·Clinical Research·

Effect of biometric characteristics on biomechanical properties of the cornea in cataract patient

Xue-Fei Song [1,2], Achim Langenbucher [3], Zisis Gatzioufas [1], Berthold Seitz [1], Moatasem El-Husseiny [1]

[1]Department of Ophthalmology, Saarland University Medical Center, Homburg Saar 66424, Germany

[2]Department of Ophthalmology, Ninth People's Hospital, Shanghai Jiao Tong University, School of Medicine, Shanghai 200011, China

[3]Experimental Ophthalmology, Saarland University, Homburg Saar 66424, Germany

Correspondence to: Xue-Fei Song. Department of Ophthalmology, Saarland University Medical Center, Kirrberger Str 100, Homburg Saar 66424, Germany. 89215667@qq.com

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Abstract

• **AIM: To determine the impact of biometric characteristics on the biomechanical properties of the human cornea using the ocular response analyzer (ORA) and standard comprehensive ophthalmic examinations before and after standard phacoemulsification.**

• **METHODS: This study comprised 54 eyes with cataract with significant lens opacification in stages I or II that underwent phacoemulsification (2.8 mm incision). Corneal hysteresis (CH), corneal resistance factor (CRF), Goldmann-correlated intraocular pressure (IOPg), and corneal-compensated intraocular pressure (IOPcc) were measured by ORA preoperatively and at 1mo postoperatively. Biometric characteristics were derived from corneal topography [TMS-5, anterior equivalent (EQ_{TMS}) and cylindric (CYL_{TMS}) power], corneal tomography [Casia, anterior and posterior equivalent (EQ_{aCASIC}, EQ_{pCASIA}) and cylindric (CYL_{aCASIA}, CYL_{pCASIA}) power], keratometry [IOLMaster, anterior equivalent (EQ_{IOL}) and cylindric (CYL_{IOL}) power] and autorefractor [anterior equivalent (EQ_{AR})]. Results from ORA were analyzed and correlated with those from all other examinations taken at the same time point.**

• **RESULTS: Preoperatively, CH correlated with EQ_{pCASIA} and CYL_{pCASIA} only (P=0.001, P=0.002). Postoperatively, IOPg and IOPcc correlated with all equivalent powers (EQ_{TMS}, EQ_{IOL}, EQ_{AR}, EQ_{aCASIA} and EQ_{pCASIA}) (P=0.001, P=0.007, P=0.001, P=0.015, P=0.03 for IOPg and P<0.001, P=0.003, P<0.001, P=0.009, P=0.014 for IOPcc). CH correlated postoperatively with EQ_{aCASIA} and EQ_{pCASIC} only (P=0.021, P=0.022).**

• **CONCLUSION: Biometric characteristics may significantly affect biomechanical properties of the cornea in terms of CH, IOPcc and IOPg before, but even more after cataract surgery.**

• **KEYWORDS:** cataract surgery; biometric characteristics; biomechanical properties; ocular response analyzer; corneal tomography; correlation analysis

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INTRODUCTION

In addition to intraocular lens (IOL) implantation following cataract surgery, the alteration of corneal biomechanical characteristics was also believed to contribute to refractive changes [1]. Corneal hysteresis (CH), corneal resistance factor (CRF), corneal-compensated intraocular pressure (IOPcc), and Goldmann-correlated intraocular pressure (IOPg) are variables derived from ocular response analyzer (ORA, Reichert, NY, USA, software version 3) to assess corneal biomechanical characteristics[2].

In ORA examination, metamorphosis in human cornea resulting from energy accumulation, which postpone the applanation signal peaks in opposite directions, leads to an applanation pressure variance. Such difference in applanation pressures is defined as CH, and the mean value of both pressures was named IOPg [2]. From the manufacturer's instruction, CRF is an indicator of the unitary corneal resistance which could only be influenced by corneal elastic properties, and IOPcc is less influenced by corneal biomechanical properties by utilizing CH information[3].

Variables provided by ORA were accounted as reliable indices, though with some query and contradictions in intraocular pressure (IOP) examinations[1,3-8].

However, studies on biomechanical properties and biometric characteristics are mostly focusing on central corneal thickness (CCT)[3,8]. According to our knowledge, there are no studies in the scientific literature about a potential relationship between those biomechanical properties of the cornea and biometric characteristics obtained from standard comprehensive ophthalmic examinations before and after standard phacoemulsification.

The purpose of this study was to assess the potential impact of characteristics as determinant by corneal topography, tomography and keratometry analysis on biomechanical properties before and after standard cataract surgery.

SUBJECTS AND METHODS

Study Group and Protocol Fifty-four eyes were studied in the cross-sectional study, which underwent phacoemulsification (2.8 mm incision) from May 2012 to January 2013. All eyes studied were in stages I or II with visually significant lens opacification.

Ethics committee of Saarland University approved this study protocol, following the tenets of the Declaration of Helsiniki. All participants signed written informed consent forms with absolute comprehension of the study.

Inclusion Criteria Cataract eye aged between 40 and 80 with normal fundus, without corneal pathologies and oclular sugeries history.

Exclusion Criteria Astigmatism of more than 3.00 diopters (D). Any other ocular surgery needed beside phacoemulsification.

Surgical Technique All surgeries were performed by El-Husseiny M, using a retrobulbar anesthesia. Corneal incision of 2.8 mm was made by a corneal keratome. Ninety degree away from the main incision, two paracenteses less than 0.9 mm were performed with the corneal keratome. Healon ophthalmic viscosurgical device (OVD, Abbott Medical Optics, Illinois, USA) was injected in the anterior chamber. With a capsulorhexis forceps, capsulorhexis was performed. With balanced saline solution, hydrodissection and hydrodelineation were performed. By using the stop-and-chop technique from Alcon Infiniti (Alcon, Texas, USA), phacoemulsification was achieved. Healon was used again for IOL implantation, and then aspirated. After hydrating the incision, the wounds were tightly sealed. Topical ofloxacin 0.3% and prednisolone acetate 1% were routinely used after surgery.

Patient Examination Song XF performed ophthalmic examination on all patients, including slit lamp evaluation, posterior segment inspection, Snellen charts for visual acuity, ORA (Reichert, Inc., software version 3) for biomechanical characteristics, IOLMaster (Carl Zeiss Meditec) for biometry, EM-3000 (TOMEY corp.) for endothelium imaging, Topographic Modeling System 5 (TMS-5, TOMEY corp.) and CASIA (TOMEY corp.) for tomography.

Examinations were taken between 7 a.m. to 10 a.m. to minimize the diurnal fluctuation reported before[2].

All examinations were performed before surgery and 4wk after that, which would minimize biomechanical alteration caused by wound healing procedure.

Main Outcome Measures CH, CRF, IOPg, and IOPcc were measured with the ORA preoperatively and at 1mo postoperatively. Biometric characteristics were derived from corneal topography included: anterior equivalent (EQ_{TMS}) and cylindric (CYL_{TMS}) power. Those derived from corneal tomography included: anterior and posterior equivalent (EQ_{aCASIC}, EQ_{pCASIA}) and cylindric [anterior and posterior cylindric (CYL_{aCASIA}, CYL_{pCASIA})] power. Those derived from keratometry included: anterior equivalent (EQ_{IOL}) and cylindric (CYL_{IOL}) power. Anterior equivalent (EQ_{AR}) was derived from the autorefractor. Results from ORA were analyzed and correlated with those from all other examinations taken at same time point in a cross-sectional manner.

Statistical Analysis Statistical analysis was performed with SPSS (version 19.0 for Windows, SPSS, Inc.). Mean ± standard deviation (SD), range and median were calculated and expressed. To identify the significant biometric characteristics which could potentially affect the biomechanical properties before and after surgery, Pearson rank correlation coefficients r was used in a correlation analysis. Statistical significance was considered as a P-value less than 0.05.

RESULTS

At the preoperative examination stage, CH showed a moderate negative correlation with EQ_{pCASIA} and a moderate positive correlation with CYL_{pCASIA}. That means, that a flatter corneal back surface is associated with a higher CH. All other preoperatively measured biometric characteristics which were not significantly correlated with biomechanical properties are presented in Table 1.

The impact of biometric characteristics on biomechanical properties (postoperative) is shown in Table 2. At the postoperative examination stage, CH showed a mild positive correlation with EQ_{aCASIA} and a mild negative correlation with EQ_{pCASIA}. That means, that a steeper corneal front surface and a flatter corneal back surface are associated with a higher CH. Both IOPcc and IOPg showed a moderate negative correlation with EQ_{TMS}, EQ_{IOL}, EQ_{AR}, EQ_{aCASIA}, and a moderate positive correlation with EQ_{pCASIA}. That means, that steeper corneal front and back surfaces are associated with a higher IOP. All other postoperatively measured biometric characteristics which were not significantly correlated with biomechanical properties are presented in Table 2.

DISCUSSION

In this study, we assessed biomechanical properties before and after standard cataract surgery and correlated these values with biometric characteristics such as equivalent power and cylindric power of the cornea obtained by corneal topography, tomography, and keratometry.

The biomechanical properties are shown alongside with the biometric data in Table 1 for the preoperative and Table 2 for the postoperative situation.

Table 1 Impact of biometric characteristics on the preoperatively measured biomechanical properties

Biometrical impact (D)		CH	CRF	IOPcc	IOPg
EQ_{TMS}	*r*	0.033	0.088	0.103	0.065
	P	0.814	0.529	0.461	0.641
CYL_{TMS}	*r*	0.293	0.209	-0.099	-0.051
	P	0.031	0.129	0.477	0.716
EQ_{IOL}	*r*	0.215	0.052	-0.149	-0.155
	P	0.118	0.709	0.282	0.263
CYL_{IOL}	*r*	0.203	0.007	-0.243	-0.187
	P	0.140	0.962	0.077	0.177
EQ_{AR}	*r*	0.231	0.080	-0.140	-0.139
	P	0.092	0.567	0.312	0.317
EQ_{aCASIA}	*r*	0.201	0.114	-0.132	-0.064
	P	0.033	0.368	0.422	0.237
CYL_{aCASIA}	*r*	0.28	-0.128	-0.106	-0.157
	P	0.04	0.358	0.444	0.255
EQ_{pCASIA}	*r*	[1]-0.434	-0.213	0.181	0.189
	P	0.001	0.122	0.190	0.172
CYL_{pCASIA}	*r*	[1]0.419	0.248	-0.229	-0.128
	P	0.002	0.071	0.096	0.357

CH: Corneal hysteresis; CRF: Corneal resistance factor; IOPcc: Corneal compensated intraocular pressure; IOPg: Goldmann-correlated intraocular pressure; EQ_{TMS}: Average corneal power of the anterior surface (TMS-5); CYL_{TMS}: Astigmatism of the anterior surface (TMS-5); EQ_{IOL}: Average corneal power of the anterior surface (IOL Master); CYL_{IOL}: Astigmatism of the anterior surface (IOL Master); EQ_{AR}: Average corneal power of the anterior surface (Autoref K readings); EQ_{aCASIA}: Average corneal power of the anterior surface (CASIA); CYL_{aCASIA}: Astigmatism of the anterior surface (CASIA); EQ_{pCASIA}: Average corneal power of the posterior surface (CASIA); CYL_{pCASIA}: Astigmatism of the posterior surface (CASIA). [1]Significant values. [a]Moderate or strong statistically significant correlation.

Table 2 Impact of biometric characteristics on the 1mo postoperatively measured biomechanical properties

Biometrical impact (D)		CH	CRF	IOPcc	IOPg
EQ_{TMS}	*r*	-0.281	0.180	[1]-0.457[b]	[1]-0.447[b]
	P	0.038	0.188	<0.001	0.001
CYL_{TMS}	*r*	0.116	0.052	-0.086	-0.055
	P	0.397	0.708	0.532	0.687
EQ_{IOL}	*r*	0.248	-0.090	[1]-0.348[b]	[1]-0.326[a]
	P	0.068	0.514	0.009	0.015
CYL_{IOL}	*r*	0.179	0.120	-0.099	-0.043
	P	0.190	0.381	0.472	0.753
EQ_{AR}	*r*	0.273	-0.035	[1]-0.329[a]	[1]-0.311
	P	0.043	0.801	0.014	0.030
EQ_{aCASIA}	*r*	0.043	0.010	-0.042	-0.031
	P	0.021	0.624	0.003	0.007
CYL_{aCASIA}	*r*	0.055	0.058	-0.013	0.009
	P	0.690	0.673	0.926	0.948
EQ_{pCASIA}	*r*	[1]-0.307[a]	0.154	[1]0.454[b]	[1]0.436[b]
	P	0.022	0.262	<0.001	0.001
CYL_{pCASIA}	*r*	0.129	-0.100	-0.215	-0.213
	P	0.348	0.468	0.114	0.119

CH: Corneal hysteresis; CRF: Corneal resistance factor; IOPcc: Corneal compensated intraocular pressure; IOPg: Goldmann-correlated intraocular pressure; EQ_{TMS}: Average corneal power of the anterior surface (TMS-5); CYL_{TMS}: Astigmatism of the anterior surface (TMS-5); EQ_{IOL}: Average corneal power of the anterior surface (IOL Master); CYL_{IOL}: Astigmatism of the anterior surface (IOL Master); EQ_{AR}: Average corneal power of the anterior surface (Autoref K readings); EQ_{aCASIA}: Average corneal power of the anterior surface (CASIA); CYL_{aCASIA}: Astigmatism of the anterior surface (CASIA); EQ_{pCASIA}: Average corneal power of the posterior surface (CASIA); CYL_{pCASIA}: Astigmatism of the posterior surface (CASIA). [1]Significant values. [a,b]Mild/ moderate or strong statistically significant correlation.

According to the results of EQ_{pCASIA}, a flatter corneal back surface is associated with a higher CH preoperatively and, a steeper corneal back surface is associated with a higher IOP. Although a high correlation between curvatures of anterior and posterior corneal surface was found, calculation of the corneal power ignoring the posterior surface would underestimate the power reduction affect corneal refractive surgery[9-12]. For that reason, Langenbucher *et al*[13] evaluated the effect of a separate measurement of the anterior and posterior corneal surface to calculate the total refractive power of the cornea after myopic laser *in situ* keratomileusis. Eom *et al* [14] attempted to improve the Sanders-Retzlaff-Kraff (SRK)/T formula which is the most commonly used formula for IOL power calculation in the US, with corneal power specific constants depending on both, values of anterior and posterior surface data of the cornea. In addition, corneal power of the posterior surface was also reported to change in corneas of patients with type I and II diabetes mellitus [15]. Considering the data of previous studies and our result on EQ_{pCASIA} and biomechanical values, we conclude that, in a cataract surgery, information about the corneal power of the posterior surface may help to understand the unique indices provided by ORA (CH and IOPcc), which are related to the viscoelastic properties of the corneal tissue that can be attributed to the damping effects of the cornea[16].

From the results shown both in Tables 1 and 2, CH is the only ORA index correlated to biometric characteristics, both in the preoperative and postoperative situation. As an indication for viscous damping in the cornea, CH is related to the ability of the cornea to absorb and dissipate energy[2]. CH was only correlated with the corneal power of the anterior surface EQ_{aCASIA} among the four values from different devices that had been approved for interchangeable use in Wang *et al*'s [17] work. Results derived *via* CASIA, IOLMaster and TMS-5 also suggest that the interchangeable use of those data is possible (data not shown). But intercorrelation between CH and anterior corneal power was only moderate.

Theoretically, IOPcc is a pressure measurement that utilizes information considering CH providing an IOP value that is less affected by corneal properties [3], which may offer an attractive alternative to traditional IOP measurements including Goldmann applanation tonometry (GAT). Under normal IOP condition, corneal biomechanics play a major role for the stability of the globe, which were supported by the ORA values [18]. However, such difference did not appear in our present research. According to our results, IOPcc and IOPg showed a moderate negative correlation with corneal power values (EQ_{TMS}, EQ_{IOL}, EQ_{AR}, EQ_{aCASIA} and EQ_{pCASIA}), which are indices derived from different devices (TMS-5, IOL Master, Autoref K readings and CASIA). That means, that steeper corneal front and back surfaces are associated with a higher IOP. Unlike the mild intercorrelation of CH with anterior corneal power, both IOPcc and IOPg showed a moderate correlation with the biometric characteristics. *In vitro* studies on radial keratotomy focusing on corneal power and IOP obtained by GAT showed that, the effect of IOP on corneal power was weak and did not significantly influence the corneal shape flattening [19-21]. This is in contrast to our findings, but might be explained due to the differences in the measurement setup. We believe, that cataract surgeons should - from a biomechanical point of view - not restrict to tomography examinations, but also consider corneal compensated IOP especially in follow-up studies after cataract surgery.

Up to our knowledge, this is the first clinical study providing the impact of biometric characteristics on biomechanical properties before and after cataract surgery. The roles of topography and tomography values as well as biometric data on the biomechanical properties are discussed. In conclusion, in a patient for cataract surgery, information about the corneal power of the posterior surface may help to understand the unique indices provided by ORA (CH and IOPcc). Cataract surhageons should from a biomechanical point of view not restrict to tomography examinations, but also consider corneal compensated IOP especially in follow-up studies after cataract surgery. Further research work should be done with a larger clinical study population to further investigate correlations among biometric characteristics and biomechanical properties in cataract surgery more in detail.

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