Effect of Multifocal Intraocular Lens on Contrast Sensitivity in Primary Angle-Closure Patients

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ABSTRACT

Objective: To study the effect of multifocal intraocular lens (MIOL) implantation on contrast sensitivity (CS) compared to monofocal intraocular lens (mIOL) in primary angle-closure (PAC) or primary angle-closure glaucoma (PACG) patients.

Materials and Methods: This prospective study included patients with PAC or PACG and visually significant cataract. Phacoemulsification with MIOL or mIOL (patient preference) was performed. Collected data included best-corrected distant visual acuity (BCVA), intraocular pressure (IOP), anterior chamber depth (ACD), and contrast sensitivity (CS) measured at spatial frequency 1.5, 3.0, 6.0, 12.0, and 18.0 cycles per degree (CPD) preoperatively, and at 2-6 months postoperatively. Preoperative and postoperative parameters were then compared.

Results: Of the 45 eyes from 35 patients that were enrolled, 33 eyes (15 PAC, 18 PACG) from 26 patients completed the study. Fourteen eyes (11 patients) received diffractive MIOL, and 19 eyes (15 patients) received aspheric mIOL. Preoperative CS was not significantly different between groups. Postoperatively, BCVA, and CS at each spatial frequency were significantly improved in both groups (all $p<0.001$). Mean postoperative CS at spatial frequency 1.5, 3.0, 6.0, 12.0, and 18.0 CPD was 28.03, 42.63, 44.84, 10.82, and 2.86 in the MIOL group, and 29.55, 49.63, 46.20, 16.83, and 7.09 in the mIOL group, both respectively. Postoperative CS was not significant different between groups at any spatial frequencies. IOP was decreased ($p=0.001$) and ACD increased ($p<0.001$) postoperatively in both groups.

Conclusion: No significant difference in visual acuity or contrast sensitivity was observed between MIOL and mIOL after cataract removal in patients with PAC/PACG.

Keywords: Effect; multifocal intraocular lens; monofocal intraocular lens; contrast sensitivity; primary angle-closure patients (Siriraj Med J 2023; 75: 501-507)

INTRODUCTION

Primary angle-closure glaucoma (PACG) is responsible for approximately half of all glaucoma blindness worldwide[1]; however, primary angle-closure (PAC) and PACG are more prevalent in Asians[2-4] than in Europeans.[5,6] Cataract surgery with intraocular lens (IOL) implantation in glaucoma eyes has been reported to improve visual acuity, and to reduce postoperative intraocular pressure (IOP) and the number of required medications.[7]

Reduction in IOP and the number of postoperative anti-glaucoma medications was reported to be greater in eyes with PACG than in eyes with open-angle glaucoma or without preexisting glaucoma.[7,8] Phacoemulsification with monofocal intraocular lens (mIOL) provides excellent visual quality, but spectacles are required to improve near vision. Multifocal intraocular lens (MIOL) was reported to achieve good overall vision (both near and distant) with less dependence on spectacles.[9,10] However, patients with MIOL may experience unwanted effects that included glare, halos, and reduced contrast sensitivity

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(CS) compared to mIOL.[11-13] Few studies have reported the use of MIOL in eyes with concurrent ocular diseases, especially glaucoma.[7,10,13] Since both MIOL and glaucoma can decrease CS, a potential interactive effect may limit the use of MIOL in eyes with coexisting cataract and glaucoma.[11,13] However, glaucoma eye with good disease control without visual field defect may benefit from cataract surgery and MIOL implantation.

The aim of this study was to investigate the effect of MIOL implantation on CS compared to mIOL implantation in patients with PAC or PACG.

MATERIALS AND METHODS

This prospective non-randomized clinical study was conducted at the Department of Ophthalmology of the Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand during January 2014 to December 2015. The study protocol and informed consent procedures were both approved by our center's institutional review board (IRB) (COA no. Si 384/2014). Each patient provided written informed consent prior to participation. Visually significant cataract patients aged >18 years with PAC or PACG who underwent prophylaxis peripheral iridotomy at least 2 months prior to participation were eligible for inclusion. Patients with preexisting glaucomatous visual field defect, except generalized depression; with any other concurrent ocular diseases that could affect visual acuity, except cataract; and/or, history of ocular inflammation or ocular surgery, except laser peripheral iridotomy, which is a routine procedure for treating PAC/PACG were excluded.

Primary angle closure was defined as an eye with invisible non-pigmented trabecular meshwork greater than 180 degrees and evidence of peripheral anterior synechiae on gonioscopy or history of increased IOP (>21mmHg) without glaucomatous optic disc appearance, or glaucomatous pattern visual field damage. Primary angle closure glaucoma was defined as an eye with invisible non-pigmented trabecular meshwork greater than 180 degrees on gonioscopy with glaucomatous optic damage (cup-to-disc ratio greater than 0.5 and/or localized neuro-retinal rim defect) and a history of high IOP (>21 mmHg). Patients with PACG must have been under good disease control, which was defined as IOP under 20 mmHg with 1 to 3 topical anti-glaucoma medications without deterioration of visual field, except generalized depression from cataract. The Humphrey visual field testing within 6 months before participation in patient with PACG was used to evaluate the visual field defect. Intra-ocular lens calculation was performed at the baseline visit using IOL Master (Carl Zeiss Meditec, Inc., Dublin, CA, USA). All patients received information about the advantages and disadvantages of MIOLs (Tecnis ZMB00; Abbott Medical Optics, Santa Ana, CA, USA or Acrysof IQ Restore SN6AD1; Alcon, Fort Worth, TX, USA), and of mIOLs (Tecnis ZCB00; Abbott Medical Optics or Acrysof IQ SN60WF; Alcon) before choosing the type of IOL that they individually preferred. Cataract surgery was performed by a single surgeon (NK). Topical anesthesia was applied before standard phacoemulsification (2.2 mm temporal clear cornea incision and continuous curvilinear capsulorhexis) and IOL implantation into the capsular bag. Eyes with any intraoperative or postoperative complication were excluded.

Data specific to uncorrected and best-corrected distant visual acuities (UCVA and BCVA) in logMAR, auto-refraction, slit-lamp ophthalmoscopic examination, intraocular pressure (IOP) measurement with Goldmann applanation tonometry, contrast sensitivity (CS), anterior chamber depth (ACD), central corneal thickness (CCT), and axial length (AL) were collected on the preoperative screening day, and at the 2 to 6-month postoperative follow-up. CS was measured under normal room light (photopic) conditions without glare to evaluate patient quality of vision during the performance of their daily activities using a Functional Vision Analyzer (FVA) (Stereo Optical, Inc., Chicago, IL, USA). This test produces sine-wave gratings of different spatial frequencies. The absolute values of distance CS were obtained at five spatial frequencies (1.5, 3, 6, 12, and 18 cycles per degree; CPD). Visante® AS-OCT (Carl Zeiss Meditec) was used to determine CCT and ACD. ACD was defined as the distance between the corneal endothelium and the anterior surface of the crystalline lens (preoperative) or iris plane (postoperative). Axial length was obtained using IOL Master.

Statistical analysis included descriptive statistics to summarize patient demographic and clinical data. All statistical analyses were performed using SPSS Statistics software (version 16.0 for Windows) (SPSS, Inc.; IBM Corporation, Armonk, NY, USA). Data are described as mean plus/minus standard deviation (SD) for continuous data with normal distribution, and as median and interquartile range (IQR) for non-normally distributed continuous data. Categorical data are described as number and percentage. Comparisons of continuous data with normal distribution were made using Student's t-test for unpaired data, and using Mann-Whitney U test for non-normally distributed data. Categorical data were compared using chi-square test or Fisher's exact test. A p-value of less than 0.05 was defined as denoting statistical significance.

RESULTS

There were 45 eyes from 35 patients with a mean age of 65.7 years enrolled in this study; however, only 33 eyes of 26 patients completed the study. There were 6 males and 20 females. The only reason for exclusion was the inability to complete the preoperative or postoperative CS measurement. Fourteen eyes were PAC, and 19 eyes were PACG. Fourteen eyes from 11 patients received diffractive MIOLs (7 Tecnis ZMB00, and 7 Acrysof IQ Restore SN6AD1), and 19 eyes from 15 patients received aspheric mIOLs (17 Tecnis ZCB00, and 2 Acrysof IQ SN60WF). All patients underwent uneventful cataract surgery and completed at least 2 months of follow-up. Preoperative patient characteristics compared between the MIOL and mIOL groups are summarized in Table 1. There was no statistically significant difference in age, gender, preoperative distance UCVA or BCVA, IOP, CCT, or axial length between the MIOL and mIOL groups, but the MIOL group had significantly more PAC than the mIOL group (p=0.001). The mIOL group had significantly shallower ACD than the MIOL group (p=0.01). Preoperative contrast sensitivity compared between the MIOL and mIOL groups is shown in Fig 1. No statistically significant difference was observed between groups for preoperative CS; however, the MIOL group had lower CS at all spatial frequencies compared to the mIOL group. After phacoemulsification with IOL implantation, the postoperative CS improved significantly at all spatial frequencies in both groups (all $p \leq 0.001$). Postoperative CS compared between the MIOL and mIOL groups is shown in Table 2. The postoperative CS tended to be lower in the MIOL group, but there was no statistically significant difference between groups at any of the evaluated spatial frequencies. Postoperative contrast sensitivity compared between the MIOL and mIOL groups is shown in Fig 2. Postoperative distance BCVA improved significantly in the MIOL group (p=0.013) and the mIOL group (p=0.003). The mean postoperative IOP significantly decreased in the MIOL (p=0.008) and mIOL (p=0.02) groups, and the mean postoperative ACD significantly increased in the MIOL (p=0.048) and mIOL (p=0.001) groups. There was no statistically significant difference in postoperative distance BCVA (p=0.377), IOP (p=0.084), or ACD (p=0.98) between groups. A comparison of preoperative and postoperative ocular parameters in the MIOL and mIOL groups is shown in Table 3.

TABLE 1. Preoperative patient characteristics compared between the MIOL and mIOL groups.

Characteristics	MIOL group (15 eyes) (Mean±SD)	mIOL group (21 eyes) (Mean±SD)	*P*-value
Mean age (years)	66.7±5.5	65.0±8.9	0.701
Gender (male : female)	2:9	4:11	0.385
Diagnosis (eyes) (PAC:PACG)	10:4	4:15	***0.001***
BCVA (logMar)	0.186±0.123	0.221±0.181	0.706
IOP (mmHg)	14.9±1.7	16.6±3.5	0.132
Axial length (mm)	22.4±0.7	22.9±1.0	0.136
ACD (mm)	2.1±0.3	1.8±0.2	***0.010***
CCT (microns)	527.7±40.6	538.4±23.9	0.356
IOL power (diopters)	23.5±2.2	23.14±3.1	0.705
Contrast sensitivity (CPD)*	median (IQR)	median (IQR)	
1.5	9.0 (19.8)	18.0 (22.0)	0.199
3.0	17.3 (29.0)	29.0 (47.0)	0.186
6.0	8.7 (17.3)	12.0 (45.0)	0.287
12.0	0.0 (3.8)	0.0 (11.0)	0.506
18.0	0.0 (0.0)	0.0 (0.0)	0.483

A p-value<0.05 indicates statistical significance (*Mann-Whitney U test)

Abbreviations: MIOL, multifocal intraocular lens; mIOL, monofocal intraocular lens; IOL, intraocular lens; SD, standard deviation; IQR, interquartile range; PAC, primary angle-closure; PACG, primary angle-closure glaucoma; BCVA: best-corrected visual acuity; IOP, intraocular pressure; ACD, anterior chamber depth; CCT, central corneal thickness; CPD, cycles per degree

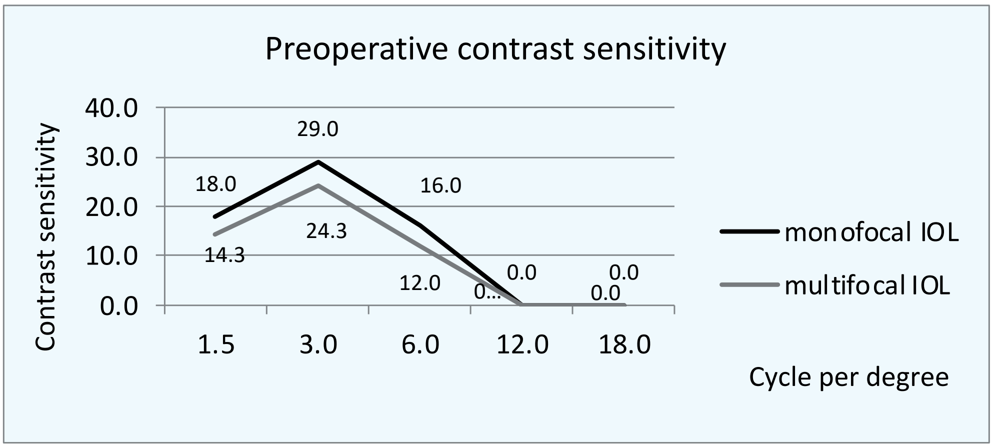

Fig 1. Preoperative contrast sensitivity compared between the multifocal intraocular lens (MIOL) and monofocal IOL (mIOL) groups.

TABLE 2. Postoperative contrast sensitivity compared between the MIOL and mIOL groups.

Spatial frequency (CPD)	MIOL group median (IQR)	mIOL group median (IQR)	*P*-value
1.5	20.4 (18)	25.0 (24.4)	0.377
3.0	30.9 (43.7)	51.3 (27.6)	0.142
6.0	35.0 (48.0)	45.0 (38.3)	0.760
12.0	9.7 (30.0)	10.0 (14.5)	0.602
18.0	2.0 (12.0)	4.0 (5.0)	0.287

A *p*-value<0.05 indicates statistical significance (Mann-Whitney U test)
Abbreviations: MIOL, multifocal intraocular lens; mIOL, monofocal intraocular lens; CPD, cycles per degree; IQR, interquartile range

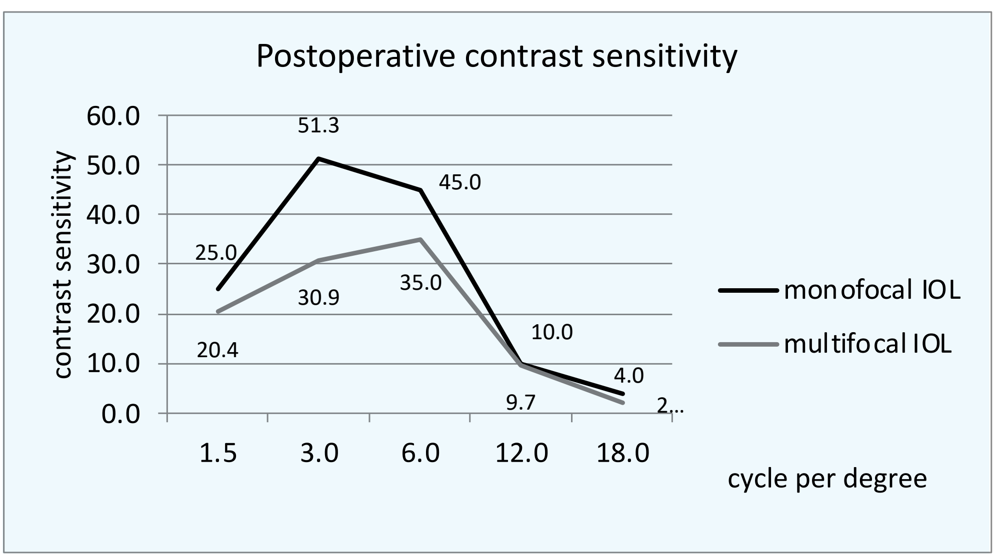

Fig 2. Postoperative contrast sensitivity (median) compared between the multifocal intraocular lens (MIOL) and monofocal IOL (mIOL) groups.

TABLE 3. A comparison of preoperative and postoperative ocular parameters in the MIOL and mIOL groups.

Parameters	MIOL group (Mean±SD) Pre-op	Post-op (a)	*P*	mIOL group (Mean±SD) Pre-op	Post-op (b)	*P*	Comparison a and b *P*
BCVA (logMAR)	0.186±0.123	0.093±0.073	***0.013***	0.221±0.181	0.074±0.099	***0.003***	0.377
IOP (mmHg)	14.9±1.7	12.5±2.5	***0.008***	16.6±3.5	14.3±2.8	***0.020***	0.084
ACD (mm)	2.1±0.3	3.0±0.1	***0.048***	1.8±0.2	3.1±0.3	***0.001***	0.98

A *p*-value<0.05 indicates statistical significance (Mann-Whitney U test)
Abbreviations: MIOL, multifocal intraocular lens; mIOL, monofocal intraocular lens; BCVA, best corrected visual acuity; IOP, intraocular pressure; ACD, anterior chamber depth

DISCUSSION

Cataract surgery with mIOL implantation generally results in improved CS in patients with and without glaucoma.[13] The results of the present study demonstrate that cataract surgery with MIOL or mIOL implantation can improve CS in patients with PAC/PACG. It was not until the 1980s that MIOLs started being used for cataract surgery. Several studies confirmed that MIOLs provide good near and distance visual acuity, more spectacle independence, and high patient satisfaction.[14] In contrast, MIOLs can also produce unwanted optical effects, including halos, glare, and decreased CS.[11,15-17] A decrease in resolution of visual quality associated with MIOLs is measured by reduced CS. Multifocal optics distribute light through several foci, so CS is reduced and glare disability increased when the image of a distance focus is overlapped by the out-of-focus images generated from the multifocal design.[18] The increased depth of focus experienced after MIOL implantation is usually obtained at the expense of image clarity. However, it has been proposed that this reduction in CS may be significant in eyes with preexisting impairment of CS.[19]

The positive effect of cataract surgery on CS may be to some degree negated by a loss of CS at low spatial frequencies after MIOL implantation. In our study, the postoperative CS improved significantly in patients who received MIOLs, and the postoperative CS of MIOLs was comparable to those of mIOLs. Few studies have demonstrated the benefits of MIOLs in eyes with concomitant ocular disease, especially glaucoma.[10] To our knowledge, this is the first study to report the use of MIOLs in angle-closure eyes. There are some anatomical characteristics associated with age and angle-closure, such as short axial length, thick pigmented iris, and increased thickness of the crystalline lens.[20] Cataract surgery in angle closure provides the opportunity to 'kill two birds with one stone' by restoring vision and eliminating a narrow angle.[21] Cataract surgery also helps to prevent or delay progression along the PAC spectrum, and reduces the incidence of PACG, particularly in regions where angle-closure is prevalent.[7]

Improvement in glaucoma control after cataract surgery was reported, and the observed improvement was found to be more pronounced in angle-closure than in open-angle glaucoma.[7,14] Our study demonstrates the positive effect of cataract surgery in PAC/PACG, including deepening of the ACD and IOP reduction. Deepening of the ACD and relief of the crowding angle were hypothesized to result in improvement of aqueous outflow with subsequent IOP reduction.[14,22] It should be noted that we included only PAC and PACG with mild glaucomatous optic neuropathy and well-controlled IOP without significant visual field loss in order to reduce the likelihood of VF progression after cataract surgery. Teichman and Ahmed recommended considering some specific glaucoma patients as candidates for MIOL implantation, including glaucoma suspects, ocular hypertensive patients without optic disc or visual field damage, and well-controlled glaucoma patients with early or mild visual field damage.[11] Our study showed improvement in postoperative visual acuity, and there was no significant difference in uncorrected distance visual acuity between the MIOL and mIOL groups. This same finding was previously reported from a study that compared MIOLs and mIOLs in nonglaucomatous eyes.[14] The present study found the postoperative CS to be highest at 3 CPD in the mIOL group, and at 6 CPD in the MIOL group. CS was lower in the MIOL group than in the mIOL group at all spatial frequencies (1.5-18 CPD), especially at 3 CPD, but the difference was not statistically significant. Kim, *et al*. reported CS outcome to be significantly lower in the MIOL group than in the mIOL group.[12] However, those previous studies investigated the performance of previous spherical MIOLs. With the introduction of aspheric MIOLs, some of the loss of CS may be ameliorated.[14] The mIOLs used in this study were aspheric IOLs, which reduce spherical aberration by counteracting corneal sphericity that increases with aging. The MIOLs were diffractive aspheric IOLs, which have a posterior diffractive surface to decrease spherical aberration produced by multifocality resulting in less CS loss.[14]

Even though eyes with MIOLs were previously reported to experience reduced CS, this loss is not perceived as functionally significant in normal eyes, and it is counterbalanced by improvement in CS from cataract surgery, uncorrected near visual acuity, and depth of focus.[23] Furthermore, patients with cataract and glaucoma may have already grown accustomed to preoperative CS reduction, which increases the likelihood that they would not notice or be affected by the small loss of CS from MIOLs.[19,24] This suggests that the slight decrease in CS in the MIOL group compared to the mIOL group in our study may not be clinically significant.

This study has several limitations. First, we were forced to exclude several patients who were unable to produce reliable CS, either preoperatively or postoperatively, due to the complicated CS testing process. This resulted in our having a much smaller sample size than we had anticipated. Second, the IOL models used in this study included 2 different models in each group, and these two different models may exert different effect on CS. Third, we did not test binocular visual function, which may cause negative or positive effect on visual quality and patient satisfaction. Fourth and last, the follow-up CS measurement was performed during the short-term follow-up when there was no posterior capsular opacity and/or completed brain adaptation – both of which could affect CS and visual quality.

In conclusion, cataract patients with PAC or mild PACG may be considered for cataract surgery with MIOL implantation because they have high potential for good IOP control, less chance of VF progression, and may even become disease-free after surgery. MIOL implantation in the setting of PAC/early stage PACG improved visual acuity and CS even though it caused a non-statistically significant loss of low contrast acuity compared to mIOL. However, the loss of low contrast acuity was apparently without clinical significance, and may have been an acceptable trade-off to gain enhanced near vision. A randomized controlled study in a larger study population should be conducted to evaluate the long-term effects of MIOLs on CS, visual quality, and patient satisfaction among patients with PAC/PACG.

Conflict of interest declaration

All authors declare no personal or professional conflicts of interest relating to any aspect of this study.

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All named authors meet the International Committee of Medical Journal Editors (ICMJE) criteria for authorship for this article, take responsibility for the integrity of the work as a whole, and have given their approval for this version to be published.

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