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Original research

Age-related variations in corneal biomechanical properties

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Abstract

Purpose: To determine age-related changes in corneal viscoelastic properties in healthy individuals.
Methods: This observational cross-sectional study was performed at the Department of Ophthalmology, Imam Khomeini Hospital, Ahvaz, Iran and included 302 healthy individuals in 6 age decades (range: 10−69 years). After complete ocular examination, corneal viscoelastic properties were measured by ocular response analyzer and central corneal thickness (CCT) by an ultrasonic pachymeter. Our main outcome measures were corneal viscoelastic properties in different age groups.
Results: Corneal hysteresis (CH) and corneal resistance factor (CRF) showed a significant negative correlation with age ($P < 0.001$ for both, $r = -0.353$ and $r = -0.246$, respectively). Female gender had significantly higher CH ($P = 0.017$) and CRF ($P = 0.019$). CH and CRF were significantly correlated ($P < 0.001$, $r = 0.821$). CCT showed a biphasic pattern with significantly higher thicknesses before 20 and after 50 years of age. CH and CRF were significantly correlated with CCT ($P < 0.001$ for both, $r = 0.21$ and $r = 0.26$, respectively) and intraocular pressure (IOP) ($P < 0.001$ for both, $r = -0.474$ and $r = 0.598$, respectively). Corneal-compensated IOP (IOPcc) was significantly higher after age 40 compared to age group <20 ($p < 0.045$). Goldmann-correlated IOP (IOPg) was significantly correlated with CCT ($P = 0.001$, $r = 0.193$), while IOPcc showed no correlation with CCT ($P = 0.265$, $r = 0.062$). CH was significantly higher in hyperopic eyes compared to emmetropic eyes ($P = 0.009$) and myopic eye ($P < 0.001$).
Conclusions: In this study, there was a decrease in CH and CRF with an increase in age. Hyperopia and female gender are associated with higher CH and CRF. CCT is higher toward the extremes of life and is significantly correlated with CH and CRF.

Keywords: Corneal hysteresis; Corneal resistance factor; Ocular response analyzer; Aging

Introduction

The viscoelastic properties of the cornea were first described by Freidenwald in 1937.[1]

However, in vivo measurement of corneal biomechanical properties was only possible in 2005 by the Ocular Response Analyzer (ORA) (Reichert Inc., Depew, New York).[2]

The instrument measures corneal hysteresis (CH) and corneal resistance factor (CRF) as the markers of corneal viscoelastic properties. Technically, CH is the difference between inward and outward applanation pressures created by an air puff and is an indicator of viscous properties of the cornea.

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However, CRF is a measurement of corneal resistance to deformation and indicates elastic properties of the cornea. Corneal properties other than central corneal thickness (CCT) have several implications especially in glaucoma[3] and corneal refractive surgery.[4]

Corneal viscoelastic properties depend on the structure and organization of collagen fibrils and extracellular matrix (ECM). Collagen fibers are responsible for strength and elasticity of the cornea while the ECM is responsible for the viscous properties. Thus, changes in collagen fibers affect CRF and changes in ECM affect CH. Structural changes with age include an increase in collagen fiber diameter as a result of an increase in number of collagen molecules and expansion of intermolecular space.[5] Ex vivo measurements of corneal biomechanical properties have shown progressive stiffening of the cornea with age.[6–9]

However, the results of in vivo measurements of corneal biomechanics are inconclusive.[10] Some studies have shown no change by age,[11–14] while some report a decrease in CH and CRF.[15–19]

This study was conducted to evaluate the corneal viscoelastic properties in different age groups.

Methods

This cross-sectional study was performed at the Department of Ophthalmology, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran. The study protocol was approved by the local ethics committee and adhered to the tenets of Declaration of Helsinki. Informed consent was obtained from all patients.

In this observational cross-sectional study, 302 healthy individuals aged 10–69 years were evaluated. Exclusion criteria included any history of ocular or systemic diseases including diabetes, hypertension, hyperlipidemia, glaucoma, ocular surgery, keratoconus, ocular or systemic medications including corticosteroids, corneal astigmatism >2 D, severe dry eye, pregnancy, and contact lens use within 1 month of the study. After a complete ocular examination, corneal viscoelastic properties were measured using ORA and CCT measured using an ultrasonic pachymeter (Pachymeter SP 3000, Tomey, Nagoya, Japan). In case of ocular disease, the sound eye and otherwise the right eye was chosen for the study. Individuals were put into 6 groups: Group 1 (10–19 years), Group 2 (20–29 years), Group 3 (30–39 years), Group 4 (40–49 years), Group 5 (50–59 years), and Group 6 (60–69 years). Our main outcome measure was corneal viscoelastic properties at different age groups. Second outcome measure was the effects of sex and refractive errors on corneal biomechanics.

ORA is an air puff tonometer that measures the corneal response to a steady air pulse. It makes two applanation measurements: a force-in applanation which has been attributed to the dampening effects of the cornea and a force-out applanation that occurs at a lower pressure than the first. The difference between the two pressures is CH and indicates viscous properties of the cornea, while CRF shows the elastic properties of the cornea. Therefore, these parameters may affect intraocular pressure (IOP) measurements more than CCT alone. The instrument also reports Goldman-correlated IOP (IOPg) and its corneal-compensated counterpart (IOPcc).

ORA parameters including CH, CRF, IOPg, and IOPcc, as well as CCT, and spherical equivalent refractive error were considered for analysis. Refractive errors of −1 to 1 D were considered as emmetropia.

Statistical analysis

To obtain a power of 0.8 and $\alpha = 0.05$, sample size of 36 cases was calculated for each age decade.

Statistical analyses were performed using SPSS software v.20 (SPSS Inc. Chicago, IL). Pearson correlation coefficient and partial correlation were used in analyses. In addition, to compare data, we used one way analysis of variance (ANOVA). Two-by-two comparisons were done using Tukey test. P values <0.05 were considered significant.

Results

Overall, 302 healthy individuals were enrolled in the study. Table 1 shows demographic data and participants' characteristics.

CH and CRF were significantly different among the age groups ($P < 0.001$, ANOVA). Group 1 (10–19 years old) showed significantly higher CH and CRF compared to all other age groups ($P < 0.001$) while other groups were not significantly different from each other (All P values >0.05, Tukey test) (Table 1, Fig. 1). CH and CRF were highly correlated ($P < 0.001$, $r = 0.821$).

Age showed a significant negative correlation with CH ($P < 0.001$, $r = -0.353$) and CRF ($P < 0.001$, $r = -0.326$). Female gender had significantly higher CH (11.35 vs 10.85, $P = 0.017$) and CRF (10.9 vs 10.4, $P = 0.019$, independent t-test).

After adjustment for gender, CCT, IOP, and refractive error, age remained significantly correlated with CH and CRF ($P < 0.001$ for both, $r = -0.398$ and $r = -0.372$, respectively).

CCT showed a biphasic pattern in which Groups 1, 5, and 6 had significantly higher CCTs compared to other groups (Table 1, Fig. 2). CH and CRF showed significant positive correlation with CCT ($P < 0.001$ for both, $r = 0.21$ and $r = 0.26$, respectively).

IOPcc was significantly higher in Group 4 compared to Group 1 ($P = 0.045$). IOPg was significantly higher in Group 1 (compared to Groups 2 and 3, $P = 0.007$) and Group 4 (compared to Group 3, $P = 0.007$). IOPg and IOPcc were significantly correlated ($P < 0.001$, $r = 0.845$) and were not significantly different ($P = 0.148$). IOPg (but not IOPcc) was significantly correlated with CCT ($P = 0.001$, $r = 0.193$) and CRF ($P < 0.001$, $r = 0.598$), while IOPcc was negatively correlated with CH ($P < 0.001$, $r = -0.474$).

The groups were not significantly different in terms of refractive error. ($P = 0.055$, ANOVA) CH and CRF showed a