

Central corneal thickness and corneal volume changes in eyes with and without pseudoexfoliation after uneventful phacoemulsification

Yonca Asfuroglu  · Ozlem Evren Kemer

Received: 16 July 2017 / Accepted: 11 December 2017 / Published online: 19 December 2017
© Springer Science+Business Media B.V., part of Springer Nature 2017

Abstract

Aim To investigate the effects of uneventful phacoemulsification on central corneal thickness (CCT) and corneal volume (CV) in pseudoexfoliative eyes during a 3 months postoperative period and compare these changes to eyes without pseudoexfoliation (PEX) syndrome. Another purpose of this study was to compare the CCT measurements done by ultrasound pachymetry (UP) with those done by the Oculus Pentacam.

Material and method A total of 42 eyes of 42 consecutive patients with cataracts and PEX syndrome that underwent uneventful phacoemulsification were enrolled in this prospective study. A control group of 42 eyes of 42 patients with cataracts/without PEX was employed for comparison. CV and CCT measurements were obtained preoperatively and at 1 and 3 months postoperatively with the Pentacam. CCT values were also measured with UP. *T* test and Wilcoxon sign test were used to compare the variables.

Results The mean age of the patients was 72.1 ± 8.3 and 66.6 ± 9.6 years in PEX and non-PEX group, respectively. In both groups, there were no significant differences between preoperative and postoperative CV (Fig. 1), CCT by the Pentacam (Fig. 2) and CCT by UP (Fig. 3) values ($p > 0.05$). CCT measurements obtained by two devices were also similar, and there were no statistically significant differences ($p > 0.05$). Changes in CV and CCT remained stable at 3 months postoperatively.

Conclusion Eyes with and without PEX syndrome exhibit similar corneal features before and after phacoemulsification. A surgery in early stages of cataracts in PEX syndrome, not only provides a non-complicated surgery, but also leads to a less damaged cornea similar to eyes without PEX.

Keywords Central corneal thickness · Corneal volume · Phacoemulsification · Pseudoexfoliation · The Pentacam

Y. Asfuroglu (✉)
Osmancik State Hospital, Omer Derindere Boulevard
Number: 105, 19500 Osmancik, Corum, Turkey
e-mail: yncatalay@gmail.com

O. E. Kemer
University of Health Sciences, Numune Education and
Research Hospital, Talatpasa Boulevard Number: 44,
06230 Altindag, Ankara, Turkey

Introduction

Pseudoexfoliation syndrome is a common age-related disorder that is characterized by the development of abnormal fibrillar material in intra- and extraocular tissues [1–3]. Presence of pseudoexfoliative material in anterior segment is strongly related to intraocular

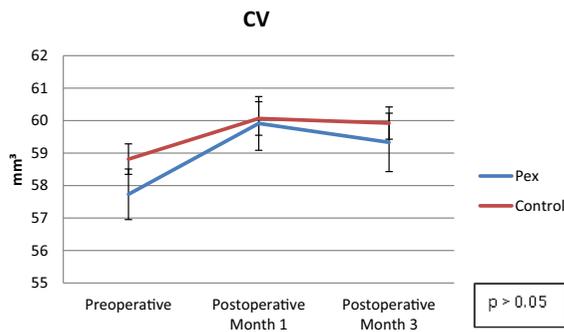


Fig. 1 Preoperative, 1st and 3rd month postoperative measurements of 10 mm corneal volume (CV). Pex: $p = 0.16$ /Control: $p = 0.15$, *Pex and control group: ANOVA test

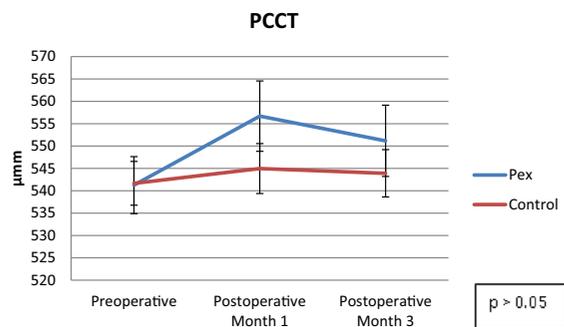


Fig. 2 Preoperative, 1st and 3rd month postoperative measurements of central corneal thickness by Pentacam (PCCT), Pex: $p = 0.41$ /Control: $p = 0.9$, *Pex group: Kruskal–Wallis test, Control group: ANOVA test

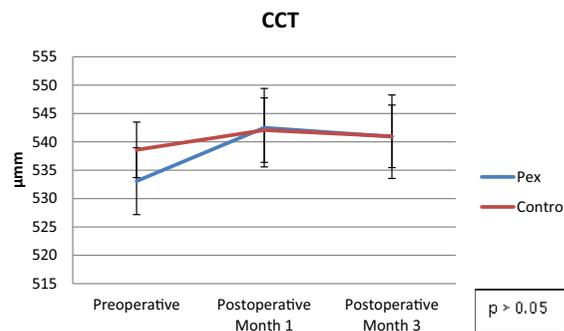


Fig. 3 Preoperative, 1st and 3rd month postoperative measurements of central corneal thickness by ultrasonic pachymetry (CCT), Pex: $p = 0.57$ /Control: $p = 0.77$, *Pex group: ANOVA test, Control group: Kruskal–Wallis test

complications such as poor pupillary dilatation, phacodonesis, zonular rupture and corneal endothelial decompensation [4–6]. Studies with specular microscopy report that in patients with PEX, corneal

endothelium shows different features like reduced cell density (800–1500 cell/mm²), higher variation in cell size and lower percentage of hexagonal cells [1, 7]. In clinical practice, melanin deposition in corneal endothelium, retrocorneal opacities and an irregular Descemet membrane could be detected [7]. Cornea may be more susceptible to the effects of phacoemulsification surgery in the presence of pseudoexfoliative endotheliopathy [1, 7].

CCT measurement is an important step for pseudoexfoliative eyes that are about to undergo phacoemulsification. Besides traditional ultrasound pachymetry, the Pentacam (Oculus Inc., Wetzlar, Germany), with a rotating Scheimpflug camera, captures images of the anterior segment of the eye and it is another quantitative method to evaluate CCT [8, 9]. The Pentacam also gives us valuable information about corneal volume which is a noninvasive method to evaluate corneal endothelium. 3.0, 5.0, 7.0 and 10.0 mm CV measurements could be obtained from the device [10, 11].

In this prospective study, we aimed to investigate the effects of uneventful phacoemulsification on CCT and CV (10 mm) in pseudoexfoliative eyes during a 3 months postoperative period and compare these changes to eyes without PEX. Another purpose of this study was to compare the CCT measurements done by ultrasound pachymetry (Alcon, 40 MHz) with those done by the Oculus Pentacam.

Materials and Methods

This study was conducted in Ankara Numune Education and Research Hospital between April 2014 and February 2015. A total of 42 eyes with cataracts of 42 consecutive patients (22 females, 20 males) with PEX syndrome that underwent uneventful phacoemulsification were enrolled in this prospective study. A control group of 42 eyes of 42 patients (24 females, 18 males) with cataracts/without PEX was employed for comparison. Patients with any type of glaucoma, history of previous ocular surgery or trauma, angle closure, phacodonesis, co-existing ocular disease were excluded. The study protocol adhered to the tenets of the Declaration of Helsinki. Informed consent was obtained from each patient prior to any procedure.

PEX syndrome was identified when presence of PEX material was noted on lens capsule, iris or corneal

endothelium with repeated in-office IOP measurements < 21 mmHg, no evidence of glaucomatous optic neuropathy and absence of any perimetric defect. Control subjects were individuals without evidence of pseudoexfoliation deposits on anterior segment structures, who had repeated IOP readings of < 21 mmHg, no evidence of glaucomatous optic neuropathy and absence of any perimetric defect. In both groups, the evaluation of optic disk and retinal nerve fiber layer (RNFL) was made with optical coherence tomography (Zeiss Stratus; Carl Zeiss, Inc., NY, USA). All patients have a similar degree of nuclear opacification (NO3, NO4) and cortical opacification (CO2, CO3) according to The Lens Opacities Classification System III (LOCS III).

Pre- and postoperatively all patients underwent corrected visual acuity assessment using the Snellen chart, anterior and posterior segment examination, IOP measurement by Goldmann applanation tonometry (pachymetry corrected), preoperative gonioscopy using a Goldmann three-mirror lens and optic disk evaluation.

CCT measurements were performed by ultrasonic pachymetry and the Oculus Pentacam. Ten millimeter CV was also evaluated using the Pentacam.

Pentacam measurements were taken in a room under standard dim illumination without pupil dilation. The Oculus Pentacam uses a rotating Scheimpflug camera and a monochromatic slit-light source that together rotate 360° around the optical axis of the eye. The system acquires 25 images of the anterior segment of the eye.

All surgeries were performed by one surgeon (OEK) under topical or sub-tenon anesthesia, using a superotemporal clear corneal incision. A continuous curvilinear capsulorhexis size of 5.5–6 mm was ensured. Intracameral adrenalin (%0.0001) was used for pupil dilation for all patients. Following hydrodissection, the nucleus was emulsified using the stop and chop technique, using Alcon Ozil IP system. For the stop and chop technique, torsional mode was adjusted as follows: linear torsional amplitude 85% continuous mode, vacuum limit 330 mm Hg, aspiration rate 32 ml/min and bottle height at 90 cm. Cortical clean up was performed, and a one-piece foldable hydrophobic acrylic intraocular lens (Acrysof SA60AT, Alcon) was inserted. The incision was closed with stromal hydration.

Postoperatively, patients were prescribed topical antibiotics four times daily for a week and steroids six times daily for 2 weeks. Topical steroids tapered during one-month period. At postoperative 1st and 3rd month, CCT and CV measurements were repeated and recorded in both groups.

Statistical analysis was performed with Eviews. Numerical variants were reported as means ± Standard deviations (SD). While ANOVA and Kruskal–Wallis tests were used to compare the variables in pre and postoperative period in one group, *t* test and Wilcoxon Sign test were used to compare these values between two groups. CCT measurements obtained by UP and the Pentacam were also compared using *t* test. A value of $p < 0.05$ was considered statistically significant.

Results

The mean age of the patients was 72.1 ± 8.3 and 66.6 ± 9.6 years in PEX and control group respectively. While in PEX group, there were 22 females and 20 males; control group had 24 females and 18 males. There were no significant differences in age and sex distribution in both groups ($p > 0.05$). Tables 1, 2 and 3 show the mean CV, PCCT (by the Oculus Pentacam) and CCT (by UP) values in both groups preoperatively and at postoperative month 1 and 3. In both groups, there were no significant differences between preoperative and postoperative CV, (Fig. 1), PCCT (Fig. 2) and CCT (Fig. 3) values ($p > 0.05$). When two groups were compared with each other, changes in these parameters were similar and not statistically significant ($p > 0.05$). CCT measurements obtained by two devices were also similar, and there were no statistically significant differences ($p > 0.05$). Changes in

Table 1 Pre- and postoperative CV parameters

CV (mm ³)	PEX group	Control group
Preoperative	57.73 ± 5.04	58.81 ± 3.04
Postoperative month 1	59.91 ± 5.36	60.07 ± 3.35
Postoperative month 3	59.33 ± 5.83	59.92 ± 3.22

Mean ± standard deviation. CV Corneal volume

Pex: $p = 0.16$ /control: $p = 0.15$

Table 2 Pre- and postoperative PCCT parameters

PCCT (μmm)	PEX group	Control group
Preoperative	541.26 \pm 41.28	541.67 \pm 31.70
Postoperative month 1	556.69 \pm 51.01	544.98 \pm 36.20
Postoperative month 3	551.17 \pm 51.62	543.90 \pm 34.30

Mean \pm standard deviation, PCCT central corneal thickness by Pentacam

PEX: $p = 0.41$ /control: $p = 0.9$

Table 3 Pre- and postoperative CCT parameters

CCT (μmm)	PEX group	Control group
Preoperative	533.07 \pm 38.21	538.60 \pm 31.69
Postoperative month 1	542.50 \pm 44.85	542.07 \pm 36.80
Postoperative month 3	540.90 \pm 47.67	540.98 \pm 35.72

Mean \pm standard deviation, CCT central corneal thickness by ultrasonic pachymetry

PEX: $p = 0.57$ /control: $p = 0.77$

CV, PCCT and CCT remained stable at 3 months postoperatively.

Discussion

Corneal volume and central corneal thickness could be considered as indirect indicators of corneal endothelial function. Corneal endothelial cells are assessed by specular microscopy although it is difficult to evaluate all the corneal layers other than the central 1 mm² [12, 13]. Scheimpflug Pentacam calculates 3, 5, 7, 10 mm³ CV and gives us information about the entire cornea [11, 14]. In a Pentacam study, Doganay [15] et al. evaluated CV in PEX syndrome, PEX glaucoma and control group and found no statistical difference. Many studies showed that after phacoemulsification, due to endothelial damage, corneal volume increases and swelling of these cells could result in corneal edema in PEX and non-PEX eyes [16, 17]. In two different studies, Suzuki et al. [14, 18] reported that 1 and 3 months after surgery, 10.0 mm CV remained significantly higher than preoperatively. In another Scheimpflug study, it was shown that, while endothelial cell density measured by specular microscopy remained stable, 10 mm CV rose significantly [19].

In our study, we evaluated 10 mm CV with the Pentacam and these values were similar in both groups preoperatively. Despite the volumetric rise, there were no significant differences between preoperative and postoperative 1 and 3 month CV values in PEX and control group ($p > 0.05$). As we only included early stages of cataracts to this study, corneal endothelial swelling caused by phacoemulsification may not have lasted for a month. In PEX group, because of the fact that we excluded patients with phacodonesis and angle closure; damage caused by phacoemulsification might have been reduced.

Studies with specular microscopy show corneal endothelial changes including decreased cell density, higher coefficient of variation in cell size, and lower percentage of hexagonal cells in PEX [1]. On the other hand, there are different studies about the CCT measurements in PEX. While some studies claim that in PEX, CCT values are significantly lower [20–22] than those in non-PEX eyes; many writers report that there is no significant difference in CCT between these eyes [15, 23].

In patients with pseudoexfoliative keratopathy, corneal endothelial cells could easily be damaged during phacoemulsification and this could result in corneal decompensation [7, 24]. While de Freitas Valbon et al. [25] showed no significant change in non-PEX eyes 1 month after phacoemulsification, Hayashi et al. [16] reported a transient increase in CCT in eyes with PEX compared to non-PEX eyes. Demircan et al. [26] also found that at 1 and 7 day after phacoemulsification, percentage change in CCT was significantly higher in PEX group than that in the control group.

In our study, we did not find any significant differences in preoperative CCT values between PEX and non-PEX eyes. At 1 and 3 months after surgery, despite the numerical rise, changes in CCT measurements were not statistically significant in both groups. It is possible that corneal endothelial changes caused by surgical trauma are apparent during the early stages of the postoperative period. In our study group, absence of mature cataracts and zonular laxity in PEX gives us similar results with non-PEX eyes after phacoemulsification. This similarity may also be caused by the lack of high ultrasonic power and prolonged surgical manipulation which are usually needed in late stages of PEX.

CCT values taken by the Pentacam consist of the area between corneal epithelium and corneal endothelium. Pre-corneal tear film is not included. Central corneal thickness on pupil center and apex, thinnest corneal area, could also be obtained from the device [10, 11]. Gao [27] et al. suggested that topical anesthetic drops increase CCT up to 63% so UP measurements are higher than those evaluated by the optical systems, but there are studies claiming that UP probe could damage the corneal epithelium so calculated CCT values remained lower [28, 29]. Many studies showed that the CCT measurements taken by the Pentacam and UP were correlated [9, 30]. Similar to these studies, we found that CCT values obtained by the Pentacam and UP were similar preoperatively and postoperatively in PEX and non-PEX eyes. At 1 and 3 months after surgery, despite CCT measurements taken by the Pentacam were slightly higher than those taken by UP, this was not statistically significant. According to our study, it could also be suggested that CCT measurements taken by Pentacam and UP are highly correlated in PEX and non-PEX eyes both preoperatively and postoperatively.

There were some limitations in this study. BSS volume, energy used for phacoemulsification and surgical time for each patient were not recorded. However, since our study and control group comprised of early stages of cataracts and complicated cases were not involved, it could be assumed that these parameters did not significantly affect our results. In this study, we focused on the short-term changes in CV and CCT after uneventful phacoemulsification in PEX and non-PEX patients and we observed that PEX and non-PEX eyes exhibit similar corneal features before and after phacoemulsification. As our study group did not include late pseudoexfoliative cases with zonular laxity, mature cataracts or angle closure, surgery led to clear corneas similar to non-PEX eyes. A surgery in early stages of cataracts in PEX not only provides a non-complicated surgery, but also leads to a less damaged cornea similar to eyes without PEX. However, long-term follow-up studies in pseudophakic PEX patients are needed to support our study.

Compliance with ethical standards

Conflict of interest All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership,

employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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 (name the institution/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.

References

- Quiroga L, Lansingh VC, Samudio M, Peña FY, Carter MJ (2010) Characteristics of the corneal endothelium and pseudoexfoliation syndrome in patients with senile cataract. *Clin Experiment Ophthalmol*. 38(5):449–455
- Schlötzer-Schrehardt U, Naumann GO (2006) Ocular and systemic pseudoexfoliation syndrome. *Am J Ophthalmol* 141(5):921–937
- Sein J, Galor A, Sheth A, Kruh J, Pasquale LR, Karp CL (2013) Exfoliation syndrome: new genetic and pathophysiologic insights. *Curr Opin Ophthalmol* 24(2):167–174
- Belovay GW, Varma DK, Ahmed II (2010) Cataract surgery in pseudoexfoliation syndrome. *Curr Opin Ophthalmol* 21(1):25–34
- Katz LJ, Zangalli C, Clifford R, Leiby B (2013) Combined cataract and glaucoma surgery: the effect of pupil enlargement on surgical outcomes (an American Ophthalmological Society thesis). *Trans Am Ophthalmol Soc* 111:155–168
- Shingleton BJ, Crandall AS, Ahmed II (2009) Pseudoexfoliation and the cataract surgeon: preoperative, intraoperative, and postoperative issues related to intraocular pressure, cataract, and intraocular lenses. *J Cataract Refract Surg* 35(6):1101–1120
- Naumann GOH, Schlötzer-Schrehardt U (2000) Keratopathy in pseudoexfoliation syndrome as a cause of corneal endothelial decompensation: a clinicopathologic study. *Ophthalmology* 107:1111–1124
- Rabsilber TM, Khoramnia R, Auffarth GU (2006) Anterior chamber measurements using Pentacam rotating Scheimpflug camera. *J Cataract Refract Surg* 32:456–459
- Barkana Y, Gerber Y, Elbaz U, Schwartz S, Ken-Dror G, Avni I et al (2005) Central corneal thickness measurement with the Pentacam Scheimpflug system, optical low coherence reflectometry pachymeter, and ultrasound pachymetry. *J Cataract Refract Surg* 31:1729–1735
- Rajeev J, Grewal SPS (2009) Pentacam: principle and clinical applications. *J Curr Glaucoma Pract* 3(2):20–32
- Grewal SPS (2001) Evaluation of anterior segment pathologies using pentacam. *Highlights Ophthalmol* 36(1):17–20

12. Bourne WM, Kaufman HE (1976) Specular microscopy of human corneal endothelium in vivo. *Am J Ophthalmol* 81:319–323
13. Laing RA, Sandstrom MM, Leibowitz HM (1979) Clinical specular microscopy. II. Qualitative evaluation of corneal endothelial photomicrographs. *Arch Ophthalmol* 97:1720–1725
14. Suzuki H, Oki K, Takahashi K, Shiwa T, Takahashi H (2007) Functional evaluation of corneal endothelium by combined measurement of corneal volume alteration and cell density after phacoemulsification. *J Cataract Refract Surg* 33:2077–2082
15. Doganay S, Tasar A, Çankaya C, Fırat PG, Yologlu S (2012) Evaluation of Pentacam-Scheimpflug imaging of anterior segment parameters in patients with pseudoexfoliation syndrome and pseudoexfoliative glaucoma. *Clin Exp Optom*. 95:218–222
16. Hayashi K, Manabe S, Yoshimura K, Kondo H (2013) Corneal endothelial damage after cataract surgery in eyes with pseudoexfoliation syndrome. *J Cataract Refract Surg* 39(6):881–887
17. Wong MM, Shukla AN, Munir WM (2014) Correlation of corneal thickness and volume with intraoperative phacoemulsification parameters using Scheimpflug imaging and optical coherence tomography. *J Cataract Refract Surg* 40(12):2067–2075
18. Suzuki H, Takahashi H, Hori J, Hiraoka M, Igarashi T, Shiwa T (2006) Phacoemulsification associated corneal damage evaluated by corneal volume. *Am J Ophthalmol* 142(3):525–528
19. Jun YL, Kim JY, Joo CK (2011) Early changes in corneal edema following torsional phacoemulsification using anterior segment optical coherence tomography and Scheimpflug photography. *Jpn J Ophthalmol* 55:196–204
20. Özcürü F, Aydın S, Dayanir V (2011) Central corneal thickness and corneal curvature in pseudoexfoliation syndrome with and without glaucoma. *J Glaucoma* 20:410–413
21. Kırgız A, Akdemir MO, Kaldırım H et al (2014) Psödoeksfoliasyon Sendromlu Olguların Santral korneal Kalınlıklarının Normal Bireylerle Karşılaştırılması. *İstanbul Med J* 15:32–34
22. Tomaszewski BT, Zaleska R, Mariak Z (2014) Evaluation of the endothelial cell density and the central corneal thickness in pseudoexfoliation syndrome. *J Ophthalmol* 2014:123683
23. Acar BT, Buttanrı İB, Sevim MŞ, Esen D, Acar S (2010) Evaluation of anterior segment parameters in pseudoexfoliation syndrome patients. *Turk J Ophthalmol* 40:217–221
24. Ringvold A (1994) Corneal endothelial involvement in pseudoexfoliation syndrome. *Arch Ophthalmol* 112:297–298
25. de Freitas Valbon B, Ventura MP, da Silva RS, Canedo AL, Velarde GC, Ambrósio R Jr (2012) Central corneal thickness and biomechanical changes after clear corneal phacoemulsification. *J Refract Surg* 28(3):215–219
26. Demircan S, Atas M, Yurtsever Y (2015) Effect of torsional mode phacoemulsification on cornea in eyes with/without pseudoexfoliation. *Int J Ophthalmol* 8(2):281–287
27. Gao L, Fan H, Cheng AC, Wang Z, Lam DS (2006) The effects of eye drops on corneal thickness in adult myopia. *Cornea* 25(4):404–407
28. Kim HY, Budenz DL, Lee PS, Feuer WJ, Barton K (2008) Comparison of central corneal thickness using anterior segment optical coherence tomography vs ultrasound pachymetry. *Am J Ophthalmol* 145(2):228–232
29. Uçakhan OO, Ozkan M, Kanpolat A (2006) Corneal thickness measurements in normal and keratoconic eyes: pentacam comprehensive eye scanner versus noncontact specular microscopy and ultrasound pachymetry. *J Cataract Refract Surg* 32(6):970–977
30. Rashid RF, Farhood QK (2016) Measurement of central corneal thickness by ultrasonic pachymeter and oculus pentacam in patients with well-controlled glaucoma: hospital-based comparative study. *Clin Ophthalmol* 10:359–364