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The Effect of Pupil Dilation on Ocular Biometry Measurements in the Senile Cataractous Eyes

Senil Kataraktlı Gözlerde Pupil Dilatasyonunun Oküler Biyometri Ölçümlerine Etkisi

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ABSTRACT

Objective: The study aimed to evaluate the effect of cycloplegia on the ocular biometric parameters and intraocular lens (IOL) power calculated by Sanders–Retzlaff–Kraff/Theoretical (SRK/T) formula in the cataractous eyes.

Materials and Methods: This cross-sectional study included 68 senile cataractous eyes of 68 patients scheduled to undergo cataract surgery. Measurements of anterior chamber depth (ACD), axial length (AL), white-to-white (WtW) diameter, keratometry (K1, K2, Kmean), central corneal thickness (CCT), and pupil size (PS) were obtained with AL-Scan (Nidek Co., Ltd, Gamagori, Japan) before and after cycloplegia. The SRK/T formula was used to calculate IOL power with target refraction of 0 D. Cycloplegia induced by cyclopentolate hydrochloride %1.

Results: The mean age of the patients was 70.60±4.07 years (range 65 to 80). A significant increase was observed in ACD after cycloplegia ($p< 0.001$). There was no statistically significant difference between pre-dilation and post-dilation AL, WtW, CCT, K1, K2, Kmean, and IOL power readings ($p> 0.05$). Two cases observed a decrease above 0.5 D of IOL power after cycloplegia.

Conclusions: Cycloplegia induced by cyclopentolate hydrochloride %1 does not affect the measurement of the AL, WtW, CCT, keratometry, and SRK/T calculated IOL power except ACD in senile cataractous eyes.

Keywords: AL-Scan, axial length, cycloplegia, IOL power, senile cataract

ÖZ

Amaç: Çalışmada, kataraktlı gözlerde siklopleji̇nin oküler biyometrik parametrelere ve Sanders-Retzlaff-Kraff/teorik (SRK/T) formülü ile hesaplanan göz içi lens (GİL) gücüne etkisini değerlendirmek amaçlanmıştır.

Materyal ve Metot: Bu kesitsel çalışmaya, katarakt cerrahisi planlanan 68 senil kataraktlı hastanın 68 gözü dahil edildi. Siklopleji öncesi ve sonrası AL-Scan (Nidek Co. Ltd, Gamagori, Japonya) ile ön kamara derinliği (ÖKD), aksiyel uzunluk (AU), beyazdan beyaza (BB) çap, keratometri (K1, K2, K ortalama), merkezi kornea kalınlığı (MKK) ve pupil çapı (PÇ) ölçüldü. Göz içi lensi gücü, hedef refraksiyon 0 olacak şekilde SRK/T formülüne göre hesaplandı. Siklopleji için %1'lik siklopentolat hidroklorür kullanıldı.

Bulgular: Hastaların yaş ortalaması 70,60±4,07 yıl (65-80) idi. Siklopleji sonrası ÖKD'de anlamlı bir artış izlendi ($p< 0,001$). Dilatasyon öncesi ve sonrası AU, BB, MKK, K1, K2, Kortalama ve GİL gücü değerleri arasında istatistiksel olarak anlamlı fark yoktu ($p> 0,05$). Siklopleji sonrası iki olguda GİL gücünde 0,5 D'nin üzerinde bir azalma gözlemlendi.

Sonuç: Senil kataraktlı gözlerde %1'lik siklopentolat hidroklorürün neden olduğu siklopleji SRK/T formülüyle hesaplanan ortalama GİL gücünü etkilememektedir.

Anahtar Kelimeler: Aksiyel uzunluk, AL-Scan, GİL gücü, senil katarakt, siklopleji

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INTRODUCTION

Cataract surgery is one of the most common ophthalmic surgeries worldwide and is considered one of the refractive surgeries. Postoperative visual and refractive expectations of the patients have increased due to developments of small incision surgical techniques and intraocular lens (IOL) technology. Accurate ocular biometry and precise calculation of targeted postoperative results are required to obtain satisfying results in cataract surgery. The rates of errors in IOL power calculation are due to axial length (AL) of 36%, anterior chamber depth (ACD) of 42%, and keratometry (K) values of 22%.[1]

The measurement of AL with optical biometry has been shown to produce significantly more precise IOL power, thereby avoiding possible compression of the eye with applanation A-scan ultrasound and difficulty with immersion A-scan ultrasound in AL measurements.[2] Optical biometry is currently considered as the gold standard for AL measurement except in uncooperative patients, posterior subcapsular, dense cataract, or fixation instability such as macular degeneration.[3,4]

Cyclopentolate is a widely used synthetic anticholinergic mydriatic with the advantage of rapid onset and successful mydriasis. The pharmacological effect of cyclopentolate is due to the competitive antagonism of muscarinic acetylcholine receptors, causing a mydriatic and cycloplegic effect. Clinically, it induces the relaxation of the circular muscle of the iris (mydriasis) and prevents the radial ciliary muscle's contraction, relaxing the suspensory ligaments and, therefore, the lens capsule (cycloplegia).[5]

The present study aimed to evaluate the effect of cycloplegia induced by cyclopentolate hydrochloride %1 on AL-Scan readings and IOL power in eyes with senile cataracts.

MATERIALS AND METHODS

Ethical Status: The study followed the tenets of the Declaration of Helsinki. Ethical board approval was obtained from the Ethical Committee of Kafkas University Faculty of Medicine, Kars, Turkey (Date: 31.01.2018, decision no: 28) before the study was initiated. Written informed consents were obtained from all participants.

Studying Group: Sixty-eight eyes of 68 participants over 65 years of age with various degrees of senile cataract were included in the study. Cases with previous intraocular or corneal surgery, penetrating eye trauma, chronic eye disease, unhealthy corneas, any macular pathology, complicated cataracts (secondary to chronic uveitis, trauma, glaucoma, and silicone oil), and eyes with insufficient signaling were excluded.

Study and Evaluations: After evaluating the best corrected visual acuity, the presence of cataracts was roughly confirmed by examining the anterior segment with a slit lamp biomicroscopy. Then, biometric parameters were measured before dilation with the Al-Scan. Phenylephrine, tropicamide, and cyclopentolate are frequently used mydriatic agents in clinical practice. The strong mydriatic effect of cyclopentolate can last for 24 hours. The long-lasting mydriatic effect of cyclopentolate allows ocular examination and cataract surgery to be performed on the same day. Cycloplegia was achieved by three drops of an eye solution containing cyclopentolate hydrochloride 1% every 5 minutes. A complete ophthalmologic examination was performed after dilation. Intraocular pressure was measured with an air-puff tonometer. Biometric measurements were repeated approximately 45 minutes after the first instillation of cyclopentolate hydrochloride 1%. The same experienced examiner (MBÜ) performed all measurements under the same scotopic light condition. Participants were asked to blink before every measurement to create an optically smooth tear film.

Optical Biometry and IOL Power: AL-Scan optical biometer was used in this study. AL-Scan (Nidek CO., Gamagori, Japan) optical biometer uses a non-contact technique and has a 3D automated eye tracking system. Six values, including AL, ACD, K, central corneal thickness (CCT), pupil size (PS), and white-to-white (WtW) distance, may be obtained in ten seconds. The AL-Scan relies on an optical low-coherence interferometry technique through low-coherence superposition of light waves emitted from an 830 nm super luminescent diode to measure AL. It measures K using double mire rings reflected onto the cornea at 2.4 mm and 3.3 mm diameter zones. The Scheimpflug principle obtains ACD and CCT. The WtW is measured from a captured image of the anterior segment. The PS, AL, ACD, CCT, WtW, K1, K2, Kmean, and IOL power were recorded before and after cycloplegia. The IOL power required for emmetropia with a target refraction of 0 D was calculated through the Sanders–Retzlaff–Kraff/ theoretical (SRK/T) formula with an optical constant of 118.4. Pre-cycloplegic parameters were compared with post-cycloplegic parameters.

Statistical Analysis: Statistical analysis was performed with SPSS for Windows (version 20.0, SPSS, Inc., Chicago, Illinois, USA). All results are presented as mean ± SD. Paired t-test was used to compare variables between the pre and post-cycloplegia. Bland–Altman plot was used for ocular biometry confirmation testing with limits of agreement (LoA) at 95%. A value of $p< 0.05$ was accepted to be statistically significant.

RESULTS

The mean age of the patients was 70.60±4.07 years (range; 65 to 80 years), including 30 (44%) females and 38 (56%) males. The results of the AL-Scan measurements pre and post-cycloplegia and the differences are shown in Table 1. Pre- and post-cycloplegia was not statistically significant for mean AL, K1, K2, Kmean, CCT, WtW, and IOL power measurements (p> 0.05). Only two patients in the study demonstrated changes in IOL power higher than 0.5 D (post-cycloplegia, a decrease of 0.63 D and 0.85 D). After cycloplegia, the ACD significantly increased by 0.08±0.05 mm (p< 0.001).

Table 1. Demographic information, and AL-Scan readings before and after cycloplegia.

		Pre-cycloplegia Mean±SD (min-max)	Post-cycloplegia Mean±SD (min-max)	Mean difference between pre-and post-cycloplegia	Limits of agreement at 95%	p
K1 (D)		43.29±1.36 (40.18-46.75)	43.28±1.35 (40.27-46.68)	0.0088±0.2297	-0.0468 to 0.0644	0.752
K2 (D)		44.20±1.49 (40.71-47.87)	44.24±1.51 (40.91-48.08)	-0.0362±0.2526	-0.0973 to 0.0250	0.242
Kmean (D)		43.74±1.40 (40.62-47.24)	43.76±1.40 (40.69-47.28)	-0.0127±0.1984	-0.0607 to 0.0354	0.601
WtW (mm)		11.79±0.54 (10.7-12.9)	11.79±0.54 (10.7-12.9)	0.000±0.846	-0.021 to 0.021	0.99
CCT (µm)		511.10±30.58 (446-573)	511.03±30.52 (445-572)	0.074±1.097	-0.192 to 0.339	0.582
ACD (mm)		3.14±0.22 (2.64-3.62)	3.22±0.23 (2.70-3.75)	-0.0821±0.0489	-0.0939 to -0.0702	**0.001**
AL (mm)		23.42±0.69 (21.96-24.77)	23.42±0.68 (21.98-24.80)	-0.0047±0.0208	-0.0098 to 0.0003	0.067
IOL power (D)		20.60±1.67 (16.08-24.36)	20.58±1.67 (16.01-24.21)	0.0250±0.2134	-0.0267 to 0.0767	0.338
PS (mm)		4.53±0.97 (2.9-6.7)	6.55±0.93 (4.3-8.3)	-2.012±0.809	-2.208 to -1.816	**0.001**
Gender Totally (n/%)	Male			38 (%56)		
	Female			30 (%44)		
Age Totally (mean±SD)				70.60±4.07		

K: Keratometry; D: Diopter; WtW; White-to-White; CCT: Central corneal thickness; ACD: Anterior chamber depth; AL: Axial length; IOL: Intraocular lens; PS: Pupil size; SD: Standart deviation; Min: Minimum; Max: Maximum.

The Bland-Altman plots illustrate post-cycloplegia measurement differences in mean AL, IOL power, ACD, CCT, K1, and K2 (Figure 1). The 95% LoA were -0.0098 to 0.0003 mm for AL, -0.0267 to 0.0767 D for IOL power, -0.0939 to -0.0702 mm for ACD, -0.192 to 0.339 µm for CCT, -0.0468 to 0.0644 D for K1 and -0.0973 to 0.0250 D for K2.

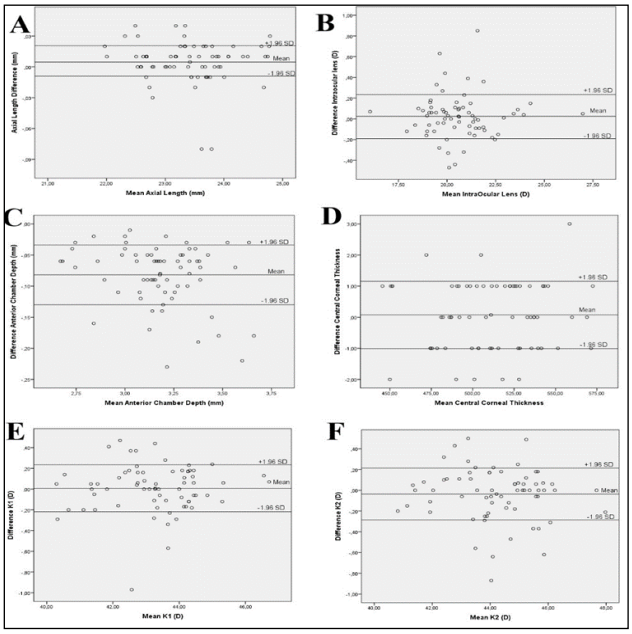

Figure 1. Bland-Altman plots of measurements before and after cycloplegia with cyclopentolate hydrochloride %1. A) Axial length; B) Intraocular lens power; C) Anterior chamber depth; D) Central corneal thickness; E) Keratometry 1; F) Keratometry 2.

DISCUSSION AND CONCLUSION

Tropicamide is the primary pharmacological agent for pupil dilation because of its rapid onset cycloplegic effect and shorter peak effect duration. However, cyclopentolate is more potent than tropicamide or phenylephrine in terms of effect. Pre-operative assessment and complete ophthalmologic evaluation including dilated fundus examination, biometry, and IOL calculations are done on the same day for patients with cataracts using cyclopentolate or tropicamide.

Our study observed no significant change in the mean CCT reading after dilation (p= 0.582). Ozyol et al. reported no significant difference in presbyopics with cyclopentolate by IOL Master 700; Momeni -Moghaddam et al. did not report any significant changes in individuals between 23 and 58 years of age with tropicamide 1% by IOL Master 700, and Hashemi et al. reported similar changes in children with the different refractive status after cyclopentolate using Allegro Biograph.[6-8] Ozcaliskan et al. and Tuncer et al. reported statistically a significant but clinically insignificant increase in the CCT after cyclopentolate, respectively, with 3 µm and 1.10 µm.[9,10] Autrata et al. detected a significant thickness increase with an average of 6 µm with 1% tropicamide+10% phenylephrine instillation in cataract patients with Lenstar LS900.[11] Zeng et al. hypothesized that Mydrin (0.5% Tropicamide+0.5% phenylephrine) destroys the integrity of the intercellular junctions among epithelial cells, which eventually causes corneal edema that mediate increase in CCT.[12] On the contrary, Palamar et al. reported a significant thinning in the mean CCT after cyclopentolate in children, and assumed that cyclopentolate, an atropine-like muscarinic receptor antagonist, probably reduced tear film thickness and caused decreased CCT measurements similar to systemic atropine.[13]

Optical biometry measures the AL from the corneal epithelium to the Bruch membrane. The results herein have shown that cycloplegia does not affect AL readings, as in many studies using tropicamide, tropicamide+phenylephrine, or cyclopentolate.[6,7,9,11,14,15] However, some studies have reported a significant increase in AL of 10 µm following cyclopentolate and 13 µm following tropicamide 0.4%.[10,16] Cheng and Hsieh hypothesized that a posterior shift of the lens-ciliary body diaphragm might produce a compression force pushing toward the vitreous cavity which may cause temporary elongation of the AL or AL change may be related to the sagittal corneal depth after cycloplegia.[16] Cycloplegic agents can affect the choroidal thickness.[17,18] A decrease in subfoveal choroidal thickness, an increase in CCT, and an elongation of 9 µm in AL were observed after cyclopentolate in myopic children.[18] Cyclopentolate mediate vasoconstriction of the choroidal perivascular plexuses and contraction of nonvascular smooth muscle cells, thus causing choroidal thinning. Therefore, elongation in AL after cycloplegia may develop secondary to choroidal thinning. The increase in the AL shown in the studies above was clinically insignificant. Because an error of 0.01 mm (10 µm) in the AL is equivalent to an error of about ±0.027 D in the spectacle plane.[1]

The WtW corneal diameter is important for anterior chamber IOL/phakic IOL implantation, the size of capsular tension ring, and IOL calculation. The WtW is correlated with the lens diameter.[19] In the present study, no significant difference was observed between the pre-and post-dilation WtW values. Some studies have reported a significant increase in WtW after dilation.[6,10] Huang et al. suggested that the image analysis system distinguishes the difference in the light and shade in the region between the iris and the sclera, and fits the best circle to the detected edge. Iris bundling increases tissue darkness and may therefore affect edge detection. Pupil dilation with iris bunching may make the difference between the iris and sclera more obvious. The image analysis system detects the edge closer to the iris sclera interface. This can make WtW measurements after pupil dilation larger than those obtained before dilation.[15]

Some studies have reported no significant change in keratometry readings following cycloplegia.[7,9,11,14] However, the pupil dilation could affect the keratometric readings, although differences were not clinically significant. Corneal flattening or steeping has been reported after cycloplegia.[10,16,20] Bakbak et al. found a significant steeping of 0.04 mm in the K1 reading with Lenstar LS 900 in cataractous eyes. The authors speculated that tropicamide 1% may have caused corneal epithelial changes, thus affecting the reproducibility of the K values.[20] In contrast, another study reported a significant flattening of 0.054 D in the mean keratometric reading with AL-Scan in presbyopics.[10] During miosis, the contractive force of ciliary muscles (CMs) acts on the sclera spur where the ciliary body is attached, and the centripetal force of the peripheral cornea steepens the cornea. Cycloplegia may release the contractile force of the CMs and flatten the cornea.[16] In the current study, no significant change was observed in the K1, K2, or Kmean after cycloplegia.

The ACD significantly increased after pupil dilation in this study (–0.0821±0.0489 mm) ($p<0.001$). Tuncer et al. found that the ACD was significantly increased after cyclopentolate in all age groups, and the most significant increase was observed in the age group of 10-20 years.[10] Ozyol et al. reported significant deepening of the ACD in both pre-presbyopics and presbyopics and significant thinning in the LT

after cyclopentolate. The deepening of the ACD and thinning in the LT were higher in pre-presbyopic patients.[6] Similarly, Teshigawara et al. reported significant changes in ACD and LT in eyes with cataracts after tropicamide±phenylephrine.[22] The anterior portion of the CMs becomes thicker throughout life, and there is no significant decrease in the contractile ability of the muscle, even in eyes with established presbyopia.[23] The contraction ability of the CMs may explain the deepening of the ACD by pulling the lens backward after cycloplegia in presbyopic and cataractous eyes, as in the current study.

The SRK/T is one of the third-generation formulas representing a linear regression method combination on a theoretical eye model. The formula only requires the AL and K, and estimates the effective lens position. The manufacturer provides the ACD constant for SRK/T. This study observed no significant change in the mean IOL power calculated by the SRK/T after cycloplegia. Can et al. reported that cyclopentolate did not affect the IOL power using SRK/T in healthy subjects, except for an increase of power of more than 0.50 D in 2 cases.[14] The IOL power was calculated with the SRK/T, which uses two different predictions (ideal IOL power for emmetropia, lowest myopic sphere equivalent residual refraction) was not affected after tropicamide+phenylephrine.[24,25] In our study, IOL power decreased by higher than 0.5 D (0.63 D and 0.85 D) after cycloplegia in only 2 patients. When 2 cases were evaluated, it was seen that the decrease in the IOL power was caused by the increase in the keratometric values, although the AL was almost the same (Case 1 pre-cycloplegia Kmean: 43.58 D; post-cycloplegia Kmean:44.18 D, and case 2 pre-cycloplegia Kmean:42.65 D; post-cycloplegia Kmean:43.41 D). A 0.1-mm error in the corneal radius is equivalent to an error of about 0.57 D, and a 0.1 D error in the IOL power is equal to an error of about 0.067 D in the spectacle plane by assuming normal eye dimension, accuracy within 0.1 mm is necessary.[1] In some cases, a difference of 0.067 D in the refractive prediction may cause a shift in the closest refractive prediction value to the target refraction that could result in a 0.5 D difference in the IOL power determined.[6] The ACD was the only factor that changed statistically in the present study. An error of 0.1 mm in the ACD may result in a 0.1 D error in the post-operative refraction. According to the results of the present study, it may result in an error of approximately 0.08 D, although the ACD may deepen after cycloplegia.

Unlike the SRK/T, fourth-generation formulas use four predictions (AL, K, ACD, and LT). The mean absolute change in predicted postoperative refraction (PPR) between pre- and post-dilation was significantly higher for fourth-generation formulas compared with third-generation. The fourth-generation formulas show a positive correlation between the change in PPR and the change in ACD.[26] Another new generation formula, Barrett Universal II, is one of the most reliable formulas using five variables (K, AL, ACD, LT, and WtW).[27,28] Unlike the SRK/T, IOL power is affected by cycloplegia with the Barrett Universal 2. In a study, the recommended IOL power changed in 23.3% of cases after cycloplegia when using Barrett Universal II, while SRK/T showed no change.[22]

This study had some limitations. All types of cataracts were included in the study, and no grading system was used to classify the lens opacities. Another area for improvement was the lack of repeatability of the results. However, this was a minor limitation, as the high repeatability and reproducibility of the AL-Scan were confirmed previously.[14] The study population consisted of elderly cataract patients who had low vision. This could lead to fixation difficulties. In this study, the required IOL power for emmetropia was calculated according to a target refraction of 0 D. However, stock IOLs are manufactured in 0.5 D intervals.

In conclusion, the present findings indicate that pupil dilation with cyclopentolate hydrochloride 1% in senile cataractous eyes does not cause significant changes in the mean AL, WtW and K values. However, it causes a significant increase in ACD. Pupil dilation did not significantly affect the mean IOL power calculated by the SRK/T formula. Although, the IOL power measurement with the SRK/T formula could be performed immediately after the examination while the patient is dilated, surgeons should be careful about the effect of pupil dilation on IOL power prediction. It should be kept in mind that in a few cases, deviations in IOL power may occur due to keratometry after dilation.

Ethics Committee Approval: Our study was approved by the Ethics Committee of Kafkas University (Date: 31.01.2018, decision no: 28). The study was carried out in accordance with the international declaration, guidelines, etc

Conflict of Interest: No conflict of interest was declared by the authors.

Author Contributions: Concept – MBÜ; Supervision – MBÜ, EB, HG; Materials – MBÜ, EB; Data Collection and/or Processing – MBU, EB; Analysis and/ or Interpretation – MBÜ, EB, HG; Writing – MBÜ.

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