

Research Article

Comparative Study of Corneal Biomechanical Properties between Myopes and Hyperopes

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Received: December 20, 2013; Accepted: January 12, 2014; Published: February 14, 2014

Abstract

Purpose: The aim of this study is to compare the biomechanical corneal properties between myopes and hyperopes among Saudi Arabian adults using an Ocular Response Analyzer.

Methods: The study involves 50 healthy Saudi Arabian adults: 18 males (35.35 %) and 32 females (64.65%), with a mean age 25.66 ± 5.8 years (range 15 – 44). The subjects were divided into two groups: **Group 1** includes 78 eyes of 39 myopic subjects with spherical equivalents ranging from -1.25 DS to -10.00 DS; **Group 2** includes 21 eyes of 11 hyperopic subjects with spherical equivalents ranging from +1.00 DS to +5.50 DS. An Ocular Response Analyzer [Reichert Ophthalmic Instruments, Buffalo, USA] was used to measure the corneal biomechanical properties such as Corneal Hysteresis (CH), Corneal Resistance Factor (CRF), IOPcc and IOPg. The Pentacam [Oculus, Wetzlar, Germany] was used to measure the Central Corneal Thickness (CCT).

Results: This study found that CH has a highly significant correlation with spherical equivalent in hyperopes ($r=0.684$; $P<0.001$) compared with an insignificant correlation with spherical equivalent in myopes ($r = -0.009$; $P=0.939$). Also, it was found that a highly significant difference between myopes and hyperopes in CH values exists ($P<0.001$). Our study did not show any significant correlation between CRF and spherical equivalent with myopes ($r=0.071$; $P=0.536$) or with hyperopes ($r=0.357$; $P=0.112$). A significant correlation was found between CCT and the amount of spherical equivalent in hyperopes ($r = 0.510$; $P<0.001$). In myopes the CCT had an insignificant correlation with the amount of spherical equivalent ($r = -0.013$; $P = 0.913$). The amount of CCT in this study is significantly correlated with corneal hysteresis in myopia ($r = 0.504$; $P<0.0001$) and in hyperopia ($r = 0.651$, $P<0.001$). In the myopia group of our study, it was found that CH had a significant correlation with IOPcc ($r = -0.640$; $P<0.0001$) and was more significant than in hyperopic group ($r = -0.457$; $P=0.037$).

Conclusion: In conclusion, this study found that hyperopic refractive errors have higher and significant values of corneal hysteresis and other biomechanical properties.

Keywords: Corneal biomechanical properties; Corneal hysteresis; Ocular response analyzer.

Introduction

The cornea is composed of a pressurized, thick-walled, partially woven, uni-directional, fibril-reinforced laminate bio-composite; it represents an excellent compromise between stiffness, strength and extensibility. It is able to withstand internal and external forces that may stress it, distort its shape or threaten its integrity [1].

The cornea is a complex anisotropic composite with non-linear elastic and viscoelastic properties. It is a *composite* because its properties are determined by the interaction of disparate materials like collagen and polyanionic ground substance, and is *anisotropic* because its properties are not directionally uniform [2].

A new measure of corneal biomechanics was identified by David Luce called Corneal Hysteresis (CH) which equates to the difference in the inward and outward pressure values obtained during dynamic

bidirectional application employed by the Ocular Response Analyzer (ORA), as a result of viscous damping in the cornea. The corneal biomechanical properties, corneal hysteresis and Corneal Resistance Factor (CRF) are subjects of recent research interest [3]. Corneal hysteresis is thought to predominantly reflect the viscous properties of the cornea and CRF is an empirically derived measurement of the cornea's elastic properties [4]. These parameters are derived from the complex interaction between the cornea's collagen composition, thickness, hydration, age, and other physiological factors [5].

Until now, studies to correlate corneal findings with refractive errors among different age groups have produced conflicting results [6]. The aim of the current study is to correlate corneal biomechanical properties between myopes and hyperopes among Saudi Arabian adults using an Ocular Response Analyzer.

Subjects and Methods

This study involves 50 healthy Saudi Arabian human subjects of both genders. It was conducted from the 23rd of February 2013 until the 10th of May 2013, at two locations: King Saud University, College of Applied Medical Sciences (female campus, Oleisha), and at the Alhokama Eye Specialist Center. The mean age was 28 years old and the range was between 15 to 44 years old. The subjects were divided into two groups: **Group 1:** included 78 eyes of 39 myopic subjects with spherical equivalents ranging from -1.25 DS to -10.00 DS; **Group 2:** includes 21 eyes of 11 hyperopic subjects with spherical equivalents ranging from +1.00 DS to +5.50 DS. Patients with keratoconus, Fuch's dystrophy, glaucoma, anterior segment inflammation or any systemic diseases with ocular complications were excluded. All subjects underwent full ophthalmological examination including a visual acuity test, subjective refraction and slit lamp examination. The automated refraction was done to determine refractive errors, the slit lamp examination was used to evaluate the anterior segment, and the central corneal thickness was measured using Pentacam [Oculus, Wetzler, Germany] [7].

The key point of this study is to measure corneal biomechanical properties using the Ocular Response Analyzer [Reichert Ophthalmic Instruments, Buffalo, USA]. This is a non-contact tonometer that allows measurement of corneal biomechanical properties by way of the corneal hysteresis measurement. The CH value provides a basis for understanding two additional parameters: Corneal-Compensated Intraocular Pressure (IOPcc) and Corneal Resistance Factor (CRF) [8].

Statistical Analysis

The collected data were entered into SPSS 17.0 (SPSS Inc.) for statistical analysis. Datasets for myopic and hyperopic refractive errors groups were compared using an analysis of variance. The Pearson correlation coefficient was used to assess the relationship between spherical equivalent power and the corneal biomechanical properties. This was then compared to the relationship between myopia and hyperopia using the student t-test, unpaired.

Results

A total of 99 eyes of 50 patients were analyzed. The demographic factors revealed 18 males (35.35 %) and 32 females (64.65%), with a mean age of 25.66 ± 5.8 years (range 15 – 44). **Group 1:** included 78 eyes of 39 myopic subjects with a spherical equivalent mean and standard deviation of 3.73 ± 1.64 , ranging from -1.25 DS to -10.00 DS. **Group 2:** included 21 eyes of 11 hyperopic subjects with spherical equivalent mean and standard deviation of 2.84 ± 1.42 , ranging from +1.00 DS to +5.50 DS.

In myopic subjects we did not find any significant correlation between Spherical Equivalent (SE) and corneal biomechanical parameters as shown in table 1 and Figure 1.

In hyperopic subjects, a very high significant correlation was found of Spherical Equivalent (SE) with corneal hysteresis CH ($r = 0.684$; $P=0.001$) Figure (2a) and with IOPcc ($r = -0.656$; $P=0.001$), and found a highly significant correlation of Spherical Equivalent (SE) with CCT ($r = 0.510$; $P=0.018$) Figure 2c shown in table 2.

Table 1: The correlation between corneal biomechanical properties and spherical equivalent of myopes.

Corneal Biomechanical Parameters	r	P-Value
CH	-.009	.939
CRF	.071	.536
CCT	-.013	.913
IOPcc	.105	.359
IOPg	.145	.206

Figure 1: Correlation between spherical equivalent and corneal biomechanical parameters in myopes.

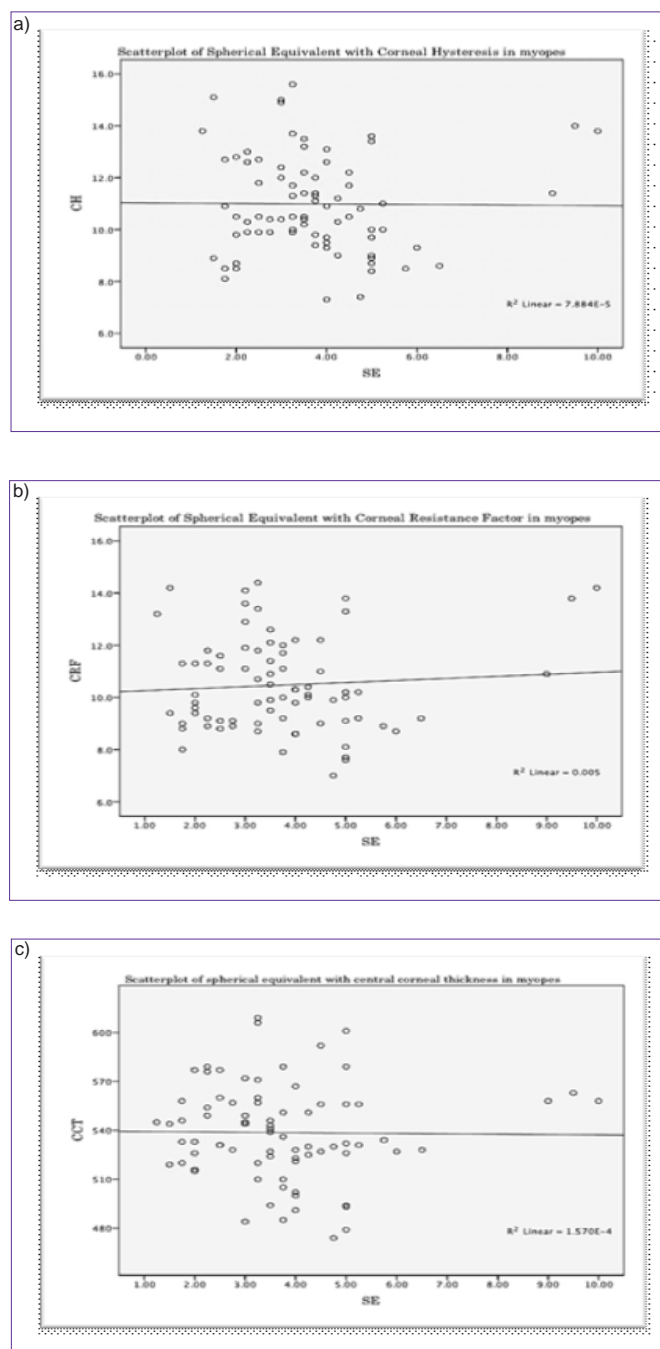
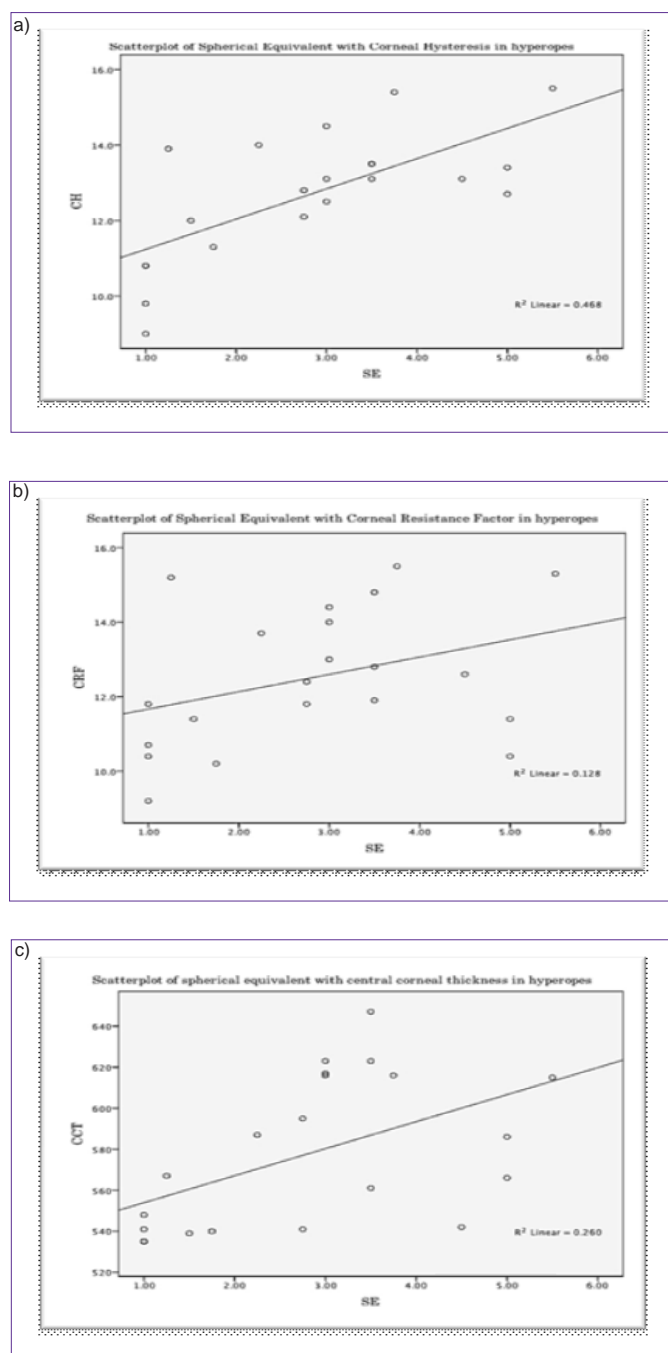


Table 2: The correlation between corneal biomechanical properties and spherical equivalent of hyperopes.

Corneal Biomechanical Parameters	r	P-Value
CH	.684	0.001***
CRF	.357	0.112
CCT	.510	0.018**
IOP cc	-.656	0.001***
IOP g	-.303	0.182

Figure 2: Correlation between spherical equivalent and corneal biomechanical parameters in hyperopes.



A t-test was used for the independent groups; a very high significant difference was seen between the two groups amongst the various parameters of CH, CRF and CCT (P= 0.0001). There was also

Table 3: Difference between corneal biomechanical properties in two groups.

Biomechanical Parameters	t	P-Value
CH	-3.763	.00001***
CRF	-4.594	.00001***
CCT	-5.185	.00001***
IOP cc	0.196	.845
IOP g	-2.494	.014*

* Significant at 0.05 %
 ** Significant at 0.001 %
 *** Significant at 0.0001%

a significant difference in IOPg (P= 0.014) shown in table 3.

Discussion

Corneal biomechanical properties, as measured with an Ocular Response Analyzer appear to be affected by variation in refractive spherical equivalent. Corneal hysteresis is thought to represent the cumulative effects of corneal thickness, hydration, rigidity and other unknown factors. The present study was the first to compare groups with refractive errors and spherical equivalent values. The CH shows a strong correlation with the amount of spherical equivalent in hyperopes (r=0.684; P<0.001). This is in contrast to myopes, in which the CH shows no significant correlation with the amount of spherical equivalent (r = - 0.009; P=0.939). Shen et al. [9], found a significantly lower CH in high myopes than normal subjects (P=0.0001), but CH was not significantly correlated with refractive error either in high myopes (r=0.155, P>.05) or emmetropes (r=0.006,P>0.05). Palkitsi et al. [6], in a study among myopic adults with a spherical equivalent mean -4.81±3.13 D (range -14 to +0.25) the corneal hysteresis values appear to be lower for high myopes and tend to increase slightly as the refraction moves toward emmetropia (P<0.001). Chang et al. [10], found that corneal hysteresis CH had a significant positive but weak correlation (r= 0.206; P<0.001) with the spherical equivalent (-2.51±1.84 D). Song et al. [11], did not find any correlation between corneal hysteresis and refractive error among Chinese children. However, the latter two studies included much younger subjects and those with lower amounts of spherical equivalent than in our study. We found the difference in CH between myopes and hyperopes to be statistically significant (P<0.00001). Hedge et al. [12], in a study involving children found no significant difference in the value of CH between myopes and hyperopes (P = 0.13). That was the only study that included hyperopes as a subgroup. Radhakrishnan et al. [13], did not find a significant correlation between corneal hysteresis and refractive error (P=0.82), but found a weak but significant correlation between CRF and spherical equivalent in myopes (r=0.04; P=0.03). Our study did not show any significant correlation of CRF with myopes (r=0.071; P=0.536) or hyperopes (r=0.357; P=0.112). Lim et al. [14], found that CH and CRF did not vary with myopia status (P=0.79 and 0.83, respectively). Shen et al. [9] found similar CRF values in both high myopes and emmetropes (P=0.351).

According to Luce DA [3], the corneal resistance factor can be expressed as follows:

$$(CRF = k_1 * (P_1 - P_2) + 0.3 * k_1 P_2 + k_2)$$

Therefore, the result can be partially changed due to the CH value ($P_1 - P_2$).

In the study of Shah et al. [15], in normal eyes there exists a significant correlation between CRF and CH ($P < 0.0001$, $r = 0.8$). However, previous studies [6,9,13], and the current study did find that one parameter will be correlated with refractive error and the other will not, which may form some doubt as to whether a relationship exists. Another obvious difference was found in the correlation between Central Corneal Thickness (CCT) with the amount of spherical equivalent between the two groups. A significant correlation was found between CCT and the amount of spherical equivalent in hyperopes ($r = 0.510$; $P < 0.001$). In myopes, the CCT had no significant correlation with the amount of spherical equivalent ($r = -0.013$; $P = 0.913$). Also the difference in CCT between the two groups was statistically significant ($P < 0.0001$). The amount of CCT was higher in hyperopes (578.10 ± 36.860) than myopes (538.63 ± 29.239). Also Hedge et al. [12], shows a significantly higher CCT in hyperopes ($P = 0.007$), which might cause the higher CH ($P = 0.02$) and CRF ($P = 0.03$).

The amount of CCT in this study is strongly correlated to corneal hysteresis in myopia ($r = 0.504$; $P < 0.0001$) and in hyperopia ($r = 0.651$; $P < 0.001$). This relation is stronger than the same relation in previous study by Shah et al. [15] in which normal eyes showed a moderate relationship between CCT and CH ($r = 0.426$).

The corneal compensated IOP (IOPcc) is mathematically derived from CH according to the formula: $IOPcc = P_2 - kP_1$. We understand that IOPcc possibly correlates with refractive error. However, our study found a significant correlation between spherical equivalent of hyperopes and IOPcc ($r = -0.656$; $P = 0.001$) but in myopes it did not show significant values ($r = 0.105$; $P = 0.359$). Hedge et al [12], analyzed that IOP values (IOPg & IOPcc) correlated positively with hyperopia ($r = 0.8$), and the difference between myopia and hyperopia was significant when compared to IOPcc ($P = 0.006$). Our study shows no significance ($r = 0.196$; $P = 0.845$). This could be explained as corneal compensated IOPcc is less affected by corneal biomechanical properties than other methods of tonometry and therefore have no relation with CCT³. Palkitsi et al. [6], found a significant difference in CH between low level myopes ($P = 0.023$) but not between high myopes and moderates ones ($P > 0.05$). In the myopia group in our study, it was found that CH had a significant correlation with IOPcc ($r = -0.640$, $P < 0.0001$) and was more significant than hyperopic group ($r = -0.457$; $P < 0.05$). This is shown on tables 4 and 5. Corneal

Table 4: Correlation between corneal biomechanical properties in myopes.

Parameters		CRF	CCT	IOPcc	IOPg
CH	r	.854	.504	-.640	-.081
	P	.000***	.000***	.000***	.480
CRF	r		.600	-.152	.447
	P		.000***	.184	.000***
CCT	r			-.091	.269
	P			.428	.017*
IOPcc	r				.814
	P				.000***

* Significant at 0.05 %
 ** Significant at 0.001 %
 *** Significant at 0.0001%

Table 5: Correlation between corneal biomechanical properties in hyperopes.

Parameters		CRF	CCT	IOPcc	IOPg
CH	r	.838	.651	-.457	.123
	P	.000***	.001***	.037	.595
CRF	r		.670	.102	.645
	P		.001***	.661	.002**
CCT	r			-.085	.308
	P			.714	.174
IOPcc	r				.826
	P				.000***

* Significant at 0.05 %
 ** Significant at 0.001 %
 *** Significant at 0.0001%

biomechanical properties can potentially affect the accuracy of the IOP measurements [16]. Longitudinal studies could be done using more advanced instruments available in the market to evaluate the deformation of the cornea. This represents an area for future research and could possibly assist and improve the outcomes of corneal refractive surgeries.

In conclusion, this study has demonstrated that patients with hyperopic spherical equivalent tend to have significantly higher corneal hysteresis than those with myopic spherical equivalent.

References

- Leonard A Levin, Siv F E Nilsson, James Ver Hoeve, Samuel Wu, Paul L Kaufman, et al. Adler's Physiology of the Eye. USA: Elsevier Health Sciences; 2011.
- Dupps WJ Jr, Wilson SE. Biomechanics and wound healing in the cornea. Exp Eye Res. 2006; 83: 709-720.
- Luce DA. Determining in vivo biomechanical properties of the cornea with an ocular response analyzer. J Cataract Refract Surg. 2005; 31: 156-162.
- Kotecha A. What biomechanical properties of the cornea are relevant for the clinician? Surv Ophthalmol. 2007; 52 Suppl 2: S109-114.
- Fontes BM, Ambrósio R Jr, Alonso RS, Jardim D, Velarde GC. Corneal biomechanical metrics in eyes with refraction of -19.00 to +9.00 D in healthy Brazilian patients. J Refract Surg. 2008; 24: 941-945.
- Athina Plakitsi, Clare O'Donnell, Marco A Miranda, W Neil Charman, Hema Radhakrishnan. Corneal biomechanical properties measured with the Ocular Response Analyser in a myopic population. Ophthalmic & Physiological Optics. 2011; 31: 404-412.
- Birgit Lackner, Gerald Schmidinger, Stefan Pieh, Martin A Funovics, Christian Skorpik. Repeatability and Reproducibility of Central Corneal Thickness Measurement With Pentacam, Orbscan, and Ultrasound. Optometry and Vision Science. 2005; 82: 892-899.
- Luce DA, Tylor D. Reichert Ocular Response Analyzer; Measures Corneal Biomechanical Properties and IOP; Provides New Indicators for corneal specialists and glaucoma management. Invest Ophthalmol Vis Sci. 2006.
- Shen M, Fan F, Xue A, Wang J, Zhou X. Biomechanical properties of the cornea in high myopia. Vision Res. 2008; 48: 2167-2171.
- Chang PY, Chang SW, Wang JY. Assessment of corneal biomechanical properties and intraocular pressure with the Ocular Response Analyzer in childhood myopia. Br J Ophthalmol. 2010; 94: 877-881.
- Song Y, Congdon N, Li L, Zhou Z, Choi K, et al. Corneal hysteresis and axial length among Chinese secondary school children: the Xichang Pediatric Refractive Error Study (X-PRES). Am J Ophthalmol. 2008; 145: 819-826.
- Kaushik Hegde, Rohit Shetty, Ajoy Vincent, Harsha K. Ocular Response Analyzer in Children. Cornea. 2010; 235-240.
- Radhakrishnan H, Miranda MA, O'Donnell C. Corneal biomechanical

- properties and their correlates with refractive error. *Clin Exp Optom*. 2012; 95: 12-18.
14. Laurence Lim, Gus Gazzard, Yiong-Huak Chan, Allan Fong, Aachal Kotecha, et al. Cornea Biomechanical Characteristics and Their Correlates with Refractive Error in Singaporean Children. *Investigative Ophthalmology & Visual Science*, 2008; 49: 3852-3857.
15. Shah S, Laiquzzaman M, Cunliffe I, Mantry S. The use of the Reichert ocular response analyser to establish the relationship between ocular hysteresis, corneal resistance factor and central corneal thickness in normal eyes. *Cont Lens Anterior Eye*. 2006; 29: 257-262.
16. Medeiros FA, Weinreb RN . Evaluation of the influence of corneal biomechanical properties on intraocular pressure measurements using the ocular response analyzer. *J Glaucoma*. 2006; 15: 364-370.