Original Article

Effect of Cycloplegia on Corneal Biometrics and Refractive State

Abbas Bagheri[1,2], MD; Mohadeseh Feizi[2], MD; Aliakbar Shafii[2], OD; Amir Faramarzi[2], MD Mehdi Tavakoli[2], MD; Shahin Yazdani[1,2], MD

[1]*Ocular Tissue Engineering Research Center, Shahid Beheshti University of Medical Sciences, Tehran, Iran*
[2]*Ophthalmic Research Center, Shahid Beheshti University of Medical Sciences, Tehran, Iran*

Abstract:

Purpose: To determine changes in refractive state and corneal parameters after cycloplegia with cyclopentolate hydrochloride 1% using a dual Scheimpflug imaging system.

Methods: In this prospective cross-sectional study patients aged 10 to 40 years who were referred for optometric evaluation enrolled and underwent autorefraction and corneal imaging with the Galilei dual Scheimpflug system before and 30 minutes after twice instillation of medication. Changes in refraction and astigmatism were investigated. Corneal biometrics including anterior and posterior corneal curvatures, total corneal power and corneal pachymetry were compared before and after cycloplegia.

Results: Two hundred and twelve eyes of 106 subjects with mean age of 28 ± 5 years including 201 myopic and 11 hyperopic eyes were evaluated. Mean spherical equivalent refractive error before cycloplegia was -3.4 ± 2.6 D. A mean hyperopic shift of 0.4 ± 0.5 D occurred after cycloplegia ($P < 0.001$). The astigmatism power did not significantly change ($P = 0.8$), however, 26.8% of eyes with significant astigmatism experienced a change of more than 5 degrees in the axis of astigmatism. Changes in posterior corneal curvature were scant but statistically significant ($P = 0.001$). Moreover, corneal thickness was slightly increased in the central and paracentral regions ($P < 0.001$ and $P < 0.001$, respectively).

Conclusion: Cycloplegia causes a hyperopic shift and astigmatism axis changes, along with an increase in central and paracentral corneal thickness and change in posterior corneal curvature. The effects of cycloplegia on refraction and corneal biometrics should be considered before cataract and refractive surgeries.

Keywords: Astigmatism; Corneal Curvature; Corneal Thickness; Cycloplegia; Refraction

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INTRODUCTION

Corneal curvature and thickness, anterior chamber depth, and refraction are important factors that are used for calculations and planning many ophthalmic procedures, including cataract and refractive surgeries. Cycloplegic refraction is also frequently required in certain patient populations, such as hyperopic patients and children.

The exact mechanism of accommodation is not well known. A sequence of events including the contraction of ciliary muscles reduces zonular tension on the lens equator, which in turn increases the lens thickness and thus its refractive power for sharp near vision.[1,2]

Correspondence:
Abbas Bagheri, MD. Ophthalmic Research Center, Shahid Beheshti University of Medical Sciences, No. 23, Paidarfard St., Boostan 9 St., Pasdaran Ave., Tehran 16666, Iran.
E-mail: abbasbagheri@yahoo.com

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The cornea is the main refractive component of the eye and even small refractive changes that may occur during accommodation can significantly influence the optical state of the eye. The effects of accommodation on the cornea have been evaluated by several investigators.[3-11] It has been shown that corneal curvature changes with age.[12] The role of the cornea in accommodation may appear insignificant in comparison to the major contribution of the crystalline lens. However, the pseudo-accommodation phenomenon in pseudophakic eyes, which is mainly attributed to the changes in pupil size and depth of focus, may somehow be also related to corneal accommodation.[13,14] In some species of birds, changes in corneal curvature is estimated to contribute to as much as 40% of the total optical power of the eye during accommodation.[15] Cycloplegia is the reverse phenomenon of accommodation and free from the effects of cyclotorsion or vergence. The effects of cycloplegia on the cornea arise entirely from changes in the ciliary body contraction [6,10].

In previous studies, anterior chamber depth has been shown to increase after cycloplegia.[16-18] However, changes in the corneal curvature and thickness have not been consistent in different studies.[16-19]

The purpose of this study was to investigate the effect of cycloplegia on corneal biometrics and refraction. We used a dual Scheimpflug system (Galilei, Ziemer ophthalmic system AG, Zurich, Switzerland) for corneal imaging. This Dual Scheimpflug system employs two Scheimpflug cameras and provides noninvasive, accurate, and repeatable imaging of the anterior segment by integrating the dual Scheimpflug tomography technology with Placido disc topography.[20] This device has rarely been used for corneal biometric evaluation after cycloplegia in the past. In the current study, cyclopentolate hydrochloride 1% was used, which can produce complete cycloplegia in contrast to tropicamide[17-19,21] and is shorter-acting than atropine, which is considered as the gold standard for cycloplegia.[22,23]

METHODS

This cross-sectional prospective study included patients who were referred to our clinic for optometric evaluation over a 3-month period, from October to December 2015. The protocol of the study was approved by the scientific and ethics committee of the Ophthalmic Research Center at Shahid Beheshti University of Medical Sciences, and was conducted in accordance with the tenets of the Declaration of Helsinki. The goals and study protocol were explained to the subjects and informed consent was obtained from all the subjects or their guardians.

We included patients aged 10–40 years who exhibited minimal senile changes in the crystalline lens. All patients underwent a comprehensive eye examination including determination of visual acuity, slit lamp biomicroscopy, and fundus examination. Subjects were excluded from the study if any ocular pathology was noticed. The other exclusion criteria were history of ocular or adnexal surgery and any chronic systemic diseases, including diabetes mellitus and hypertension.

Refraction was performed using the Topcon KR- 8800 autorefractometer (Topcon Inc., Tokyo, Japan) and was repeated three times for each eye and the average value was documented.

A dual Scheimpflug system was used for measurement of corneal parameters including keratometry of the anterior and posterior corneal surfaces, total corneal power, and corneal thickness in three zones, i.e., central 0–4 mm; paracentral 4–7 mm, and peripheral 7–10 mm. The Galilei system calculates total corneal power by ray tracing and Snell's law.[24] Best fit spheres (BFSs) for the anterior and posterior surfaces, respectively, were used to detect alterations in the corneal curvature.

Subsequently, cyclopentolate hydrochloride 1% was instilled twice, 5 minutes apart in each eye, and after 30 minutes the above-mentioned measurements were repeated.

Statistical Analysis

We used three different methods to calculate the effect of cycloplegia on the power and axis of astigmatism.[25-27] In the first method, arithmatic changes in power and axis of the cylinder before and after cycloplegia were analyzed and compared. The difference between refractive and keratometric astigmatism was defined as lenticular astigmatism. The direction of axis change was considered clockwise if the difference of the axes (axis 2-axis 1) was a negative value and was considered counterclockwise if the difference of the axes was a positive value. All values were calculated for right and left eyes independently.

In the second method, we used the technique described by Holladay et al for analysis of the surgically induced changes in spherocylinders.[25] Figure 1 depicts how two oblique spherocylinders are added to each other. Vector-A and vector-B represent the magnitude and axis of the spherocylinder before and after cycloplegia, respectively, and vector-C represents the resultant of vectors A and B. In this method, the magnitudes (powers) and directions (axes) of spherocylinders before and after cycloplegia were calculated according to Holladay's 10-step formula using the Excel software for all eyes with more than 0.5 D of cylinder.

In the third method, we used the vector analysis technique introduced by Thibos et al.[26] In this method, each spherocylinder is broken up into three components, including the M- Parameter, which represents spherical equivalent power; J0 parameter, which represents the cylinder magnitude in the 90° and 180° axes (with-the-rule and against-the-rule astigmatism); and J45 parameter, which represents the cylinder power in 45° and 135° axes (oblique astigmatism). These parameters are calculated using the following formula: J0 = C/2cos2a and J45 = C/2sin2a, C = cylinder power in minus, a = cylinder axis. Changes in M, J0, and J45 parameters before and after cycloplegia were compared.

All collected data were compared before and after cycloplegia. We used mean, mode, range, and standard deviation to present the data. We also used t-tests and paired t-tests to evaluate the changes in values. To present the consistency of measurements and congruity of findings, 95% confidence intervals and 95% limits of agreement were used, respectively. To compensate for interocular symmetry, we also used the "mixed model analysis" method. SPSS software (IBM SPSS statistic for windows, version 24, Armonk, NY) was used to analyze the data.

RESULTS

A total of 106 patients, including 69 female (65.1%) and 37 male (34.9%) patients, were enrolled in the study. Both eyes of each participant were considered for the purpose of this study. The mean age was 28 ± 5 years (range, 10 to 37 years). Out of the 212 eyes enrolled in the study, 201 (94.8%) were myopic (including 32 eyes with myopia of more than −6 D) and 11 (5.2%) were hyperopic.

Spherical Equivalent

Mean spherical equivalent before cycloplegia was −3.4 ± 2.6 D, which decreased to −2.9 ± 2.6 D after cycloplegia indicating a hyperopic shift of 0.4 ± 0.5 D ($P < 0.001$) [Table 1 and Figure 2]. This hyperopic shift was more significant in hyperopic eyes as compared to the myopic eyes (0.9 ± 0.5 D versus 0.4 ± 0.5 D). The extent of hyperopic shift in hyperopic eyes was positively correlated with the amount of hyperopia before cycloplegia ($r = 0.7$, $P = 0.02$). However, this correlation was not significant in the myopic eyes ($P = 0.7$, $r = -0.02$).

Analysis of eyes with a spherical equivalent of more than + 0.5 D (which is supposed to be clinically significant) revealed a significant change (more than 0.5 D) after cycloplegia only in 28.8% of the patients. A myopic shift of less than 0.5 D was noticed in 16 myopic eyes but not in any of the hyperopic eyes.

Astigmatism

Clinically significant astigmatism (more than 0.5 D) was seen in 127 eyes (59.9%). The results of astigmatism analysis using the three mentioned methods are presented below:

Method 1: Mean cylinder power before cycloplegia was −1.2 ± 1.2 D, which changed to −1.2 ± 1.1 D after cycloplegia ($P = 0.8$). Mean change of astigmatism axes was 19 ± 41.3 degrees in both eyes without any correction of astigmatism axis (19.3 ± 10.3 degrees for the right eye and 18.7 ± 42.5 degrees for the left eye). When the post-cycloplegia cylinder axis changed by more than 90°, we corrected the second axis by subtracting 180° from the original value and adding the absolute values to the axis value before refraction, e.g., if the axis before cycloplegia was 5° and changed to 175° following cycloplegia, the value was first corrected to −5°(175 − 180 = −5), and the final value reported was 5 + 5 = 10, which reflects a 10-degree change of axis. After this correction, the mean change in the axis of significant cylinders (more than 0.5 D) was 5.3 ± 10.5 degrees. The change of

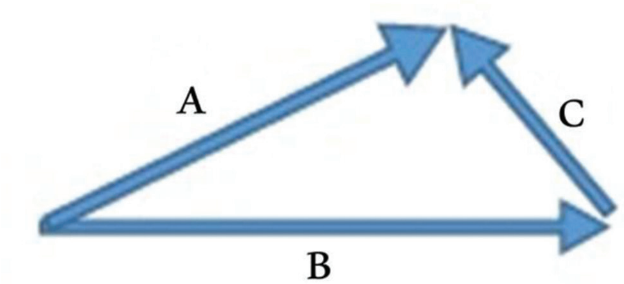

Figure 1. The basic method of trigonometric calculations of the resultant of two oblique spherocylinder. Vector-A and Vector-B represents the magnitude and axis of the spherocylinder before and after cycloplegia, respectively and vector-C represents the resultant of A and B.

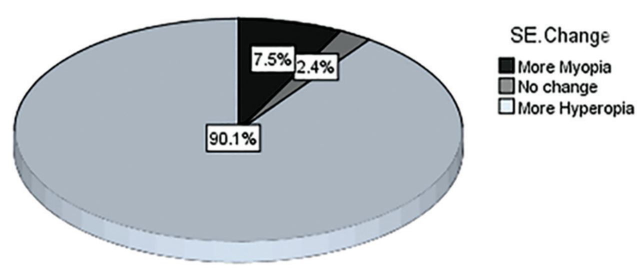

Figure 2. Changes in the spherical equivalent after cycloplegia.

Table 1. Refractive state of the eyes before and after cycloplegia

	Before Cycloplegia Mean±SD (D)	After Cycloplegia Mean±SD (D)	Difference	95% CI		*P*
				Lower	Upper	
Sphere	-2.7±2.5	-2.3±2.5	0.4±0.5	0.37	0.52	<0.001
Cylinder	-1.2±1.2	-1.2±1.1	0.00±0.25	-0.04	0.03	0.8
Spherical equivalent	-3.4±2.6	-2.9±2.6	0.4±0.5	0.35	0.49	<0.001

cylinder axis was less than 5° in 73.2% of the eyes and it was more than 5°only in 26.8% of the eyes [Figure 3]. In eyes with more than 5°of change in axis, the directions of the change were clockwise and counterclockwise in 4.2% and 2.6% of the eyes, respectively. The right eyes more predominantly showed a clockwise change of axis, while in the left eyes, the axes changed more commonly in a counterclockwise direction. Thus, following cycloplegia, the axis of astigmatism in both eyes became more intorted [Table 2].

In a notable group of eyes (41.6% of eyes before cycloplegia and 35.5% of eyes after cycloplegia), lenticular astigmatism was less than 0.25 D. In a second group of eyes (27.2% of eyes before cycloplegia and 31.5% of eyes after cycloplegia), refractive astigmatism exceeded corneal astigmatism, which reflects that corneal and lenticular astigmatism axes were similar with additive powers. In a third group of eyes (31.2% of eyes before cycloplegia and 33% of eyes after cycloplegia), refractive astigmatism was less than total corneal astigmatism, showing that lenticular astigmatism was in a different principal meridian from that of corneal astigmatism, with subtractive powers [Table 3].

As mentioned previously, mean change in the axis of total astigmatism was 5.3 ± 10.5°. Corresponding values for axes of corneal astigmatism and lenticular astigmatism after cycloplegia were 6.6 ± 9.6° and 1.3 + 14.4°, respectively [Figures 4 and 5].

Method 2: Astigmatism induced by cycloplegia was calculated by Holladay's 10-step formula for 127 eyes (59.9% of eyes) with more than 0.50 D of astigmatism. In this method, mean vector changes in refraction after cycloplegia were 0.6 ± 0.9 D in sphere, 0.2 ± 0.8 D in cylinder, and 142 ± 44° in axis.

Table 2. Changes in astigmatism (totally and in cases more than 5° change)

	Total *N* (%)	OD *N* (%)	OS N *N* (%)
Total axis changes			
Clockwise	59 (46.5)	30 (23.6)	29 (22.9)
Counterclockwise	68 (53.5)	28 (22)	40 (31.5)
Axis change >5 degrees			
Clockwise	18 (14.2)	10 (7.9)	8 (6.3)
Counterclockwise	16 (12.6)	8 (6.3)	8 (6.3)

OD, oculus dexter; OS, oculus sinister; N, number

Method 3: Changes in spherocylinders after cycloplegia were calculated by the Thibos vector analysis. In this analysis, the change in spherical equivalent (M) was 0.4 ± 0.5 D ($P < 0.001$) but changes in J0 and J45 were −0.06 ± 1.15 D and −0.07 ± 1.11 D, respectively which were not statistically significant ($P = 0.6$ and $P = 0.5$, respectively) [Table 4].

Corneal Curvature and Shape

The changes in the mean total and anterior corneal power after cycloplegia were not statistically significant ($P = 0.7$ and $P = 0.5$, respectively). However, the change in mean posterior corneal power was statistically significant, but clinically negligible (−0.02 ± 0.06 D, $P = 0.001$) [Table 5].

It is notable that absolute changes in all the corneal curvature parameters were significant. However, changes in total corneal power and power of the anterior surface of the cornea were not in the same direction, which makes these changes statistically insignificant. In contrast, in the posterior surface of the cornea, even though changes in the power were trivial, they were in the same direction (toward hyperopia) which makes them statistically significant [Table 5].

Analysis of the changes in corneal curvature exceeding 0.5 D, which is clinically notable, revealed that total, anterior, and posterior corneal curvatures remained unchanged in 95.7%, 93.9%, and 99% of the eyes, respectively [Figure 6].

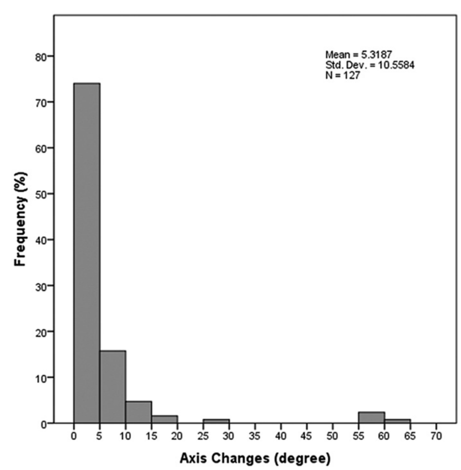

Figure 3. Changes in the axis of astigmatism after cycloplegia.

Table 3. Effect of lenticular astigmatism on corneal astigmatism to produce total astigmatism

	Before cycloplegia (%)	After cycloplegia (%)
Only corneal astigmatism	41.6	35.5
lenticular astigmatism adding to corneal astigmatism	27.2	31.5
lenticular astigmatism subtracting from corneal astigmatism	31.2	33
Total	100	100

Mean BFS before cycloplegia was 7.73 ± 0.25 D in the anterior corneal surface and 6.42 ± 0.26 D in the posterior corneal surface without any significant change after cycloplegia (*P* = 0.5 and *P* = 0.7, respectively) [Table 5].

Corneal Thickness

Mean corneal thickness was significantly increased after cycloplegia in the central and paracentral areas of the cornea (*P* =<0.001), but only a statistical trend was observed in its increase in the periphery of the cornea (*P* = 0.09) [Table 6]. Central corneal thickness was increased in 73.4%, but was decreased in 26.6% of the eyes after cycloplegia [Figure 6].

Special Subgroups

In this study, 32 eyes (5.1%) were highly myopic (-6D or more) and 11 eyes (5.2%) were hyperopic. All the previous analyses were repeated separately for these subgroups, which showed similar results as indicated above, except that in high myopic eyes, changes in posterior corneal curvature after cycloplegia was insignificant (*P* = 0.7).

Patients under 20 years of age were another distinct subgroup in this study, which included 10 eyes of 5 patients (4.7% of cases). Mean spherical equivalent was −2.2 ± 2.8 D, which changed to −2.1 ± 2.8 D after cycloplegia (*P* = 0.1). In this subgroup, the total, anterior, and posterior corneal curvatures did not change significantly (*P* = 0.3). Furthermore, the central, paracentral, and peripheral corneal thickness changes were also not statistically significant (*P* = 0.9, *P* = 0.2, and *P* = 0.2, respectively). Mixed model analysis compensating for inter-ocular symmetry was repeated on all the data and showed comparable results.

DISCUSSION

The current study showed a significant hyperopic shift after cycloplegia associated with significant hyperopic changes in the posterior corneal curvature. It also revealed a significant increase in central and paracentral corneal thicknesses after cycloplegia. We enrolled both

Table 4. Vector analysis of astigmatism before and after cycloplegia

	Before Cycloplegia Mean±SD (D)	After Cycloplegia Mean±SD (D)	Difference	SD	95% CI		*P*
					Lower	Upper	
M	-3.4±2.6	-2.9±2.6	-0.4	0.5	-0.35	-0.49	<0.001
J0	0.07±0.68	0.13±0.77	-0.06	1.15	-0.26	0.14	0.6
J45	-0.01±0.82	0.06±0.72	-0.07	1.11	-0.27	0.12	0.5

Table 5. Changes in corneal curvatures and its components after cycloplegia

	Before cycloplegia mean±SD	After cycloplegia mean±SD	Difference	95% CI				95% LOA		Absolute	
				SD	Lower	Upper	*P*	Lower	Upper	Mean±SD	*P*
Ant. Kf	43.06±1.47	43.05±1.48	-0.01	0.17	-0.04	0.01	0.3	-0.42	0.39	0.15±0.15	<0.001
Ant. Ks	44.59±1.56	44.62±1.56	0.03	0.34	-0.01	0.07	0.2	-0.58	0.63	0.21±0.23	<0.001
Ant.K_ave	43.82±1.42	43.83±1.43	0.01	0.23	0.02	0.04	0.5	-0.45	0.47	0.16±0.18	<0.001
Post Kf	-6.19±0.26	-6.21±0.26	-0.02	0.07	-0.03	-0.01	0.002	-0.21	0.17	0.07±0.07	<0.001
Post Ks	-6.58±0.32	-6.61±0.32	-0.02	-0.10	-0.04	0.00	0.02	-0.31	0.26	0.08±0.12	<0.001
Post.K_ave	-6.39±0.27	-6.41±0.28	-0.02	0.06	-0.03	-0.01	0.001	-0.20	0.16	0.06±0.07	<0.001
TCP mean	43.63±1.39	43.64±1.39	0.01	0.17	-0.03	0.04	0.7	-0.50	0.51	0.16±0.2	<0.001
Ant.BFS	7.73±0.25	7.73±0.25	0.00	0.01	0.00	0.00	0.5	-0.04	0.04	0.01±0.01	<0.001
Post.BFS	6.42±0.26	6.42±0.3	0.00	0.05	-0.02	0.02	0.7	-0.30	0.30	0.07±0.14	<0.001

Ant, anterior; Post, posterior; K, keratometry; f, flat; s, steep; ave, average; TCP, total corneal power; BSF, best fit sphere; LOA, limit of agreement; CI, confidence interval; SD, standard deviation

Table 6. Changes in corneal thickness in different zones of the cornea after cycloplegia

	Before cycloplegia mean±SD	After cycloplegia mean±SD	Diff	SD	95% CI		*P*
					Lower	Upper	
Corneal Thickness							
Central	565±32	568±32	3.2	3.8	2.6	3.8	<0.001
Paracentral	611.4±34	615.3±35.4	3.9	4.9	2.7	5.0	<0.001
Peripheral	687±47.2	693±67.1	6.0	13.6	-0.9	12.9	0.09

Diff, difference; SD, standard deviation; CI, confidence interval

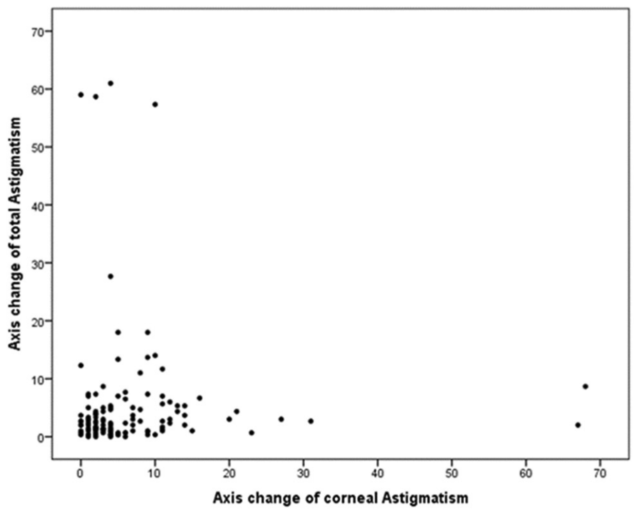

Figure 4. Comparing axis changes in total astigmatism and corneal astigmatism.

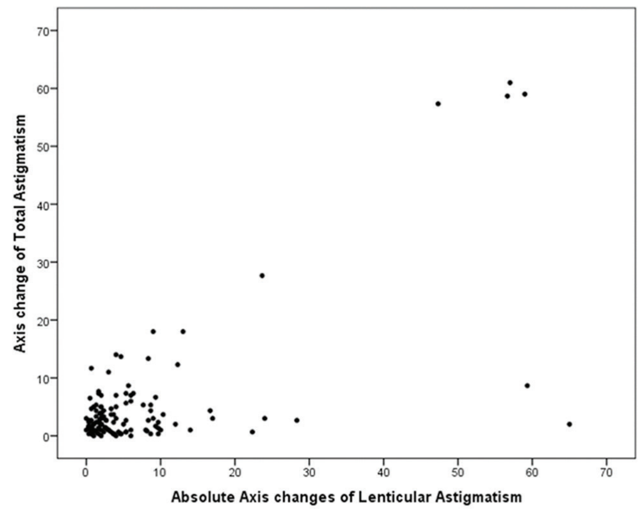

Figure 5. Comparing axis changes in total astigmatism and lenticular astigmatism.

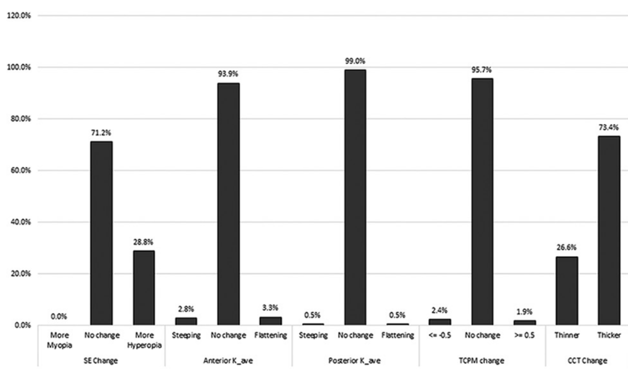

Figure 6. The frequency of changes in refraction, corneal curvatures, and corneal thickness in eyes with more than 0.5 D change in spherical equivalent. (SE, spherical equivalent; anterior K_ave, average keratometry of anterior corneal surface; posterior K_ave, average keratometry of posterior corneal surface; TCPM, mean of total corneal power; CCT, central corneal thickness).

myopic and hyperopic patients in order to present a sample with a mixture of different refractive errors and thus increase the external validity of our study. In addition, we used cyclopentolate hydrochloride 1%, which can produce complete cycloplegia.[22,23]

A dual Scheimpflug system was used for corneal measurements. In comparison to Pentacam, which uses one Scheimpflug camera, two Scheimpflug cameras are employed in the Galilei device, so it can provide more accurate and repeatable measurements, especially the posterior corneal curvature and corneal thickness.[20,28,29] The Galilei system measures the total corneal power by ray tracing, using Snell's law and considering the powers and refractive indices of both the anterior and posterior corneal surfaces.[24] In contrast to Placido disc-based keratometry systems, which measure only the anterior surface curvature of the cornea, elevation-based systems provide measurements of total corneal power which is much more accurate for calculating the power of intraocular lenses in certain circumstances, including the eyes with prior refractive surgery.

We found a mean hyperopic shift of 0.4 ± 0.5 D, which was more significant in the hyperopic eyes than the myopic eyes (0.9 D in hyperopic versus 0.4 D in myopic eyes) and, also more significant with higher amounts of hyperopia. This may show the role of tonic hyperopia and the effect of the medication on manifesting latent hyperopia. Hiraoka et al[30] and Fan et al[31] reported a slightly higher hyperopic shift after cycloplegia as compared to our results. This difference can be explained by the lower mean age, higher hyperopia, and use of atropine as a more potent cycloplegic agent in those studies. In our study, the hyperopic shift in myopic patients was not related to the severity of myopia, and even myopia was increased in 16 eyes after cycloplegia. This myopic shift may be related to the effect of spherical aberrations following pupil dilation.

The changes in astigmatism during accommodation are controversial.[32] Dobrowsky suggested that the eye can decrease the amount of astigmatism by selective sectorial contraction of the ciliary muscles during accommodation.[33] This phenomenon was later called "astigmatic accommodation" by Brzezinski. Other hypotheses include a non-uniform elasticity of the crystalline lens, which induce additional astigmatism during accommodation called "accommodative astigmatism."[34]

We evaluated the changes in astigmatism after cycloplegia in our series by three methods, which revealed subtle changes in the power of astigmatism; this finding is in accordance with the findings of other studies.[19,35] The astigmatism axis, however, changed more than 5° in 26.8% of the eyes with nearly equal frequency in clockwise or counterclockwise directions. In this study, we showed that corneal astigmatism changed after cycloplegia independently from that of lenticular astigmatism. In addition to the non-uniform accommodation mentioned above, changes in astigmatic axis after cycloplegia can be explained by the increase in higher order aberrations following pupil dilation.[36] Millodot et al[37] reported changes in astigmatism axis more than 5° after cycloplegia in various directions in half of their cases. Bannon et al[38] also found that accommodation changed the axis of astigmatism (with power >1.0 D) in 34% of the subjects.

Changes in corneal astigmatism after cycloplegia were not significant in our study which is consistent with the results reported by Cheng et al[19] and Palamar et al[35] but contradictory to others.[9,37]

In our study, corneal astigmatism was almost equal to refractive astigmatism in 40% of the eyes, while in the other 60%, lenticular astigmatism either added to or subtracted from corneal astigmatism in order to constitute refractive astigmatism. These values did not show much difference following cycloplegic drops, which reflects a similar contribution of lenticular astigmatism before and after cycloplegia. This finding is in accordance with that of another study.[37]

The effects of accommodation and cycloplegia on corneal curvature are debated, and different results have been reported from several studies.[3,7,9,16,17,19,30,35] Our study showed non-significant changes in corneal curvature after cycloplegia. Young et al[39]and Schachar et al[40] believed that the cornea does not play a significant role in accommodative amplitude.

Some authors suggested that changes in the corneal astigmatism during accommodation are related to convergence and cyclotorsion which occur together, along with near vision.[6,10] When changes in the cornea due to cycloplegia are studied in a fashion similar to our study, the effects of convergence and cyclotorsion are omitted.

We found non-significant changes in total corneal power and the power of the anterior corneal surface following cycloplegia, which is in agreement with the findings of studies using either cyclopentolate or tropicamide.[18,35] As evident from the data presented in Table 5, the absolute values of changes in all corneal parameters were statistically significant. We found that following cycloplegia with cyclopentolate, changes in the total corneal power were not significant but within a wide range (reflected in absolute values which changed significantly); therefore, we discourage the use of total corneal power measured in the cycloplegic state for intraocular lens power calculations. Similarly, Ni and colleagues[4] found no significant effects of accommodation on corneal curvature with a high variability of values among normal subjects.

In this study, the minus power of the posterior corneal surface was slightly increased, which was statistically, although not clinically, significant. This can be explained by the fact that values changed in most cases in the same direction (i.e., a hyperopic shift or a decrease in the refractive power of the cornea). Theoretically, the posterior surface of the cornea may contribute more to accommodation, considering its proximity to the ciliary muscles. Nevertheless, this finding was not consistent in high myopic and, also younger patients in this study. In a similar study by Saitoh et al,[21] posterior tangential corneal power was studied in 28 cases after using tropicamide, and no significant change was detected. It must be noted that small but statistically significant changes in posterior corneal curvature in the present study may be caused by the repeatability of the measurements of Galilei device which was reported before.[28]

In few studies, accommodation has been associated with certain changes in the corneal shape.[9] Saitoh et al[21] reported that anterior and posterior BFS were increased after tropicamide, along with a flatter corneal shape, although the anterior corneal power remained unchanged. In our study, anterior and posterior BFS did not change significantly after cycloplegia.

In the present study, central and paracentral corneal thicknesses were increased significantly following cycloplegia, which is comparable to few previous studies.[17,41] Three hypotheses have been suggested for the increase in corneal thickness post cycloplegia. The first one suggests that eye drops containing benzalkonium chloride as a preservative may damage the corneal epithelial and endothelial cells, leading to corneal stromal edema.[42] In the second theory, reflex tearing after eye drop instillation may cause an overestimation of corneal thickness. In our study, however, all corneal measurements were taken at least 30 minutes following drop instillation, which is long enough to allow the tear film to return to the normal level. In addition, we found more significant thickness changes in the central cornea, while the tear film typically collects in more peripheral parts adjacent to the lower lid margin. Furthermore, the anti-muscarinic effects of cycloplegic agents may inhibit or reduce reflex tear secretion.[17] The third theory is the probable effects of contraction or relaxation of ciliary muscles on the cornea. In one study by Read and colleagues,[10] corneal pachymetry did not reveal significant changes in thickness with 5 D of accommodation. In another study by Palamar and colleagues[35] involving children aged between 6 and 16 years, cycloplegia with cyclopentolate decreased central corneal thickness, which is in contrast to our results in adults. They assume that topical instillation of cyclopentolate hydrochloride, which is an atropine-like muscarinic receptor antagonist, probably decreases tear film thickness and reduces central corneal thickness measurements. The probable different corneal hysteresis and endothelial cell counts between children and adults may be another reason of the different outcomes.

Anterior chamber depth increased after cycloplegia in most of the previous studies, which is predictable. Anterior chamber depth is an important component in some formulas for calculating intraocular lens power (e.g., Haigis and Holladay-2) which needs caution while measurements are taken on cycloplegic patients.[18] Anterior chamber depth was not evaluated in this study considering the consistent result from all the previous studies.

The limitations of this study include the following: the small number of hyperopic patients as well as the lack of data related to anterior chamber depth. The test-to-test variability for the Galilei was not investigated, which might be greater than the small changes noted. Large-scale studies are required in the future to find more details about the effects of cycloplegia in different refractive states, including hyperopia, and in different age groups.

In conclusion, although the cornea is the most powerful refractive component of the eye, changes in power, curvature, and thickness of the cornea after cycloplegia are not comparable to those of the crystalline lens. This study showed that even though some corneal parameters do not change significantly, the change in their absolute values is still significant and in various directions. In addition, we found that central corneal thickness increases and a hyperopic shift occurs in both myopic and hyperopic eyes following cycloplegia. Even small changes in the shape, curvature, and thickness of the cornea can impact biometric measurements of the anterior segment. The precision of such measurements is crucial for optimal outcomes after cataract and refractive surgeries. Our recommendation is to consider likely inaccuracies of biometric values of the cornea and anterior segment measured in the cycloplegic state, especially before planning for cataract and refractive surgeries.

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Conflicts of Interest

There are no conflicts of interest.

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