Biomechanical Properties of the Cornea in Fuchs’ Corneal Dystrophy

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PURPOSE. To investigate the effects of Fuchs’ corneal dystrophy (FCD) on corneal biomechanical properties and the results of IOP readings in relation to changes in corneal hysteresis (CH) and central corneal thickness (CCT).

METHODS. Corneal biomechanical properties, including CH, corneal resistance factor (CRF), and CCT, were measured with the ocular response analyzer (ORA) in 11 eyes of 11 patients with clinically confirmed FCD and 12 eyes of 12 healthy subjects. The ORA was also used to determine the values of intraocular pressure (IOPg) and corneal compensated IOP (IOPcc). Goldmann application tonometry (GAT) was also measured.

RESULTS. CH measured 10.3 ± 1.6 mm Hg (range, 8.7–13.8) in normal eyes and 6.9 ± 1.8 mm Hg (range, 4.6–11.7) in FCD eyes (P = 0.001). CRF in the normal and FCD eyes was 10.5 ± 1.5 mm Hg (range, 8.5–13.5) and 8.1 ± 1.9 (range, 4.5–11.2), respectively (P = 0.005). CCT was higher in FCD eyes (606 ± 20 μm; range, 578–635) than in normal eyes (538.4 ± 24.9 μm; range, 495–575; P = 0.0001). IOPcc was 16.2 ± 2.2 mm Hg (range, 13.5–18.7) in control eyes compared with 17.6 ± 2.7 mm Hg (range, 12.8–18.6) in FCD eyes (P = 0.201). However, IOPcc in the FCD group (21.8 ± 4.6 mm Hg; range, 12.8–29.0) was higher than in the control group (16.5 ± 3.4 mm Hg; range, 11.9–23.9; P = 0.006). GAT in the normal and FCD eyes was 16.7 ± 2.1 mm Hg (range, 12.8–18.6) and 16.9 ± 2.3 mm Hg (range, 13.1–19.0), respectively (P = 0.205).

CONCLUSIONS. FCD led to a change of corneal biomechanical properties. CH and CRF were significantly lower in FCD eyes than in normal eyes. IOPcc was significantly higher in FCD eyes than in control eyes. These values may be useful in addition to CCT when assessing corneal rigidity. Thus, FCD may cause an underestimation error in IOP measurement. (Invest Ophtalmol Vis Sci. 2009;50:3199–3202) DOI:10.1167/iovs.08-3312

Fuchs’ corneal dystrophy (FCD) is usually a bilateral and progressive disorder of aging that predominantly affects women. Thus far, central corneal thickness (CCT) is taken into account as the only parameter to determine corneal rigidity in vivo. Few previous studies have evaluated corneal dysurities induce changes in corneal biomechanical characteristics (Tanimoto SA, et al. IOVS 2005;46;ARVO E-Abstract 4850). The aim of this study was to investigate the effect of FCD on corneal biomechanical properties. Furthermore, the results of IOP readings in relation to changes of corneal hysteresis (CH) and CCT were analyzed.

MATERIALS AND METHODS

Eleven eyes of 11 patients (three men, eight women) with clinically confirmed FCD were recruited sequentially among patients at the Department of Ophthalmology at the Lozano Blesa University Clinic Hospital in Zaragoza, Spain. Although seven of our patients had a bilateral FCD, we limited the contribution of each patient to one eye to avoid interdependency. The average age of the patients was 68.2 ± 2.8 years (range, 49–85). The diagnosis of FCD was made by an experienced corneal specialist (MDB) using a noncontact specular microscope (SP-2000 P; Topcon, Tokyo, Japan). Mean endothelial cell density was 1562 ± 679 cells/mm², and distinct pleomorphism and polymegathism of the endothelial cells were observed in this group.

As a control group matched for age, we analyzed 12 eyes from 12 healthy subjects (seven men, five women) selected from employees of the hospital. The mean age of the subjects was 65.7 ± 1.8 years (range, 57–78). All had normal corneas (based on history and examination). Subjects who had refractive errors such as myopia >2 diopters (D), hyperopia >1 D, or astigmatism >1 D and those who had undergone previous eye surgery, glaucoma, eye infection, diabetes mellitus, or other acute or chronic diseases or who had a history of wearing contact lenses or using any topical eye medication were excluded from both groups.

Corneal hysteresis (CH), corneal resistance factor (CRF), and central corneal thickness (CCT) were measured (Ocular Response Analyzer [ORA]; Reichert Ophthalmic Instruments, Buffalo, NY) with a patented dynamic bidirectional applanation process.1 The ORA applied force to the cornea with a rapid air puff. With an electro-optical system, the corresponding deformation of the cornea was detected. The air pulse induced inward, and then outward, corneal movement, which provided two applanation measurements. Hysteresis resulted from the damping of the cornea because of its biomechanical properties and was derived from the difference of the two applanation measurements during the applanation process. The ORA also determined the values of noncontact tonometer intraocular pressure (IOPg) and corneal compensated IOP (IOPcc). In addition, Goldmann applanation tonometry (GAT) was measured.

The study and data accumulation were performed with the approval of the local ethics committee, informed consent was obtained from each subject participating in the study, and the study protocol was consistent with the tenets of the Declaration of Helsinki.

Values were presented as mean with SD. The two-sample Mann-Whitney U test for nonparametric numbers was used for determining whether the values of a particular variable differed between two groups. Bivariate correlation was accomplished for nonparametric numbers, resulting in the Spearman R coefficient. The level of statistical significance was set at P < 0.05. Data analysis was conducted using commercial software (SPSS software, version 15.0; SPSS, Inc., Chicago, IL).
RESULTS

Mean CH was 10.3 ± 1.6 mm Hg (range, 8.7-13.8) in normal eyes compared with 6.9 ± 1.8 mm Hg (range, 4.6-11.7) in FCD eyes. The difference was statistically significant (P = 0.001, Mann-Whitney U test). Mean CRF in the normal and FCD eyes was 10.5 ± 1.5 mm Hg (range, 8.5-13.3) and 8.1 ± 1.9 (range, 4.5-11.2), respectively; the difference was significant (P = 0.005; Mann-Whitney U test). CCT was higher in FCD eyes (606.0 ± 20.0 µm; range, 578–635) than in normal eyes (538.4 ± 24.9 µm; range, 495–575; P = 0.0001, Mann-Whitney U test). Mean IOPg in the normal and FCD eyes was 16.2 ± 2.2 mm Hg (range, 13.5-18.7) in normal eyes compared with 17.6 ± 2.7 mm Hg (range, 12.8-18.6) in FCD eyes. The difference was significant (P = 0.006; Mann-Whitney U test). IOP cc in the FCD group (21.8 ± 4.6 mm Hg; range, 12.8-29.0) was higher than in controls (16.5 ± 3.4 mm Hg; range, 11.9-23.9; P = 0.006). GAT in the normal and FCD eyes was 16.7 ± 2.1 mm Hg (range, 12.8-18.6) and 16.9 ± 2.3 mm Hg (range, 13.1-19.0), respectively (P = 0.205). Table 1 shows the biomechanical measurements in normal and FCD eyes. Figure 1 shows the relationship (scatterplot) between CRF and CCT of normal eyes and FCD eyes. There is a statistically significant direct correlation in normal eyes (r = 0.92; P = 0.01; nonparametric Spearman correlation coefficient) and a statistically significant inverse correlation in FCD eyes (r = -0.81; P = 0.05; nonparametric Spearman correlation coefficient). CH and CCT showed a weaker relationship in normal eyes (r = 0.56; P = 0.07; nonparametric Spearman correlation coefficient) and in FCD eyes (r = -0.49; P = 0.08; nonparametric Spearman correlation coefficient) than the one between CRF and CCT, probably because of the small sample size (Fig. 2). Figure 3 shows the relationship (scatterplot) between CH and IOPcc of normal eyes (r = -0.70; P = 0.01; nonparametric Spearman correlation coefficient), and FCD eyes (r = -0.62; P = 0.05; nonparametric Spearman correlation coefficient). Both groups of eyes showed a statistically significant inverse correlation. IOPg was not significantly correlated to CH in either group. Similarly, neither IOPg nor IOPcc was significantly correlated to CRF in either the FCD group or the control group. With the use of standard automated perimetry and optical coherence tomography, chronic glaucoma was diagnosed in 3 of 11 patients with FCD. All required topical antiglaucomatous therapy.

DISCUSSION

In vivo, the biophysical factors that contribute to the rigidity and elasticity of the cornea and maintain its shape are not well understood. Hysteresis, a parameter to characterize the biome-
Mechanical status of the cornea, is the result of the ocular resistance caused by the combined effect of corneal thickness, ocular rigidity, and biomechanical properties.\textsuperscript{1}

Some clinical conditions such as FCD, keratoconus, LASIK, high myopia,\textsuperscript{2} and glaucoma may induce changes of corneal biomechanical properties and lead to decreases in CH (del Buey MA, et al. IOVS 2008;49;ARVO E-Abstract 653). In the present study, patients with FCD also had lower CH and CRF, indicating that some aspects of the biomechanical properties of the cornea became altered.

Figure 2. Scatterplot showing the relationship between CCT (μm) and CH (mm Hg) in FCD eyes and control eyes.

Figure 3. Scatterplot showing the relationship between CH (mm Hg) and IOP\textsubscript{cc} (mm Hg) in FCD eyes and control eyes.
A strong association between CRF and CCT has been demonstrated (Luce DA. IOVS 2006;47:ARVO E-Abstract 2266). CRF is decreased in patients with keratoconus and who undergo LASIK, and in each of these conditions, CCT is also decreased because of the corneal damage or surgery. After contact lens wear with eye closure for 3 hours, CRF increased, and there was a significant correlation between corneal swelling and CRF. In our study, CRF was positively correlated with CCT in the control eyes. However, CRF was negatively correlated with CCT in the FCD eyes (the higher the CCT, the lower the CRF). This may indicate that in edematous corneas the CCT should not be taken into account as the only parameter for corneal rigidity that can be determined in vivo. Thus, CRF may be related not only to corneal hydration but also to some other as yet unknown aspects of corneal biomechanics. Patients with FCD have decreased endothelial cell density, thicker Descemet’s membrane, and the corneal central region is usually involved.

Corneal biomechanical properties potentially affect the accuracy of IOP measurements. In the present study, there was no significant difference in IOPc between the FCD and control groups. Previous studies have established that GAT will overestimate IOP in patients with thick corneas and underestimate IOP in those with thin corneas. The relationship between CCT and IOP is nonlinear and may be different in the corneas of normal eyes and eyes with chronic diseases. IOPcc is a pressure measurement to provide an IOP value that is claimed to be less affected by corneal properties than GAT. Our results showed that CH was negatively correlated with IOPcc in both groups of eyes: the lower the CH, the higher the IOPcc. Therefore, the observed diminished CH and elevated CCT might have caused an underestimation error in IOP measurement in FCD eyes. In fact, as we mentioned in the Results, glaucoma was diagnosed in 3 of 11 patients with FCD (with perimetry and optical coherence tomography). In summary, FCD leads to a change of corneal biomechanical properties and may cause an underestimation error in IOP measurement, with a consequent delay in the diagnosis of glaucoma.

References