ARTICLES

Analysis of patients with good uncorrected distance and near vision after monofocal intraocular lens implantation

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PURPOSE: To analyze factors contributing to uncorrected visual acuity of at least 6/12 for distance and at least J4 for near (pseudoaccommodation) after monofocal intraocular lens (IOL) implantation.

SETTING: Iladevi Cataract and IOL Research Center, Ahmedabad, India.

METHODS: In a case-controlled study of 30 eyes (30 patients) that had phacoemulsification, those with pseudoaccommodation were assigned to cases and 30 eyes (30 patients) without pseudoaccommodation were designated as controls. Controls were matched by identical best corrected visual acuity, age, and postoperative duration. Subjective refraction was done with retinoscopy. Factors analyzed included corneal astigmatism, pupil size, axial IOL movement, amplitude of accommodation, axial length (AL), and age. Corneal astigmatism was noted on topography and interpreted as against the rule (ATR) (180 $\pm$ 15 degrees), with the rule (WTR) (90 $\pm$ 15 degrees), and oblique (OB) (45/135 $\pm$ 30 degrees). Pupil size was noted on topographic display and AL and anterior chamber depth (ACD) on immersion A-scan. The axial IOL movement was calculated as the difference in ACD after instillation of cyclopentolate 1% (Cyclopent) and subsequently pilocarpine nitrate 2% (Carpinol) at separate visits, and amplitude of accommodation was measured with static and dynamic retinoscopy. Multivariate logistic regression and odds ratio with 95% confidence intervals were determined.

RESULTS: Mean spherical equivalent was -0.45 ± 0.63 diopter (D) in cases and -0.35 ± 0.83 D ($P = .61$) in controls. Multivariate logistic regression in cases versus controls: corneal astigmatism (ATR versus WTR and OB collectively): 10.19 [1.8,57.44], $P = .009$; pupil size: 0.45 [0.07,2.71], $P = .38$; axial IOL movement: 1.39 [0.51,0.77], $P = .514$; amplitude of accommodation: 2.95 [0.93,9.3], $P = .065$; AL: 0.55 [0.29,1.02], $P = .058$; and age: 0.98 [0.5,1.95], $P = .963$.

CONCLUSION: The study suggests a significant role of ATR corneal astigmatism in good uncorrected distance and near vision after monofocal IOL implantation.

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Monofocal intraocular lens (IOL) implantation is the established mode of visual rehabilitation following phacoemulsification. It has been accepted that monofocal IOL implantation corrects visual acuity for either distance or near vision. However, our clinical experience has shown that patients with monofocal IOL implantation occasionally have good uncorrected visual acuity (UCVA) for distance and near vision.[1–3] Various factors such as astigmatism,[1,4–12] pupil size,[2,3,12–14] axial IOL movement,[15,16] axial length,[17] age,[18] corneal multifocality,[19,20] and aberrations[20] have been shown to be responsible for such a phenomenon.

We designed a case-controlled study to determine factors contributing to the phenomenon of good UCVA for distance and near vision in eyes with monofocal IOL implantation.

PATIENTS AND METHODS

Study Population

In a case-controlled series, the sample size was set at 30 patients each in cases and controls because the phenomenon of possessing good UCVA for distance and near vision is seen only

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occasionally in patients after monofocal IOL implantation. In a pilot study of 100 consecutive monofocal pseudophakic patients, conducted at the Iladevi Cataract and IOL Research Center before this study began, it was found that the approximate incidence of this phenomenon was 9%. The sample size calculated from this incidence with an allowable error of 20% would be very large. Because the current study had a control group, a sample size of 30 would be adequate to detect statistical difference. Approval was obtained from the Institutional Review Board. Patients were educated about the purpose of the study, and informed consent was obtained from all.

From October 2003, recruitment began of patients older than 45 years with eyes having a postoperative duration between 2 and 6 months and UCVA of 6/12 or better for distance and J4 or better for near as cases. This recruitment continued until May 2004, by which time there were 30 cases. During the process of screening patients for cases, 350 eyes were examined. All these eyes had uneventful phacoemulsification at the institute with monofocal AcrySof IOL (SA60AT, Alcon Laboratories) implantation in the bag for uncomplicated age-related cataracts. All eyes had an intact anterior capsulorhexis and total anterior capsule overlap over the IOL optic edge for 360 degrees. A single eye of each patient was recruited. Uncorrected visual acuity for distance (at 6 m) was tested with English letters on Snellen chart and near (at 33 cm) using a standard Jaeger chart. To recruit patients for controls, the same inclusion criteria of age, postoperative duration, type of IOL implantation, and either right or left eye (matched with case) were applied. However, these patients differed from cases by having UCVA of less than 6/12 for distance and less than J4 for near. These controls were randomly selected from another ongoing study evaluating visual outcome following AcrySof SA60AT IOL implantation in eyes having uneventful phacoemulsification for uncomplicated age-related cataracts. When the sample size of 30 eyes each in cases and controls was reached, the recruitment process stopped. All the eyes in cases and controls had a best corrected visual acuity (BCVA) of 6/6 for distance and N6 for near. Uncorrected visual acuity assessment in all the eyes was done under the same room illumination.

Inclusion criteria for cases and controls were age above 45 years, eyes operated at the Iladevi institute with SA60AT AcrySof IOL implantation, and eyes with BCVA of 6/6 and J1. Exclusion criteria were previous ocular trauma, retinal pathology, visible zonulysis, pseudoexfoliation syndrome, glaucoma, uveitis, and previous refractive surgery.

All the participants had IOL power calculation preoperatively using the SRK II formula[21] with immersion A-scan ultrasonography on OcuScan R_xP (Alcon Laboratories). The target refraction was −0.5 diopter (D). All the surgeries were performed by a single surgeon (A.R.V.) using the standardized surgical technique of phacoemulsification with the implantation of AcrySof SA60AT IOL in the capsular bag.[22–24]

Examination

All patients in the case and control groups had complete eye examinations. Subjective refraction was done after retinoscopy in cases and controls. All the refractions were entered in an Excel file (Microsoft Inc.). Astigmatism was transformed into the myopic cylinder. The spherical equivalent for distance was calculated in each eye. The factors analyzed in cases and controls were corneal astigmatism, pupil size, axial IOL movement, amplitude of accommodation, axial length, and age, which were assessed by a single observer who was masked to the recruitment of the participant to either the case or control group.

Corneal astigmatism was assessed with the Humphrey topographer (Carl Zeiss Meditec) under constant room illumination before instillation of any medication. In each eye, measurements were repeated 5 times to obtain a well-focused, properly aligned image of the eye. During the interval between the measurements, patients were allowed to blink their eyes normally. A difference of more than 0.50 D between the 2 meridians was defined as corneal astigmatism. Corneal topographic astigmatism was interpreted as against-the-rule (ATR) when the steepest meridian was at 180 ± 15 degrees; with the rule (WTR) when the steepest meridian was at 90 ± 15 degrees; and oblique (OB) when the steepest meridian was between the range of ATR and WTR (ie, 45/135 ± 30 degrees). Pupil size was noted on the videokeratography display by asking the patient to fixate on the center of the Placido mapping at standard illumination.

Axial IOL movement was measured using the immersion mode on OcuScan R_xP A-scan ultrasonography as a difference in anterior chamber depth (ACD) after instillation of cyclopentolate 1% (Cyclopent) and subsequently pilocarpine nitrate 2% (Carpinol) at 2 separate visits.[25] Before instillation of pilocarpine nitrate 2% and cyclopentolate 1%, appropriate counseling was given about the side effects of the eyedrops. Pilocarpine nitrate 2% was instilled twice 5 minutes apart. Anterior chamber depth was measured 30 minutes after the first instillation. In a separate visit 1 week later, cyclopentolate 1% was instilled twice 5 minutes apart. Cycloplegic ACD measurements were also taken 30 minutes after the instillation of the first drop. At least 10 ACD measurements were taken at each visit. The machine gave the average of the 10 best readings, which was taken as the final reading. Axial IOL movement was calculated as the difference between the ACD measurements on these 2 visits, with pilocarpine nitrate 2% and cyclopentolate 1%.

The amplitude of accommodation was measured using the retinoscopy method (Streak Retinsocope, Welch Allyn).[26] For distance retinoscopy, patients were asked to fixate on a visual chart projected at a distance of 5 m. For near retinoscopy, patients were asked to maximally fixate on a chart mounted on the streak retinoscope at a distance of 33 cm. The difference between distance and near refraction on the retinoscopy was the amplitude of accommodation in diopters.

Axial length measurement was done on the OcuScan R_xP immersion ultrasound with a sound velocity of 2120 m/s for the lens (on the pseudophakic acrylic mode) and 1532 m/s for the anterior chamber and vitreous. Ten readings were taken on the machine. Readings with a variation of 0.2 mm or more were discarded, and an average of the readings with a variation of 0.2 mm or

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less was treated as the value of axial length. Age was noted during the recruitment of patients in each group.

Statistical Analysis

Data were entered in an Excel spreadsheet and imported into the Systat statistical package (version 8.0, SPSS) for Windows. The test of proportion was applied to the numeral frequencies of the factors in cases and controls. In the study, the phenomenon of possessing good UCVA for distance and near vision can be expressed as 2 values, presence (cases) or absence (controls), making the dependent variable a binary outcome. Therefore, logistic regression was used to assess the significance of the factors in a multivariate scenario. The model establishes a relationship between probabilities of occurrence of an event based on different values generated by independent variables by means of log odds. These log odds can be converted to represent odds of an event. When more than 1 independent variable is used in the model, these coefficients are adjusted for effects of other variables. The 95% confidence intervals were determined. The Mann-Whitney *U* test was also applied for amount of astigmatism by comparing the medians of ATR, WTR, and OB. The Fisher exact test was applied to determine the association between amount of astigmatism (<0.5 D and ≥0.5 D) and type of astigmatism (axis = ATR versus WTR + OB) in cases and in controls. A Kruskal-Wallis test was applied to check the difference in amount of accommodation by axis and amount of astigmatism (<0.5 D or ≥0.5 D). This test was applied separately in the test and control groups and in both groups taken together.

The test of proportion revealed significance only in ATR corneal astigmatism. A dummy of ATR corneal astigmatism was used to help obtain the odds of possessing good UCVA for distance and near vision when ATR occurred compared to WTR and OB taken collectively as a reference category. A dummy variable is a binary variable. It is coded as 1 for the category of interest (ATR) and 0 for the reference category (WTR and OB collectively). The explanation of a dummy variable is as follows: When there are different subgroups in a single factor (astigmatism in this study) analyzed using multiple logistic regression, each subgroup (ATR, WTR, and OB) cannot be taken as an individual factor. All nonsignificant subgroups (WTR and OB) are put together into a reference category in comparison with a significant subgroup (ATR in the present study).

The model used here is stated as: Probability of occurrence of the phenomenon of possessing good UCVA for distance and near vision = $1/(1+e^{-Z})$, where Z = b0 + b1 (dummy for ATR on corneal topography versus WTR and OB collectively) + b2 (decadal age) + b3 (pupil size) + b4 (axial IOL movement) + b5 (amplitude of accommodation) + b6 (axial length). The factors evaluated were corneal topographic astigmatism, pupil size, axial IOL movement, amplitude of accommodation, axial length, and age.

RESULTS

In this study, 350 patients were screened. Mean postoperative duration was 3.75 months ± 2.35 (SD) (range 2 to 6 months) in cases and 3.78 ± 2.33 months (range 2 to 6 months) in controls. There was no significant difference in the mean spherical equivalent (−0.45 ± 0.63 D [range 0.75 D to −1.75 D]) in cases versus that in controls (−0.35 ± 0.83 D [range = 1.75 D to −2.5 D]) (P = .61) (Figures 1 and 2).

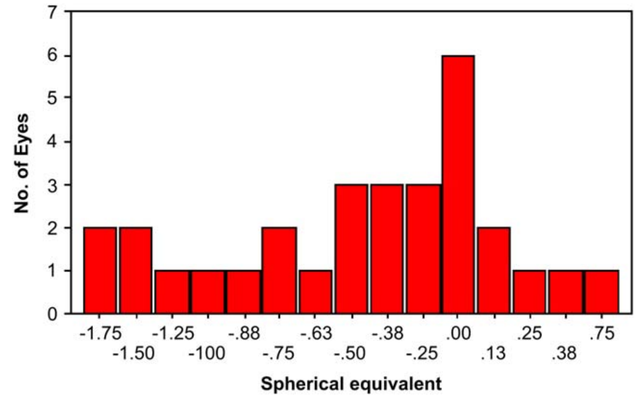

Figure 1. Postoperative refraction as spherical equivalents in cases.

The mean age of 30 cases (14 men, 16 women) was 61.9 ± 7.12 years (range 47 to 75 years) and the mean age of 30 controls (19 men, 11 women) was 61 ± 5.8 years (range 47 to 75 years). Mean, standard deviation, and the range of factors in cases and controls were as follows: ATR corneal astigmatism of 0.76 ± 0.33 D (range 0.37 to 1.25 D) and 1.01 ± 1.06 D (range 0.62 to 2.57 D); WTR corneal astigmatism of 1 ± 0.45 D (range 0.48 to 1.5 D) and 0.56 ± 0.14 D (range 0.46 to 1.75 D); OB astigmatism of 0.58 ± 0.36 D (range 0.27 to 1.32 D) and 1.05 ± 0.13 D (range 0.32 to 1.63 D); pupil size of 3.02 ± 0.35 mm and 3.14 ± 0.34 mm; axial IOL movement of 0.72 ± 0.62 mm and 0.67 ± 0.61 mm; amplitude of accommodation 0.85 ± 0.52 D and 0.75 ± 0.59 D; and axial length of 23.11 ± 0.88 mm and 23.69 ± 1.36 mm, respectively.

Table 1 shows the numerical frequencies of factors in cases and controls. The test of proportion revealed significance only in ATR corneal astigmatism (P = .02). Fifty percent of the patients with pseudoaccommodation were in the age group of 60 to 69 years, and only 10% of the patients were younger than 50 years.

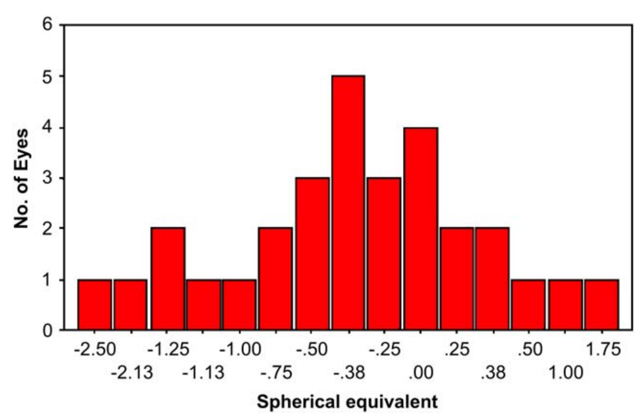

Figure 2. Postoperative refraction as spherical equivalents in controls.

Table 1. Number of frequencies of factors in cases and controls.

Factors	Eyes (%)		*P* Values of the Test of Proportion*
	Cases (n = 30)	Controls (n = 30)	
Corneal astigmatism (D)†			
ATR	11 (36.7)	4 (13.3)	0.02
WTR	6 (20.0)	9 (30.0)	0.28
OB	13 (43.3)	17 (56.7)	0.28
Pupil size (mm)‡			
≤2.5	2 (6.7)	1 (3.3)	0.7
>2.5	28 (93.3)	29 (96.7)	0.83
IOL shift (mm)¶			
Up to 0.99	18 (60.0)	22 (73.3)	0.37
≥1	12 (40.0)	8 (26.7)	0.21
Age (y)			
<50	3 (10.0)	3 (10.0)	NR
50 to 59	6 (20.0)	6 (20.0)	NR
60 to 69	15 (50.0)	15 (50.0)	NR
70+	6 (20.0)	6 (20.0)	NR

ATR = against the rule; NR = not required; OB = oblique; WTR = with the rule
*Test of proportions applied on row percentages
†Videokeratography done with Zeiss Humphrey's corneal topographer
‡Measured on videokeratography
¶Calculated as a difference in ACD during pharmacologic cycloplegia (cyclopentolate 1%) and ciliary muscle stimulation (pilocarpine nitrate 2%) with immersion A-scan ultrasound

Table 2 shows the results of multivariate logistic regression. Against-the-rule corneal astigmatism, compared to WTR and OB collectively, was found to be statistically significant. Against-the-rule corneal astigmatism increased the odds of occurrence of pseudoaccommodation 10 times as compared to other types of corneal astigmatism. The rest of the factors analyzed in this study were not associated with the phenomenon of pseudoaccommodation.

The Mann-Whitney *U* test on the medians in cases versus controls was ATR: 0.72 D versus 0.6 D ($P = .95$); WTR: 1 D versus 0.57 D ($P = .13$); and OB: 0.55 D versus 0.94 D ($P = .32$). The Fisher exact test did not show any association between type of astigmatism (WTR and OB versus ATR) and amount of astigmatism (<0.5 D and ≥0.5 D) ($P = .64$ in controls and $P = .25$ in cases). The Kruskal-Wallis test showed that the type and amount of astigmatism were not significant in controls ($P = .25$) and cases ($P = .58$) taken separately and together ($P = .37$).

DISCUSSION

The present study, on the basis of multiple logistic regression analysis, shows the role of ATR corneal astigmatism in good uncorrected distance and near vision after monofocal IOL implantation. Other factors analyzed were not found to play a significant role.

Table 2. Results of multivariate logistic regression analysis.

Factors	B	SE	Wald	df	Sig	Exp (B)	95% CI for Exp (B)	
Corneal astigmatism*	2.321	0.882	6.921	1	0.009	10.189	1.807	57.443
Pupil size	−0.810	0.922	0.771	1	0.380	0.445	0.073	2.713
Optic shift	0.331	0.508	0.425		0.514	1.393	0.514	3.773
Amplitude of accommodation	1.081	0.586	3.401	1	0.065	2.948	0.934	9.303
Axial length	−0.601	0.318	3.586	1	0.058	0.548	0.294	1.021
Age	−0.016	0.349	0.002	1	0.963	0.984	0.497	1.949
Constant	14.984	7.097	4.458	1	0.035	3217146		

B = log odds; CI = confidence interval; Df = degrees of freedom; Exp (B) = odds; SE = standard error; Sig = significance (*P* value); Wald = Wald statistic
*ATR corneal astigmatism as compared to WTR and OB collectively

Langenbucher et al.[27,28] showed in pseudophakic eyes the ability to see improved near vision as pseudophakic accommodation and pseudophakic pseudoaccommodation. They defined pseudophakic accommodation as a dynamic change in the refractive state of the eye caused by interactions between the contracting ciliary muscle and the zonular capsular bag IOL, resulting in a change in refraction at near fixation. They defined pseudophakic pseudoaccommodation as static optical properties of the pseudophakic eye independent of the ciliary muscle, resulting in improved uncorrected near vision.

The phenomenon of possessing good UCVA for distance and near vision after monofocal IOL implantation has been attributed to optical properties of the eye and IOL system, including movement of the IOL along the anterior–posterior axis,[15,16] enhanced depth of focus associated with myopic astigmatism,[1,4–12] corneal multifocality,[19] and corneal aberrations.[20] Moreover, age was also found to be inversely related to this phenomenon.[18] Studies analyzing this phenomenon have compared it with phakic eyes,[2,3,12,13] without any comparative group,[1,4,6,7,9–11,16,19] in an in vitro setup,[17] or as a single factor.[1,4–14] Therefore, we designed this study to evaluate more than 1 factor contributing to this phenomenon of pseudoaccommodation[4,5,6,13,27–30] in the clinical scenario in which controls were also pseudophakic. The control group was also homogeneous with regard to the type of IOL implanted. It is very important that controls are also identical to cases except for inadequate UCVA for distance and near vision. To avoid recruitment bias in the control group, only patients who had a BCVA of 6/6 for distance and N6 for near vision were recruited in both groups. Similarly, we opted to recruit only patients with eyes operated on for senile uncomplicated cataracts because larger amplitude of accommodation has been reported in young individuals.[16] We examined patients 2 to 6 months after implantation of an AcrySof SA60AT IOL, although studies have shown that this IOL stabilizes as early as 1 month following implantation.[31]

Corneal topography has been a recognized method to evaluate postoperative astigmatism.[32] An alternative method to evaluate astigmatism is keratometry. Although we were aware that aberrometry would be more precise, due to the lack of availability of this technology, we opted for corneal topography.

Refractive errors following cataract surgery have been found to be responsible for pseudoaccommodation. Datiles and Gancayco[11] reported that low myopia with low astigmatism could lead to good uncorrected distance and near vision. Following extracapsular cataract extraction, they found a mean spherical error of -2 ± 0.88 D and a mean cylindrical error of 1.75 ± 0.89 D. Huber[1,4] also noted myopic astigmatism of up to 2 D without accompanying spherical error or a compound astigmatism of up to 3 D, allowing adequate visual acuity for distance and near. From these studies, it is not clear whether the astigmatism was ATR or WTR. Bradbury et al.[10] also concluded that refraction with no spherical error and only a myopic astigmatism of -1.5 D at 180 degrees giving WTR is desirable for good postoperative 6/12 and N/10 vision in 82% of cases. Trinidade et al.[8] and our previous study[9] showed that eyes with no spherical error and only low ATR myopia can have good visual acuity for reading and distance. It is known that ATR astigmatism improves the clarity of English letter types. In the present study, we can explain the role of ATR astigmatism in cases based on Sturm's conoid principle. In eyes with ATR astigmatism, the focal line from a distant object closest to the retina is the horizontal one, while the focal line from a nearby object closest to the retina is the vertical one. As we had measured visual acuity using the English language, whose alphabet has a pronounced vertical element, we believe that the phenomenon of Sturm's conoid might have helped patients read well. It would be more interesting to assess UCVA in such eyes using different languages. On applying test of proportions for factors in cases and controls, it was observed that only ATR corneal astigmatism was significant. We found it logical to apply multiple logistic regression to access the interplay of potential factors responsible for this phenomenon. Since ATR astigmatism revealed statistical significance on multivariate analysis, we further analyzed the role of astigmatism in detail using the Mann-Whitney *U* test, Fisher exact test, and Kruskal-Wallis test. However, none of the tests showed significance with regard to the amount of ATR, indicating the need for a larger sample size.

We decided to measure the pupil size on the videokeratography display because it was an easy and accepted method for pupil size measurement.[19,20] Other alternative methods include the use of a digital infrared pupillometer[33] or a fixed pupil size using a contact lens.[13] It has been shown that in eyes with pseudoaccommodation, a small pupil contributes to a large depth of focus.[2,3,12–14] Nakazawa and Ohtsuki[2,3] reported that apparent accommodation was inversely proportional to the pupillary diameter. In another study, Elder et al.[13] reported increased depth of focus with a pupil size of approximately 2.5 mm with -0.75 D myopia and in the absence of astigmatism. Charman[34] reported that a large pupil size with spherical aberrations could also increase the depth of focus in these pseudophakic eyes. Fukuyama et al.,[19] while measuring pupil size on videokeratography under standard room illumination, did not find a strong significant correlation between pseudoaccommodation and pupil size. Our results concur with those in the previous study.[19] We speculate that the insignificant difference between the groups in the present study could be because more than 90% of the eyes had a pupil larger than 2.5 mm.

Axial movement of the IOL can be measured using an objective method such as anterior segment optical coherence tomography or ultrasound biomicroscopy. However, we measured the axial movement of the IOL by calculating the difference in the ACD applying the pharmacologic method.[1–5,19,25,27–29,35] Although it is an indirect method, it is well accepted because it does not rely on patient compliance during the measurement procedure.[35] Studies have noted the change in ACD while calculating the effect of IOL movement on pseudoaccommodation.[16,17,25,29] For measuring ACD, apart from immersion A-scan ultrasonography, using the IOLMaster (Zeiss) based on partial coherence interferometry[25] could have been more precise.

Lesiewska-Junk and Kałużny,[16] using A-scan ultrasonography, showed that a shift of 0.42 mm (mean) in patients between 12 years and 19 years attained a pseudoaccommodation amplitude of 4.50 D. Another experiment showed that a 1 mm shift could result in different pseudoaccommodation amplitude depending on the axial length of the eye.[17] Due to the indirect method used in our study, we probably obtained higher values for axial IOL movement in cases (0.72 $\pm$ 0.62 mm) and controls (0.67 $\pm$ 0.61 mm). This can probably be attributed to pilocarpine and cyclopentolate because they are known to cause significant changes in the anterior eye segment morphology, which does not mimic natural processes during physiologic accommodation.[36–38] Legeais et al.,[39] using A-scan ultrasonography, reported that an axial movement of 0.28 $\pm$ 0.38 mm of the silicone foldable IOL bore no significant relationship to pseudoaccommodation. Also Findl et al.,[25] using dual-beam partial coherence interferometry, found that the magnitude of IOL movement was relatively small, resulting in an estimated accommodative amplitude of less than 0.5 D in most patients. Langenbucher et al.[27] found that the forward movement of the IOL corresponds to a theoretical accommodating amplitude that was low (0.29 D or 0.32 D). Findl et al.[25] and Langenbucher et al.[27] have reported accommodative amplitude in a population comprised of different IOL designs: ring haptic, plate haptic, 3-piece poly(methyl methacrylate), AcrySof, and Sensar.

Amplitude of accommodation is measured using subjective and objective methods.[40,41] Subjective methods include defocusing,[41] focometer,[40] or the push-up test using an Royal Air Force (RAF) ruler,[2,3,12,16,18–20] while objective methods include retinoscopy[40,41] and pilocarpine-stimulated accommodation on an autorefractometer.[41] A drawback of pilocarpine stimulation is that the small pupil diameters make refraction measurements difficult.[34,40] Langenbucher et al.,[28] upon analysis of accommodation after accommodating posterior chamber IOL implantation, concluded that accommodation should be assessed with several subjective and objective techniques. We used the retinoscopy method as studies testing the accuracy of the subjective push-up method (RAF ruler test) have shown that the outcome of the measurement is affected by different factors (eg, depth of focus, target size, illumination, endpoint criteria, proximal cues, pupil size, and subject variability), generally resulting in an overestimation of the true accommodative amplitude.[40] Retinoscopy, being an objective method, was preferred in the present study. To standardize our technique, a single observer (M.A.N.) performed all the retinoscopic examinations under constant room illumination with a fixed distance in all patients. Various studies have used subjective methods to assess the amplitude of accommodation. Nakazawa and Ohtsuki[2,3] reported mean pseudoaccommodation of 2.03 $\pm$ 1.03 D with the Ishihara near-point meter, Elder et al.[13] reported a pseudoaccommodation of 1.27 $\pm$ 0.57 D with the defocusing method, and Yamamoto and Adachi-Usami[12] reported a pseudoaccommodation of 5.14 D with visual-evoked potential. In the present study, we attained values that were less than those reported earlier. It is interesting that in the present study, no statistically significant difference was observed in the mean amplitude of pseudoaccommodation in cases and controls.

In the present study, there was no correlation between axial length and pseudoaccommodation. These data are in agreement with the results in previous reports by Nakazawa and Ohtsuki,[2,3] who found no correlation between axial length and pseudoaccommodation. However, in a laboratory study, Nawa et al.[17] correlated axial length to varying pseudoaccommodation. Using a ray-tracing equation, they suggested that when the IOL optic moves forward by 1 mm, the pseudophakic pseudoaccommodation is 0.8 D in long eyes and 2.3 D in short eyes.[17]

In the present study, age was not found to correlate with pseudoaccommodation. Hayashi et al.[18] reported a linear decrease in pseudoaccommodation with age in patients ranging in age from less than 40 years to 80 years. Since our study included patients who were 40 years and older, we could not establish age as a factor contributing to pseudoaccommodation.

Corneal multifocality (refractive power gradient in the pupillary area) has enabled patients to have good uncorrected distance and near vision in the presbyopic age.[19] Corneal multifocality, along with coma-like aberrations, has also been shown to have a significant positive relationship with the amount of pseudoaccommodation.[20] However, in our study, no measurements were taken of corneal multifocality and of higher-order aberrations such as spherical and coma because of the lack of technology. It is likely that such measurements could have played an interactive role in this phenomenon.

The implication of this study is that the clinician may not consider correcting ATR astigmatism present before surgery. This study opens avenues for further research on the factors affecting pseudoaccommodation comparing monofocal and multifocal IOL implantation.

To summarize, this study evaluated the factors contributing to good unaided distance and near vision in cases and controls after monofocal IOL implantation. This study does not rule out the possibility of other factors such as higher-order aberrations, which were not evaluated. The results suggest that ATR corneal astigmatism plays an interactive role in good uncorrected distance and near vision after monofocal IOL implantation.

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