and Methods

At the Rahhal Ophthalmology Clinic and the Faculty of Medicine of Valencia (Spain), we carried out a prospective non-masked study involving Caucasian patients with hyperopia. All the procedures were conducted in accordance with the principles of the Helsinki Declaration. Detailed consent forms were obtained from each patient.

All measurements were taken between 09:00-10:00 AM to avoid diurnal variations in corneal thickness and all the measurements were performed by the same person (JCI). Only one eye per patient was used in the study.

Exclusion criteria included active ocular and corneal disease, previous corneal or ocular surgery, systemic disease with ophthalmic repercussion, contact lens wearers, central applanation tonometry ≥ 21 mm Hg and a history of ocular hypertension or glaucoma and the use of any kind of ophthalmic drugs.

Inclusion criteria included age ≥ 19 years and stable refraction during one year.

100 eyes of 100 healthy hyperopic patients were examined. The mean age of the sample was 30.90±7.73 years (mean ± standard deviation) with a range between 19 and 51. There were 56 women (56%) and 44 men (44%).

Patients were assigned to group 1 and group 2 according to their manifest spherical equivalent refraction.

In group 1 the patients had a manifest spherical equivalent ≤ +4.00 diopters (D). In group 2 all patients had a manifest spherical equivalent refraction > +4.00 D. In group 1 there were 23 women (56.1%) and 18 men (43.9%). In group 2, there were 33 women (55.9%) and 26 (44.1%) men. Table 1 shows the age and refraction for each study group.

The ultrasonic pachymeter was installed in the Chiron Technolas 217 c-LASIK excimer laser room (Chiron Technolas GMBH, Dornack, Germany). Temperature was constant between 18º and 22º C and relative humidity ranged between 38 and 45%.

Ultrasonic pachymetry was performed after anaesthetising the cornea with two drops of oxibupocraine, 4 mg. After this, the ultrasonic probe was positioned in perpendicular position taking the center of the pupil as a reference point.

We measured the central corneal thickness with the DGH 2000 AP ultrasonic pachymeter (DGH Technology, Inc., San Diego, CA, USA) using the method described by Terry and Ousley (1996). Consecutive readings were made until three consecutive measurements were within 5 µm of each other. The mean of these three readings was used as the value of central corneal thickness in this study.

The statistical tests employed in the work to these ends were the Kolmogorov-Smirnov test and after this different parametric and non-parametric tests. The level of significance employed in the analysis was the usual 5% (α=0.05).

The means of two groups were compared by the t-test for two samples. The Kruskal Wallis test was used to analyse several means when more than one was compared.

Results

Table 2 shows the results of the morphometric study by sex and age in patients with manifest spherical equivalent refraction (mse) ≤ +4.00 (group 1) and > +4.00 diopters (group 2).

Table 2 reveals that there are no significant differences in mean central corneal thickness between group 1 and 2 (p= 0.346); it may be concluded that there is no significant relationship between mean central corneal thickness and spherical equivalent refraction in hyperopic patients.

Analysis of Table 2 reveals that in group 1 there is a higher mean central corneal thickness in women compared to men. In this group, mean central corneal thickness in women was higher by approximately 27 µm (p= 0.012). The minimum and maximum values were also higher in women.

With higher ages (people over the age of 30), mean corneal thickness was greater than that found in the younger patients.

The increase in corneal thickness was not linear with age since the lowest mean values (537.00 ± 45.13) were observed in patients between the ages of 26 to 29. The values presented by this intermediate age subgroup depart from the rise in the progression of mean corneal thickness with time. In spite of this, no significant differences as regards age were noted (p= 0.198).

In group 2, the mean values of the women and men are practically identical and no signifi-

Table 1.- Age and manifest refraction in group 1 and group 2.

	Group 1 (SE ≤ +4.00 D.)		Group 2 (SE > +4.00 D.)	
	Mean ± SD	**Range**	**Mean ± SD**	**Range**
Age	31.44±7.08	19 to 50	30.53±8.19	19 to 51
Age in women	33.74±7.48	19 to 50	31.09±8.67	22 to 51
Age in men	28.50±5.42	21 to 40	29.81±7.66	19 to 46
MSE (D)	+3.18±0.66	+1.75 to +4.00	+6.14±1.37	+4.50 to +9.50
MSE in women (D)	+3.13±0.73	+1.75 to +4.00	+6.58±1.54	+4.50 to +9.50
MSE in men (D)	+3.25±0.58	+2.00 to +4.00	+5.84±1.06	+4.50 to +8.75

SE= spherical equivalent; MSE= mean spherical equivalent refraction; D= diopters.

cant differences in mean central corneal thickness between the sexes were noted (p= 0.947).

In group 2, mean corneal thickness differed according to the patient age. Mean central corneal thickness was seen to be higher in older patients (≥ 36 year old), whereas the lowest values were found in the younger patients (≤ 25 year old).

Nevertheless, as can be observed in group 1, the differences between the age subgroups are not significant (p= 0.628).

Discussion

To our knowledge this is the first study that reports values of central corneal thickness in hyperopic patients who have undergone excimer laser surgery by means of the laser *in situ* keratomileusis technique. In this study we employed ultrasonic pachymetry to determine the central corneal thickness of hyperopic patients before excimer laser *in situ* keratomileusis. To carry out ultrasonic pachymetry, corneal anaesthesia was required. The use of external corneal anaesthesia can cause a significant increase in corneal thickness due to the development of corneal edema (Herse and Siu, 1992).

In the last few years, different techniques for measuring central corneal thickness with the ultrasonic pachymeter have been proposed. For instance, the mean of five consecutive readings

Table 2.- Central corneal thickness in hyperopic patients by refraction, sex and age (microns)

	Results in group 1 (MSE ≤ +4.00 D.)		
	Mean ± SD	**Range**	**P-value**
Total	555.20±33.31	490 to 624	
Women	567.00±28.68	510 to 624	
Men	540.11±33.41	490 to 600	Between sexes p= 0.012 (S-t)
≤ 25 years	557.60±29.47	516.66 to 600	
26-29 years	537.00±45.13	490 to 624	
30-35 years	561.33±28.86	510 to 590	
≥ 36 years	563.75±25.18	522 to 600	Between age p= 0.198 (KW)
	Results in group 2 (MSE > +4.00 D.)		
	Mean ± SD	**Range**	**P-value**
Total	548.95±31.87	485 to 601.66	
Women	548.73±35.32	485 to 592.33	
Men	549.23±27.55	505 to 601.66	Between sexes p= 0.947 (S-t)
≤ 25 years	542.42±27.87	505 to 601.66	
26-29 years	551.12±32.16	485 to 600.00	
30-35 years	544.85±39.77	490 to 592.33	
≥ 36 years	557.56±25.12	527.33 to 585	Between age p= 0.628 (KW)
	Comparison between group 1 and group 2		
	Mean ± SD	**Range**	**P-value**
Group 1	555.20±33.31	490 to 624	
Group 2	548.95±31.87	485 to 601.66	Between groups p= 0.346 (S-t)

MSE= manifest spherical equivalent refraction; SD= standard deviation; D= diopters; S-t= Student t-test; KW= Kruskal Wallis test.

has been proposed to obtain the valid central corneal thickness (Colin et al., 1996). Other proposals to obtain this value are the lowest of three consecutive readings (Munger et al., 1998), the lowest one after making multiple consecutive readings (Price et al. 1999), or the average of three consecutive measurements (Bechmann et al., 2001). We used the method described by Terry and Ousley (1996); that is, carrying out consecutive readings of the central corneal thickness until three consecutive readings that vary from each other by five or less microns are obtained. The mean of these three readings is calculated and taken as valid for the study.

The common nexus among the different techniques is continuous applanation of the cornea before obtaining the valid mean. Theoretically, continuous applanation of the cornea could lead to lower central corneal thickness values. However, the corneal indentation required to carry out ultrasonic pachymetry does not affect the corneal thickness value (Solomon, 1999).

Ultrasonic pachymetry requires comprehensive previous learning since it is necessary to locate the ultrasonic probe subjectively, taking the pupil centre as reference or structures adjoining the cornea. This difficulty can lead to different results among observers studying the same sample.

Bovelle et al. (1999) reported differences of nearly 20 µm in the mean central corneal thickness values in the same sample, obtained by two different observers using ultrasonic pachymetry. To avoid the differences observed by Bovelle et al. (1999), the measurements reported here were made by the same researcher with experience in these contact techniques.

There is a normal diurnal variation in corneal thickness. Harper et al. (1996) observed that central corneal thickness varies during the day, with a mean of 7.2% and a level ranging from 2.1% to 14.3%. To avoid the effect of diurnal variation, the measurements were made at the same time.

Corneal hydration can affect corneal thickness values (Terry and Ousley, 1996) and cause changes in the refractive index of the stroma (Patel et al., 2000). An increase in hydration would theoretically cause an increase in corneal thickness, while a decrease in hydration would bring about a reduction in corneal thickness. We attempted to obtain similar conditions of corneal hydration for all the patients by keeping temperature and relative humidity constant in the study room and by following the same protocol of corneal anaesthesia.

One of the most frequent causes that justifies the operations with excimer laser is when the patient wishes to stop using contact lenses. Because of this, many patients operated with excimer laser are contact lens wearers. Nevertheless, the continuous use of contact lenses reduces central corneal thickness (Liu and Pflugfelder, 2000). In our study, we included patients who were not contact lens wearers, and hence, our results are higher than those obtained in hyperopic patients who are contact lens wearers. The patients included in our study did not have pathologies involving intraocular pressure. Patients with such pathologies have central corneal thickness values different to those obtained in healthy people (Copt et al., 1999; Bron et al., 1999; Shah et al., 1999).

Studies carried out in myopic patients with ultrasonic pachymetry have reported mean central corneal thickness values ranging from 546±44.78 to 553.7±37.15 µm (Terry and Ousley, 1996; Colin et al., 1996; Faucher et al., 1997; Cennano et al., 1997; Mardelli et al., 1997; Copt et al., 1999; Price et al., 1999). These results are similar to those obtained in our study (555.20±33.31 and 548.95±31.87 µm in group 1 and group 2, respectively).

Nevertheless, these results obtained *in vivo* point to lower values than those given by studies carried out on cadavers; Merindano et al. (1997) obtained a central corneal thickness value of 770 µm in human cadaveric eyes.

In a recent study on corneal thickness with ultrasonic pachymetry, La Rosa et al. (2001) observed differences in mean corneal thickness values between Caucasian and Afro-American patients. Our study was carried out only with Caucasian patients, and therefore the results can only be extrapolated to young Caucasian patients with hyperopia.

We did not find significant differences between the central corneal thickness of the group 1 patients and that of the group 2 patients. Price et al. (1999), in their ultrasonic study which covered a broad sample of myopic patients, did not find any correlation between central pachymetry and manifest refraction.

In group 1 there were significant differences between the female and male patients ($p= 0.012$); central pachymetry was higher in the women. Other studies have not found differences in mean central corneal thickness between females and males (Rapuano et al., 1993; Bron et al., 1999; Cho and Lam, 1999; Price et al., 1999).

In group 1 females predominate, and it could be speculated that the hormonal differences between the sexes could determine different values of the corneal thickness just as they might govern the level of corneal hydration. We believe that the female hormonal condition can determine higher or lower central thickness values among the women studied. We base these assumptions on the study by Sorrentino et al. (1998), in which three months after the beginning of hormone replacement therapy in menopausal patients central corneal thickness rose by 16.6%.

However, there is also a predominance of females over males in group 2 and in this case we did not observe significant differences between women and men (p= 0.947).

This disparity between the results obtained in groups 1 and 2 suggests that there must be other factors involved in the regulation of corneal thickness.

We believe more studies should be carried out with a higher number of patients in which both women and men can be analyzed hormonally with a view to elucidating the conflicting results.

In our study we failed to find significant differences in corneal thickness according to patient age in groups 1 and 2. Longanesi et al. (1996) and Price et al. (1999) did not find them either. In a study with a sample with over 1000 people (range 10-87 year old people), Foster et al. (1998) did find a decrease in central corneal thickness with each decade of life. The number of patients analysed in this study and our own age range (19-51 years) prevents us from finding significant differences in corneal thickness due to age.

In conclusion, hyperopic central corneal thickness is similar to that reported in different studies for myopic eyes.

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