Factors Affecting Near Vision After Monofocal Intraocular Lens Implantation

Dong Hui Lim, MD; Jong Chul Han, MD; Myung Hun Kim, MD; Eui-Sang Chung, MD, PhD; Tae-Young Chung, MD, PhD

ABSTRACT

PURPOSE: To identify factors that influence near vision after monofocal intraocular lens (IOL) implantation for distance vision.

METHODS: A retrospective review was conducted of patients who underwent cataract surgery with monofocal IOL implantation from October 2009 to April 2010 at Samsung Medical Center. Eyes were classified as having good (⩾ J4) or poor (< J4) near vision. Factors analyzed included age, sex, intraocular lens (IOL) movement, axial length, pupil size, degree and type of astigmatism, IOL type, total aberration, and higher-order aberrations. Binary logistic regression and odds ratios with 95% confidence intervals were determined.

RESULTS: This retrospective study involved 84 eyes of 84 patients. Thirty-four eyes were classified as having good near vision and 50 eyes as having poor near vision. All groups had a postoperative uncorrected visual acuity greater than 0.2 logMAR (Snellen 20/32) and a refractive error within ± 0.5 diopter of spherical equivalent. Pupil size and axial length were inversely associated with good near vision (*P* = .034 and .039, respectively). A pupil size smaller than 2.6 mm and an axial length less than 23.0 mm resulted in better near vision than larger measurements after monofocal IOL implantation for distant target.

CONCLUSIONS: Among the factors analyzed, small pupil size and short axial length predicted good near vision after phacoemulsification and monofocal IOL implantation.

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Surgical techniques for intraocular lens (IOL) implantation and the lenses for implantation have improved substantially. Although IOLs are biocompatible and usually restore excellent visual acuity, postoperative near visual acuity in pseudophakic eyes is often suboptimal, and most patients need glasses for near vision. Multifocal IOLs provide good near and distance vision in many patients; however, the disadvantages include high cost, symptomatic halos, and worse best-corrected visual acuity than with monofocal IOLs.[1-4] Furthermore, multifocal IOL implantation is not appropriate in the presence of definite astigmatism or retinal problems.[1,2,4-6]

Some patients with pseudophakic eyes have good near and distance vision after monofocal IOL implantation.[7-18] This phenomenon is referred to as apparent accommodation or pseudoaccommodation. Factors reported to influence postoperative near vision include age,[7] astigmatism,[8-10,19,20] pupil size,[11-15] axial length,[10,16] axial IOL movement,[17,20] corneal multifocality,[18,21] and aberrations.[18]

The large number of factors that may be involved[7-21] and inconsistent findings between studies make the data difficult to interpret. In the current study, we included many of the factors previously investigated, aiming to identify those most strongly associated with good near vision after monofocal IOL implantation.

PATIENTS AND METHODS

Cataract surgeries with monofocal IOL implantation performed from October 2009 to April 2010 at Samsung Medical Center, Seoul, Korea, were retrospectively reviewed. All of these eyes had uneventful phacoemulsification with mono-

From the Department of Ophthalmology, Samsung Medical Center, Sungkyunkwan University School of Medicine, Seoul, Korea.

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Correspondence: Tae-Young Chung, MD, PhD, Department of Ophthalmology, Samsung Medical Center, Sungkyunkwan University School of Medicine, 50 Irwon-dong, Gangnam-gu, Seoul 135-710, Korea. E-mail: tychung@skku.edu

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focal IOLs (Acrysof IQ SN60WF; Alcon Laboratories, Inc., Fort Worth, TX) implanted in the capsular bag. The target refraction of the IOL implantations was emmetropia. The patient charts at 1 to 3 months postoperatively were reviewed. The Institutional Review Board at Samsung Medical Center approved the study protocol.

Inclusion criteria were pseudophakia, age older than 45 years, postoperative refractive error within ± 0.5 diopter (D) of spherical equivalent, postoperative astigmatism within ± 0.75 D, and postoperative uncorrected visual acuity greater than 0.2 logMAR (Snellen 20/32). The illumination at the eye was kept at approximately 250 to 300 lux, which simulated daytime conditions. Exclusion criteria were previous ophthalmic surgery, significant ophthalmic disease including retinal pathology, visible zonulysis, pseudoexfoliation syndrome, glaucoma, uveitis, and complications during surgery.

Visual acuity measurements (best corrected and uncorrected) were recorded using the logMAR chart at 3 months postoperatively. Near visual acuities were measured using the Jaeger chart. Eyes were classified as having good (⩾ J4) or poor (< J4) near vision.

We analyzed age, sex, axial IOL movement, axial length, pupil size, corneal multifocality, degree and type of astigmatism, total aberrations, and higher-order aberrations.

Axial length and axial IOL movement (measured as the difference between anterior chamber depth on two separate visits) were assessed using an IOLMaster (Carl Zeiss Meditec, Jena, Germany).[22] Anterior chamber depth measurements were performed 30 minutes after instilling pilocarpine 2% at the first visit and after instilling cyclopentolate 1% at the second visit.

Pupil size and corneal multifocality were measured using an Orbscan IIz (Bausch & Lomb, Irvine, CA) under photopic conditions. The refractive gradient of the cornea measured by the Orbscan IIz was used as an index of corneal multifocality, which was calculated as the difference between the biggest and smallest diopters within the pupillary area of each eye.[18]

The amount and type of astigmatism were measured by the WASCA (Carl Zeiss Meditec) and transformed into a myopic cylinder. Astigmatism was interpreted as with the rule when the steepest meridian was 90 ± 15 degrees, as against the rule when the steepest meridian was 180 ± 15 degrees, and as oblique when the steepest meridian was between the ranges of with the rule and against the rule. Total and higher-order aberrations for a pupil with 5.0-mm diameter were also measured using the WASCA.

Statistical analyses were performed using SPSS for Windows (version 18.0; SPSS Inc., Chicago, IL). Differences between parameters of the good and poor near vision groups were assessed using independent sample *t* tests and the chi-square test. Because the uncorrected near vision outcomes were grouped in this way, the dependent variables (factors) in regression analysis gave binary outcomes and binary logistic regression was used to assess the significance of the factors. Cut-off values were calculated using the minimum *P* value approach. The 95% confidence interval values were calculated.

RESULTS

This retrospective study analyzed the data for 84 eyes in 84 patients (29 men, 55 women). The mean postoperative follow-up duration was 2.38 ± 0.74 months for the good near vision group and 2.42 ± 0.57 months for the poor near vision group. The mean age of the patients was 65.7 ± 9.9 years (range: 46 to 83 years). Thirty-four eyes were classified as having good near vision, whereas 50 eyes were classified as having poor near vision.

The mean postoperative uncorrected distance visual acuity was 0.04 ± 0.06 logMAR (decimal 0.94 ± 0.09) for the good near vision group and 0.07 ± 0.07 logMAR (decimal 0.89 ± 0.11) for the poor near vision group. The mean postoperative best-corrected distance visual acuity was 0.02 ± 0.04 logMAR (decimal 0.97 ± 0.08) for the good vision group and 0.03 ± 0.05 logMAR (decimal 0.95 ± 0.09) for the poor vision group. The two groups did not differ significantly in either uncorrected distance visual acuity or best-corrected distance visual acuity (P = .086 and .305, respectively).

Table A (available as supplemental material in the PDF version of this article) shows the means and standard deviations for each factor in the good and poor near vision groups. Axial length (23.32 ± 1.06 and 24.01 ± 1.30 mm) and pupil size (3.24 ± 0.58 and 3.61 ± 0.65 mm) were the only two factors that differed significantly between the two groups. **Table 1** shows the results of binary logistic regression analysis. Small pupil size and short axial length were the only two factors associated with good near vision after IOL implantation (P = .039 and .034, respectively). The accepted cut-off value was 2.6 mm (P = .04) for pupil size and 23 mm (P = .027) for axial length.

DISCUSSION

The mechanisms for apparent accommodation or pseudoaccommodation remain unclear, possibly because multiple factors are involved. Most investigations of these factors report findings for only one or two of them. We consider it important to investigate

TABLE 1

Results of Binary Logistic Regression Analysis

Factor	B	SE	Wald	df	*P*	Exp (B)	95% CI for Exp (B)
Age	-0.043	0.031	1.898	1	.168	0.958	0.885, 1.005
Sex	0.178	0.730	0.059	1	.807	1.195	0.221, 3.977
IOL movement	0.285	0.632	0.203	1	.652	1.330	0.307, 3.510
Axial length	-0.771	0.375	4.242	1	.039	0.462	0.181, 0.779
Type of astigmatism	-0.061	0.399	0.023	1	.879	0.941	0.416, 4.945
Amount of astigmatism	0.617	0.738	0.697	1	.404	1.853	0.571, 10.419
Pupil size	-1.253	0.592	4.476	1	.034	0.286	0.134, 0.969
Corneal multifocality	0.305	0.348	0.771	1	.380	1.357	0.737, 2.980
RMS total aberration	1.598	1.421	1.265	1	.261	4.942	0.621, 11.084
RMS HoA	-3.753	3.148	1.421	1	.233	0.023	0.003, 8.462
RMS Z^4_0	-0.354	1.218	0.084	1	.771	0.702	0.065, 7.637
RMS Z^3_3	1.054	0.990	1.134	1	.287	2.869	0.412, 19.957
RMS Z^3_{-3}	0.005	1.314	0.000	1	.997	1.005	0.076, 13.204
RMS Z^3_1	-0.286	1.209	0.056	1	.813	0.752	0.070, 8.035
RMS Z^3_{-1}	0.459	1.279	0.129	1	.720	1.582	0.129, 19.413

B = log odds; SE =standard error; Wald = Wald statistic; df = degrees of freedom; Exp (B) = odds; CI = confidence interval; IOL = intraocular lens; RMS = root mean square; HoA = higher-order aberrations

multiple potential factors because interactions between factors may introduce bias or confounding. In a recent case–control study of factors related to uncorrected visual acuity for distance and near vision following monofocal IOL implantation, Nanavaty et al.[10] analyzed corneal astigmatism, pupil size, axial IOL movement, amplitude of accommodation, axial length, and age. Of these factors, only against-the-rule astigmatism was associated with pseudoaccommodation. Our study included more factors than in previous studies, notably corneal multifocality and ocular aberrations.

Our study revealed associations of smaller pupil size (*P* = .034) and short axial length (*P* = .039) with good near vision. Previous studies also support this relationship. Nakazawa and Ohtsuki found an inverse relationship between pseudoaccommodation and pupillary diameter.[11,12] Why small pupil size is related to good near vision is not entirely clear, but it could be that small pupils have greater depth of focus in eyes with pseudophakia.[13,15] The advantage of short axial length may be explained by an inverse effect of axial length on accommodation for a given amount of IOL movement. Nawa et al.[16] showed that as the posterior chamber of the IOL moves forward 1.0 mm, shorter eyes accommodate proportionately more than longer eyes. The accommodation per 1.0 mm of forward IOL movement varied from 0.8 D in an eye with a 27.0 mm axial length (long eye) to 2.3 D in an eye with a 21.0 mm axial length (short eye). Because the good and poor near vision groups in our study did not differ significantly in IOL movement (*P* = .652), it is plausible that short axial length correlated with good near vision.

The cut-off values for pupil size and axial length associated with good near vision after IOL implantation were calculated using the minimum *P* value approach, and the results were 2.6 mm (*P* = .04) and 23 mm (*P* = .027), respectively. Preoperative and postoperative axial lengths are not expected to differ and changes in pupil size reported after uneventful phacoemulsification are not significant.[23,24] These results suggest that good postoperative near vision may be expected if the patients have pupils less than 2.6 mm and axial lengths less than 23 mm before surgery.

In contrast to these results, Nanavaty et al.[10] did not find pupil size to be a significant factor in pseudoaccommodation. The reasons for this difference may not be explained with certainty; however, differences in the devices and environments used for measurement of pupil size may potentially contribute. We used an Orbscan IIz instead of the pupillometer or videokeratography. We find it difficult to set illumination for pupil size measurements under standard room illumination as used in most previous studies, and small differences in illumination may significantly change pupil size.

Low myopia and low astigmatism are measurable factors that may affect near and distance vision after cataract surgery.[25] For this study, we selected patients with spherical equivalent within ± 0.5 D to exclude myopia as a factor in near vision. Against-the-rule astigmatism is known to affect near vision.[8,10] In this study, the incidences of against-the-rule astigmatism were 53.0% and 50.0% in the good and poor near vision groups, respectively. The amount of astigmatism was -0.71 ± 0.44 D in the good near vision group and -0.70 ± 0.43 D in the poor near vision group. We expected to find correlations between near vision and the type or amount of astigmatism, but no correlations were found in either group. This may reflect a lower average degree of astigmatism in our study than in previous reports.[8,10]

Several studies show that aberrations[18,26,27] are associated with good near vision after monofocal IOL implantation. Oshika et al.[18] suggested that coma-like aberrations contribute to apparent accommodation in pseudophakic eyes. However, we found no correlations between good near vision and either total or higher order aberrations. This may be explained by our use of the WASCA in the current study to measure ocular aberrations rather than corneal topography to measure corneal aberrations in the previous studies. The WASCA measures ocular aberrations as the sum of corneal aberration and internal aberrations induced by the intraocular lens, aqueous humor, and vitreous body. In addition, the difference in spherical aberration between the good and poor near vision groups would probably be too small to generate significant effects on pseudoaccommodation because only one type of monofocal aspheric IOL (Acrysof IQ SN60WF) was used in our study. Denoyer et al.[26] compared near vision following implantation of IOL with no aberration and with negative spherical aberration, and showed that IOLs with no aberrations resulted in better near vision quality. These results demonstrate that the relationship between spherical aberration and pseudoaccommodation can be affected by the amount of spherical aberration. Evaluation of additional types of IOLs, including spherical and aspherical IOLs, may yield interesting results.

Corneal multifocality has been suggested to be associated with good near vision after monofocal IOL implantation.[18] We detected no correlation between corneal multifocality and good near vision in the current study.

Contrary to some investigations, we found no association between pseudoaccommodation and age. For example, Hayashi et al.[7] reported that the amplitude of pseudoaccommodation after monofocal IOL implantation decreases significantly in proportion to age, with a progressive decline in best-corrected intermediate and near visual acuities. However, accommodation was not significantly different among patients in their 50s, 60s, and 70s. In our study, age showed no relationship to near vision, possibly because the average age of our patients was 65.7 years.

We designed this study to evaluate multiple factors that could potentially affect near vision quality after monofocal IOL implantation. We suggest cut-off values for significant factors to use in practice. However, several limitations to this study must be acknowledged, including the short length of follow-up (due to patient compliance), the possibility of confounding factors in our analyses, and the restrictions inherent in retrospective studies. Additionally, the amplitude of accommodation was not measured directly, but only in terms of visual acuity measurements.

According to uncorrected near visual acuity measurements, eyes were classified as having good or poor near vision. More uncontrolled variables are involved in uncorrected near than best corrected near visual acuity and reading speed may be a better measurement of functional near vision. The study was conducted retrospectively and therefore best corrected near visual acuity and reading speed were not tested. To compensate for this weakness, the authors statistically analyzed all possible factors through multivariate regression to exclude the compounding effect.

Knowledge of factors that promote good near vision after cataract surgery may lead to improved vision quality without glasses. Through testing of multiple factors, we showed in this study that small pupil size and short axial length may be significant determinants of good near vision after monofocal IOL implantation.

AUTHOR CONTRIBUTIONS

Study concept and design (E-SC, T-YC, JCH, DHL, MHK); data collection (JCH); drafting of the manuscript (JCH, DHL); critical revision of the manuscript (T-YC, DHL); statistical expertise (JCH, DHL); administrative, technical, or material support (MHK); supervision (E-SC, T-YC)

REFERENCES

1. Agresta B, Knorz MC, Kohnen T, Donati C, Jackson D. Distance and near visual acuity improvement after implantation of multifocal intraocular lenses in cataract patients with presbyopia: a systematic review. *J Refract Surg.* 2012;28:426-435.
2. Chang JSM, Ng JCM, Lau SYF. Visual outcomes and patient satisfaction after presbyopic lens exchange with a diffractive multifocal intraocular lens. *J Refract Surg.* 2012;28:468-474.
3. Zhao G, Zhang J, Zhou Y, Hu L, Che C, Jiang N. Visual function after monocular implantation of apodized diffractive multifocal or single-piece monofocal intraocular lens randomized prospective comparison. *J Cataract Refract Surg.* 2010;36:282-285.
4. Alió JL, Pinero DP, Plaza-Puche AB, et al. Visual and optical performance with two different diffractive multifocal intraocular lenses compared to a monofocal lens. *J Refract Surg.* 2011;27:570-581.
5. Muñoz G, Albarrán-Diego C, Javaloy J, Sakla HF, Cerviño A.

Combining zonal refractive and diffractive aspheric multifocal intraocular lenses. *J Refract Surg.* 2012;28:174-181.

6. Woodward MA, Randleman JB, Stulting RD. Reasons for patient dissatisfaction in eyes with phacoemulsification with multifocal intraocular lens implantation. *J Cataract Refract Surg.* 2009;35:992-997.
7. Hayashi K, Hayashi H, Nakao F, Hayashi F. Aging changes in apparent accommodation in eyes with a monofocal intraocular lens. *Am J Ophthalmol.* 2003;135:432-436.
8. Trindade F, Oliveira A, Frasson M. Benefit of against-the-rule astigmatism to uncorrected near acuity. *J Cataract Refract Surg.* 1997;23:82-85.
9. Bradbury JA, Hillman JS, Cassells-Brown A. Optimal postoperative refraction for good unaided near and distance vision with monofocal intraocular lenses. *Br J Ophthalmol.* 1992;76:300-302.
10. Nanavaty MA, Vasavada AR, Patel AS, Raj SM, Desai TH. Analysis of patients with good uncorrected distance and near vision after monofocal intraocular lens implantation. *J Cataract Refract Surg.* 2006;32:1091-1097.
11. Nakazawa M, Ohtsuki K. Apparent accommodation in pseudophakic eyes after implantation of posterior chamber intraocular lenses. *Am J Ophthalmol.* 1983;96:435-438.
12. Nakazawa M, Ohtsuki K. Apparent accommodation in pseudophakic eyes after implantation of posterior chamber intraocular lenses: optical analysis. *Invest Ophthalmol Vis Sci.* 1984;25:1458-1460.
13. Yamamoto S, Adachi-Usami E. Apparent accommodation in pseudophakic eyes as measured with visually evoked potentials. *Invest Ophthalmol Vis Sci.* 1992;33:443-446.
14. Elder MJ, Murphy C, Sanderson GF. Apparent accommodation and depth of field in pseudophakia. *J Cataract Refract Surg.* 1996;22:615-619.
15. Percival SP, Setty SS. Prospectively randomized trial comparing the pseudoaccommodation of the AMO ARRAY multifocal lens and a monofocal lens. *J Cataract Refract Surg.* 1993;19:26-31.
16. Nawa Y, Ueda T, Nakatsuka M, et al. Accommodation obtained per 1.0 mm forward movement of a posterior chamber intraocular lens. *J Cataract Refract Surg.* 2003;29:2069-2072.
17. Lesiewska-Junk H, Kaluzny J. Intraocular lens movement and accommodation in eyes of young patients. *J Cataract Refract Surg.* 2000;26:562-565.
18. Oshika T, Mimura T, Tanaka S, et al. Apparent accommodation and corneal wavefront aberration in pseudophakic eyes. *Invest Ophthalmol Vis Sci.* 2002;43:2882-2886.
19. Huber C. Planned myopic astigmatism as a substitute for accommodation in pseudophakia. *J Am Intraocul Implant Soc.* 1981;7:244-249.
20. Gonzalez F, Capeans C, Santos L, Suarez J, Cadarso L. Anteroposterior shift in rigid and soft implants supported by the intraocular capsular bag. *Graefes Arch Clin Exp Ophthalmol.* 1992;230:237-239.
21. Fukuyama M, Oshika T, Amano S, Yoshitomi F. Relationship between apparent accommodation and corneal multifocality in pseudophakic eyes. *Ophthalmology.* 1999;106:1178-1181.
22. Findl O, Kiss B, Petternel V, et al. Intraocular lens movement caused by ciliary muscle contraction. *J Cataract Refract Surg.* 2003;29:669-676.
23. Hayashi K, Hayashi H. Pupil size before and after phacoemulsification in nondiabetic and diabetic patients. *J Cataract Refract Surg.* 2004;30:2543-2550.
24. Doganay S, Bozgul Firat P, Emre S, Yologlu S. Evaluation of anterior segment parameter changes using the Pentacam after uneventful phacoemulsification. *Acta Ophthalmol.* 2010;88:601-606.
25. Datiles MB, Gancayco T. Low myopia with low astigmatic correction gives cataract surgery patients good depth of focus. *Ophthalmology.* 1990;97:922-926.
26. Denoyer A, Denoyer L, Halfon J, Majzoub S, Pisella PJ. Comparative study of aspheric intraocular lenses with negative spherical aberration or no aberration. *J Cataract Refract Surg.* 2009;35:496-503.
27. Shentu X, Tang X, Yao K. Spherical aberration, visual performance and pseudoaccommodation of eyes implanted with different aspheric intraocular lens. *Clin Experiment Ophthalmol.* 2008;36:620-624.

TABLE A

Comparison of the Factors Between the Good and Poor Near Vision Groups

Characteristic	Good Near Vision Group	Poor Near Vision Group	*P*
Postoperative UCVA (logMAR)	0.04 ± 0.06	0.07 ± 0.07	.086
Postoperative BCVA (logMAR)	0.02 ± 0.04	0.03 ± 0.05	.305
Near visual acuity (logMAR)	0.38 ± 0.05	0.68 ± 0.20	.001
Age (years)	63.80 ± 9.99	67.00 ± 9.86	.142
Sex			.200
Male	9 (26%)	20 (40%)	
Female	25 (74%)	30 (60%)	
IOL movement (mm)	0.52 ± 0.46	0.46 ± 0.45	.533
Axial length (mm)	23.32 ± 1.06	24.01 ± 1.30	.013
Pupil size (mm)	3.24 ± 0.58	3.61 ± 0.65	.009
Corneal multifocality (diopters)	2.30 ± 1.03	2.14 ± 0.76	.438
Amount of astigmatism	-0.71 ± 0.44	-0.70 ± 0.43	.771
Type of astigmatism			.920
With-the-rule	5 (15%)	9 (18%)	
Oblique	11 (32%)	16 (32%)	
Against-the-rule	18 (53%)	25 (50%)	
Total aberrations (RMS, μm)	0.71 ± 0.32	0.74 ± 0.34	.748
Higher-order aberrations (RMS, μm)	0.28 ± 0.10	0.32 ± 0.14	.122
Spherical aberration, Z^4_0 (RMS, μm)	0.21 ± 0.14	0.20 ± 0.22	.927
Horizontal trefoil, Z^3_3 (RMS, μm)	0.28 ± 0.19	0.33 ± 0.27	.257
Vertical trefoil, Z^3_{-3} (RMS, μm)	0.23 ± 0.20	0.22 ± 0.17	.912
Horizontal coma, Z^3_1 (RMS, μm)	0.31 ± 0.20	0.30 ± 0.19	.916
Vertical coma, Z^3_{-1} (RMS, μm)	0.23 ± 0.16	0.25 ± 0.20	.651

UCVA = uncorrected visual acuity; BCVA = best-corrected visual acuity; IOL = intraocular lens; RMS = root mean square