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ORIGINAL PAPER

Effect of trabeculectomy and Ahmed glaucoma valve implantation surgery on corneal biomechanical changes

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Abstract
Purpose To evaluate alterations in corneal biomechanical properties before and 6 months after conventional trabeculectomy (TRAB) and Ahmed glaucoma valve (AGV) implantation.
Methods Thirty-nine eyes of 39 patients were evaluated retrospectively. Complete ophthalmological examinations including evaluation of corneal biomechanical properties using the Ocular Response Analyzer were performed before and after 6 months postoperatively. A mean of four measurements for corneal hysteresis (CH), corneal resistance factor (CRF), Goldmann correlated intraocular pressure (IOPg), and corneal compensated intraocular pressure (IOPcc) was recorded. The participants had undergone trabeculectomy or shunt surgery as the first surgical procedure for glaucoma treatment of uncontrolled IOP with maximum antiglaucoma eyedrops.
Results There were 20 eyes of 20 patients in trabeculectomy group and 19 eyes of 19 patients in AGV implantation group. There was no significant difference between two groups in terms of sex, age, eye laterality, lens status, antiglaucoma drug usage, preoperatively measured Mean Deviation of Humphrey Visual Field Analyzer, CH, CRF, IOPcc, and IOPg ($p > 0.05$). CH and CRF increased significantly after shunt surgery ($p < 0.001$). CH increased in trabeculectomy group postoperatively ($p < 0.001$); however, CRF showed a small amount of decrease, but this reduction was not statistically significant ($p > 0.05$). CH and CRF showed higher increase after AGV surgery than trabeculectomy surgery ($p < 0.05$). There was no significant correlation between IOP changes and CH–CRF changes in both TRAB and AGV groups ($p > 0.05$).
Conclusion According to our results, surgical technique differences may have an impact on postoperative corneal biomechanical outcomes. AGV surgery offers better corneal biomechanical results than standard trabeculectomy in 6-month follow-up.

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Keywords Ahmed glaucoma valve implantation · Cornea biomechanics · Glaucoma surgery · Ocular response analyzer · Trabeculectomy

Introduction

Elevated intraocular pressure (IOP) plays a crucial role in glaucomatous optic nerve damage [1]. IOP is an essential risk factor and parameter of which reduction can decrease the risk of glaucoma progression [2, 3]. It has been reported that corneal biomechanical properties, such as elasticity and viscosity, can be influential on corneal resistance; thus, these parameters affect the measured IOP by conventional Goldmann tonometer [4]. Earlier studies have shown that central corneal thickness (CCT) and other geometrical and material parameters related to corneal stiffness should be considered to produce IOP measurements that were free of the effects of biomechanics [5–8]. Also, it has been recognized that the rate of glaucoma progression is faster in eyes with lower corneal hysteresis (CH) and corneal resistance factor (CRF) [2]. Therefore, postoperative effects of surgical technique on corneal hysteresis of patients after glaucoma surgery are of great importance during follow-ups.

Various surgeries can remodel the biomechanics of the cornea. The effects of different surgeries such as cataract and refractive surgeries or keratoplasty have been studied [9–11]. Current reports on the effect of glaucoma surgery on corneal hysteresis are limited. Pakravan et al. [12] studied the effects of different surgeries of glaucoma and reported postoperative third months outcomes.

We aimed to evaluate alterations in corneal biomechanical properties before and 6 months after conventional trabeculectomy and Ahmed glaucoma valve (AGV) implantation.

Methods

Patients

Data from the charts of 39 subjects and 39 eyes presenting to Ankara Research and Training Hospital Glaucoma Department between May 2016 and March 2018 were evaluated retrospectively. Only one eye of each patient was included in the study. Primary open-angle and pseudoexfoliative glaucoma patients, which were unresponsive to medications, were included in the trabeculectomy group. Uveitic glaucoma with uncontrolled IOP was the indication for AGV implantation. Inactive uveitis for a minimum of 3 months before surgery were included in the study. Complete ophthalmological examinations including IOP measurement using a Goldmann applanation tonometer (Haag–Streit, Konig, Switzerland), Humphrey Field Analyzer (Zeiss, Germany), and evaluation of corneal biomechanical properties using the Ocular Response Analyzer (Reichert Inc., Depew, New York, USA) were performed. A mean of four measurements for CH, CRF, IOPg (Goldmann correlated intraocular pressure), and IOPcc (corneal compensated intraocular pressure) was recorded. Because of the potential confounding effect of diurnal IOP variation, all IOP measurements were obtained between 9:00 and 11:00 AM. All measurements were done just before surgery and 6 months postoperatively. Exclusion criteria were unsuccessful surgeries which required postoperative antiglaucomatous medications, lack of cooperation, the presence of corneal pathology (corneal edema, corneal scar, or band keratopathy), previous ocular surgeries other than cataract surgery, other ocular diseases such as congenital optic neuropathies and having a complicated glaucoma surgery. The participants had undergone trabeculectomy or shunt surgery as the first surgical procedure for glaucoma treatment of uncontrolled IOP with maximum antiglaucoma eyedrops. The decision of surgical technique was related to risk of postoperative complications that were foreseen in the first stage.

Ethical approval

The study protocol was approved by the Ethics Committee of Ankara Research and Training Hospital and was in accordance with the Declaration of Helsinki. The Ethics Committee did not require us to obtain patient consent as this study was done in a retrospective manner.

Surgical techniques

All surgeries were done by the same glaucoma specialist (U.E.), at the same center using the same technique. A fornix-based conjunctival flap and a halfthickness square-shaped scleral flap which is 4 × 4 mm in size in the superonasal quadrant were made. After formation of the scleral flap, Mitomycin-C (0.2 mg/ml) was applied by soaked sponge pieces for 3 min. A clear corneal block 1 × 2 mm in size was created using a 30° knife, and all obstructing remnants were cleared with Kelly punch. Iridectomy was performed with Vannas scissors. The scleral flap was closed with four 10-0 nylon sutures, and the conjunctiva was closed with 10-0 nylon wing sutures. In shunt surgery, after traction suture, conjunctival peritomy was performed. Two 7-0 vicryl sutures were used to suture the plate of the implant to the sclera at 9 mm posterior to the surgical limbus. AGV priming was done by gentle irrigation of the tube with a 27-gauge needle. After injection of viscoelastics into the anterior chamber by a clear corneal incision, the tube was trimmed to an appropriate length with the anterior bevel. The tube was entered into the anterior chamber through a sclerocorneal track with the aid of a 23-gauge needle. The tube was fixed to the sclera with a 10-0 nylon suture in the scleral opening and middle region of the tube. A quadrangular bovine pericardium was adjusted and covered over the exposed part of the tube and fixed with two 10-0 nylon sutures. Then, the conjunctiva was closed with 10-0 nylon running mattress sutures.

Statistical analysis

Descriptive statistics for each variable were calculated and presented as "Mean ± standard deviation" for continuous variables and "*n*, *n*%" for nominal variables. Student's *t* test was used to evaluate the statistical difference of age, Mean Deviation of Humphrey Visual Field Analyzer (MD), and CCT among surgical groups. Mann–Whitney *U* test was used to test the difference of antiglaucoma drugs of patients between surgical groups. Chi-square tests with Yates adjustment were used to examine the distribution of frequencies for categorical variables (sex, eye laterality, lens status). General linear model for repeated measures procedure was used to evaluate the difference between surgical procedures for preoperative and postoperative measurements. The model included "Surgery group" (TRAB + MMC vs AGV) and "time" (pre–postoperative) as the main effects and "Surgery group * time" interaction effects. Post hoc testing for significant interactions was performed using simple effect analysis with Bonferroni adjustment. Bonferroni corrected pairwise comparisons were performed for any significant main effect term in the model to evaluate differences among the levels within each factor when the interaction term was not significant. Pearson's correlation coefficient was used to demonstrate the relationship between changes in CH and CRF against IOPg and IOPcc. A probability value of less than 0.05 was considered significant, unless otherwise noted. SPSS 14.01 was used for statistical analysis.

Results

There were 20 eyes of 20 patients in trabeculectomy group and 19 eyes of 19 patients in AGV implantation group. Demographic characteristics, clinical findings, and preoperative ORA in both patient groups are shown in Table 1.

There was no significant difference between two groups in terms of sex, age, eye laterality, lens status (phakic, pseudophakic), CCT, median antiglaucoma drug usage, preoperatively measured MD, CH, CRF, IOPcc, and IOPg ($p > 0.05$) (Table 1).

CH and CRF values increased after shunt surgery, and this increase was statistically significant ($p < 0.001$). CH increased significantly in trabeculectomy group postoperatively ($p < 0.001$); however, CRF showed a small amount of decrease, but this reduction was not statistically significant ($p > 0.05$) (Table 2).

In postoperative comparison of two groups, CH and CRF showed higher increase after AGV surgery than trabeculectomy surgery. IOPcc and IOPg showed statistically similar decrease after both surgeries, and predicted surgical success was achieved in both groups (Table 2).

There was no significant correlation between IOPg–IOPcc changes and CH–CRF changes in both TRAB and AGV groups following the surgeries ($p > 0.05$ for all comparisons) (Table 3) (Figs. 1, 2).

Discussion

Corneal biomechanical properties can be very influential in various disciplines of ophthalmology, and their detailed assessments improve our understanding

Table 1 Baseline patient characteristics and preoperative ORA measurements of both groups

	TRAB + MMC			AGV			p value
	n (%)	Mean ± SD	Median (Min–Max)	n (%)	Mean ± SD	Median (Min–Max)	
Sex							
Female	11 (52.4%)			10 (47.6%)			0.998
Male	9 (50.00%)			9 (50.00%)			
Eye							
OD	14 (60.9%)			9 (39.1%)			0.267
OS	6 (37.5%)			10 (62.5%)			
Lens status							
Phakic	11 (55.0%)			9 (45.0%)			0.997
Pseudophakic	10 (50.0%)			10 (50.0%)			
Age (years)		64.15 ± 7.42			62.16 ± 6.96		0.393
MD		10.56 ± 1.27			10.62 ± 1.19		0.881
CCT		520.19 ± 20.45			519.74 ± 24.22		0.949
Antiglaucoma drugs			4 (3–4)			4 (3–4)	0.723

OD right eye, *OS* left eye, *CH* corneal hysteresis, *CRF* corneal resistance factor, *IOPcc* corneal compensated intraocular pressure, *IOPg* Goldmann correlated intraocular pressure, *MD* Mean Deviation of Humphrey Visual Field Analyzer, *CCT* central corneal thickness

Table 2 ORA parameters and their differences between preoperative postoperative sixth months

	Surgery				
	TRAB + MMC	AGV	p value		
	Mean ± SD	Mean ± SD	Surgery	Time	Surgery*Time
Pre-op CH	$7.38 \pm 1.75^{A,b}$	$6.67 \pm 1.05^{A,b}$	0.793	< 0.001	< 0.001
Post-op CH	$8.51 \pm 1.55^{B,a}$	$9.45 \pm 1.05^{A,a}$			
Pre-op CRF	$7.86 \pm 2.47^{A,a}$	$7 \pm 1.53^{A,b}$	0.333	< 0.001	< 0.001
Post-op CRF	$7.81 \pm 1.79^{B,a}$	$9.81 \pm 1.6^{A,a}$			
Pre-op IOPcc	24.53 ± 4.26^{a}	26.53 ± 2.84^{a}	0.104	< 0.001	0.988
Post-op IOPcc	14.56 ± 4.72^{b}	16.54 ± 3.19^{b}			
Pre-op IOPg	22.9 ± 3.93^{a}	24.83 ± 2.97^{a}	0.084	< 0.001	0.728
Post-op IOPg	13.07 ± 4.98^{b}	15.31 ± 3.4^{b}			

CH corneal hysteresis, *CRF* corneal resistance factor, *IOPcc* corneal compensated IOP, *IOPg* IOP measured by Goldmann applanation tonometer

^{A,B}Values in the same row with different superscripts show the statistical difference for each ORA parameters

^{a,b}Values in the same column with different superscripts show the statistical difference for each ORA parameters

Table 3 Correlation between CH and CRF against IOPg and IOPcc for both groups

		IOPg change	IOPcc change
TRAB			
CH change	*r*	0.051	− 0.251
	P	0.826	0.273
CRF change	*r*	0.206	0.199
	P	0.371	0.387
AGV			
CH change	*r*	0.18	− 0.031
	P	0.462	0.9
CRF change	*r*	0.388	0.111
	P	0.101	0.651

Trab trabeculectomy, *AGV* Ahmed glaucoma valve, *CH* corneal hysteresis, *CRF* corneal resistance factor, *IOPcc* corneal compensated intraocular pressure, *IOPg* Goldmann correlated intraocular pressure

of pathological alterations in the cornea [9]. It has been shown that CH and CRF were lower in primary open-angle and pseudoexfoliation glaucoma compared to healthy people [13]. However, the influence of intraocular surgery is not reported in detail, especially in glaucoma. In this study, we evaluated the changes in corneal biomechanics after two most common glaucoma surgeries. We found that shunt surgery provided more increase in CH and CRF than gold standard trabeculectomy in postoperative 6 month. Besides effective IOP reduction impact, this study was novel in its assessment of another important outcome of shunt surgery on human cornea.

Pakravan et al. examined corneal biomechanical alterations after various glaucoma surgeries including trabeculectomy, phacotrabeculectomy, and Ahmed glaucoma valve, and only phacoemulsification surgery as the control group. In this prospective report, ORA was measured before and 3 months after the surgeries. CH and CRF increased in trabeculectomy, phacotrabeculectomy, and Ahmed valve surgeries 3 months after surgery ($p < 0.001$, for all glaucoma surgeries). However, there were no statistically significant differences in CH and CRF in patients who underwent phacoemulsification [12]. Although significant outcomes were obtained within groups pre and postoperatively, comparative statistics between groups have not been widely reported. Our results showed better corneal outcomes in AGV surgery than trabeculectomy.

Lower values of CH have already shown to be correlated with worse visual fields in glaucoma patients [14, 15]. Additionally, Hussnain et al. reported that CH increases with the use of topical prostaglandins and decreases with progression in

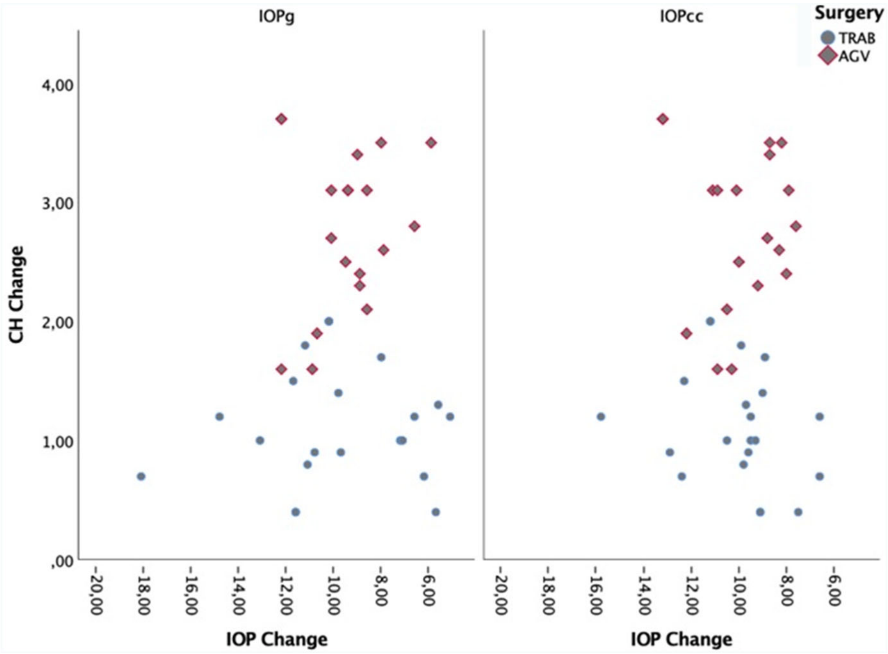

Fig. 1 Scatter plot demonstrating the correlation between changes in corneal hysteresis against postoperative intraocular pressure reduction in both surgery groups

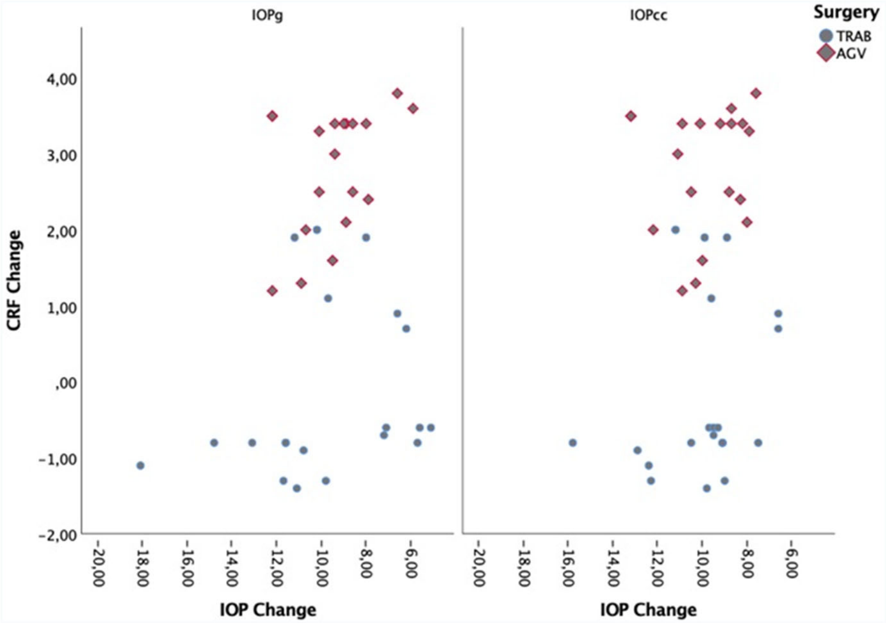

Fig. 2 Scatter plot demonstrating the correlation between changes in corneal resistance factor against postoperative intraocular pressure reduction in both surgery groups

open-angle glaucoma [16]. Therefore, postoperative higher values of these parameters could offer better prognosis, regarding glaucoma patients. Casado et al. showed higher values of CH and CRF in nonpenetrating deep sclerectomy surgery than trabeculectomy surgery [17]. Iordanidou et al. reported that this CH increase after deep sclerectomy does not depend on the reduction in IOP [18]. Similar to the previous report, our outcomes of correlation analysis between IOP reduction and CH–CRF increase did not show a significant relationship in both trabeculectomy and shunt surgery. Consequently, we hypothesized that surgical technique differences may have an impact on postoperative corneal biomechanical outcomes. Trabeculectomy and shunt surgery differ in part of the mainstream of the cornea. In trabeculectomy, a quadrangular resection of a block along the macroperforation and the number of sutures used in the scleral flap may have a significant effect on biomechanics. In AGV surgery, anterior chamber is entered 1–3 mm posteriorly to the corneoscleral limbus with a 22–23G needle.

Our study showed that the biomechanical characteristics of cornea indicate several changes following glaucoma surgeries. These alterations reflect the dynamic nature of these parameters. Concerning the effects of corneal biomechanical characteristics on routine IOP measurements, determining diagnosis, prognosis, and the probability of response to treatment, our understanding on biomechanical changes after glaucoma surgery can help us better know the pathophysiology of glaucoma diseases and make the right decisions for follow-up of patients.

This study presents some limitations. First, primary open-angle glaucoma and pseudoexfoliation glaucoma patients were included in trabeculectomy group and uveitic glaucoma patients were included in AGV group. Although corneal biomechanic changes have not been reported in uveitic glaucomas, clinical outcome of surgery in pseudoexfoliation glaucoma is different from primary open-angle glaucoma [19]. A number of subjects were limited, and future studies with a higher number of participants can provide more precise outcomes.

To our knowledge, this is the first study to compare corneal biomechanics in trabeculectomy and AGV at postoperative 6 months. Nevertheless, additional studies are still necessary to completely confirm the differences between both surgeries.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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