

Visual outcomes of cataract surgery in adult patients with hyperopia and amblyopia with the dominant vs amblyopic eye operated on first

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Послідовність хірургії катаракти у дорослих пацієнтів із гіперметропією та амбліопією: результати операції в залежності від втручання на домінантному чи амбліопічному оці

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Abstract

Purpose: To review the impact of the surgical eye sequence (dominant vs non-dominant first) on the visual outcomes of phacoemulsification with IOL implantation in patients with hyperopia and amblyopia.

Material and Methods: We retrospectively reviewed the clinical outcomes of 40 adult patients (80 eyes) with hyperopia and amblyopia who underwent surgery for cataract. Group 1 comprised 28 patients (56 eyes) in whom the amblyopic eye was operated on first. This group was subdivided into two subgroups. Subgroup 1A comprised 17 patients (34 eyes) with a baseline interocular best-corrected visual acuity

(BCVA) difference of not more than 0.1. Subgroup 1B comprised 11 patients (22 eyes) with a baseline interocular BCVA difference of more than 0.1. Group 2 comprised 12 patients (24 eyes) in whom the dominant eye was operated on first and the amblyopic eye was operated second.

Results: After surgery, BCVA increased from 0.25 ± 0.08 to 0.76 ± 0.13 ($P \leq 0.00001$) in group 1A and from 0.33 ± 0.09 to 0.54 ± 0.07 ($P = 0.00007$) in group 1B, and hardly changed in group 2 (from 0.32 ± 0.07 to 0.33 ± 0.06 , $P = 0.0678$). A cumulative uncorrected visual acuity (UCVA) of 0.7 or better was achieved in 67% of patients in group 1A; 0.5-0.6 was achieved in 68% of patients in group 1B; and 0.3-0.4 was achieved in 96% of patients in group 2. A cumulative BCVA of 0.7 or better was seen in 77% of patients in group 1A; 0.5-0.6 was seen in 86% of patients in group 1B; and 0.3-0.4 was seen in 92% of patients in group 2.

Conclusion: The surgical eye sequence is critical in cataract surgery: operating on the amblyopic eye first creates the preconditions for its more active involvement in the visual process, which improves the chances for functional rehabilitation, especially in the presence of a small baseline interocular difference in visual acuity.

Keywords: cataract, phacoemulsification, adults, hyperopia, amblyopia, visual acuity, amblyopic eye, dominant eye

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Резюме

Мета. Проаналізувати вплив послідовності хірургічного лікування катаракти (домінантне чи недомінантне око) на зорові результати у пацієнтів із супутньою гіперметропією та амбліопією.

Матеріал та методи. Проведено ретроспективне дослідження результатів хірургічного лікування катаракти у 40 дорослих пацієнтів (80 очей) з гіперметропією та амбліопією. Перша група – 28 пацієнтів (56 очей), у яких хірургію починали з амбліопічного ока. Пацієнти додатково були поділені на підгрупи. Група 1А – 17 пацієнтів (34 ока), до операції МКГЗ відрізнялася на двох очах не більше 0,1. Групу 1В склали 11 хворих (22 ока), що мали різницю МКГЗ між очима більш 0,1. До другої групи спостереження було включено 12 пацієнтів (24 ока), яким першим оперували домінуюче око, а потім амбліопічне.

Результати. Після хірургічного втручання відбулася відповідна зміна як НКГЗ, так і МКГЗ, при цьому МКГЗ збільшилась у групі 1А з $0,25 \pm 0,08$ до $0,76 \pm 0,13$ ($P \leq 0,00001$), в групі 1В з $0,33 \pm 0,09$ до $0,54 \pm 0,07$ ($P = 0,00007$), а у групі 2 майже не змінилася (з $0,32 \pm 0,07$ до $0,33 \pm 0,06$, $P = 0,0678$). Оцінка кумулятивних показників

гостроти зору виявила НКГЗ 0,7 та вище у 67% пацієнтів групи 1А, 0,5 та вище – у 68% пацієнтів групи 1В та гостроту зору 0,3–0,4 – у 96% пацієнтів 2-ї групи. Кумулятивні показники МКГЗ склали 0,7 та вище у 77% пацієнтів в групі 1А, 0,5 та вище – 86% пацієнтів в групі 1В, та 0,3–0,4 у 92% пацієнтів 2-ї групи.

Висновки. Послідовність оперативного втручання при катаракті має вирішальне значення: оперування амбліопічного ока першим створює умови для його активної участі у зоровому процесі, що підвищує ймовірність функціональної реабілітації, особливо при незначній різниці в ГЗ на доопераційному етапі між амбліопічним та домінуючим оком.

Ключові слова: катаракта, факоемулсифікація, дорослі, гіперметропія, амбліопія, гострота зору, амбліопічне око, домінуюче око.

Introduction

Amblyopia is a functional vision impairment that develops due to abnormal visual stimulation in the absence of any organic pathology of the retina or visual pathway in the early phase of visual system development [1]. Anisometropic amblyopia is a common form of amblyopia which occurs when there is a substantial difference in refractive error between the eyes, especially in high hyperopia. In such patients, long-term and chronic visual suppression to the non-preferred eye develops at the level of the central nervous system, especially if they did not use optical correction in early childhood. This results in not only reduced visual acuity (VA), but also impaired binocular and stereoscopic perception [2, 3, 4].

In the past, amblyopia has been believed to become irreversible after the age of 7-9 years. Current concepts of neuroplasticity of the adult brain, however, provide the ground for the revision of this paradigm, and indicate the potential for partial visual function recovery even in old individuals. Perceptual learning is a therapeutic method of treating amblyopia in the adults in whom conventional treatment options (occlusion, penalization, etc.) have failed to achieve an adequate improvement. It has been demonstrated that marginal or even substantial visual function improvement can be achieved after exposure to specific perceptual learning stimuli in these patients [5]. Additionally, the effectiveness of laser refractive surgery (excimer laser corneal refractive surgery, implantation of phakic intraocular lens [IOL] and refractive lens exchange) to address anisometropic amblyogenic refractive error has been demonstrated [6-9].

The complexities of the diagnosis and treatment of anisometropic amblyopia concomitant with age-related cataract are, however, greater than those of anisometropic amblyopia only. Reduced lens clarity contributes to the deterioration of visual perception, which is especially important for the eye with already diminished visual

function. At the same time, ophthalmologists have faced a practical dilemma in treating such cases: which of the two eyes is the first to be operated on? Whether the amblyopic eye is the first to be operated on to promote conditions for its activation, or the dominant eye is the first to be operated on to provide the best possible visual outcome in this eye?

We believe that the surgical eye sequence (dominant vs amblyopic first) may have an impact on general adjustment to the ocular optic system (changed due to IOL implantation), stereovision and even patient satisfaction with visual outcomes. We consider this issue to be topical and warranting measures for the formation of a systematic sequence of actions. It is in this study that we have reviewed the outcomes of phacoemulsification (phaco) with IOL implantation in patients with hyperopia and amblyopia to determine the best possible surgical eye sequence.

The purpose of this study was to review the impact of the surgical eye sequence (dominant vs amblyopic first) on the visual outcomes of phaco with IOL implantation in patients with hyperopia and amblyopia.

Material and Methods

We retrospectively reviewed the clinical outcomes of 40 patients (80 eyes; age, 36 to 64 years) who underwent surgery for cataract and moderate amblyopia at the “Eye Microsurgery Center”, Zaporizhzhia Regional Clinical Hospital, in 2021-2023.

Patients were divided into two major groups based on the surgical eye sequence (amblyopic vs dominant). Group 1 comprised 28 patients (56 eyes) in whom the amblyopic eye was operated on first. This group was subdivided into subgroups based on baseline best-corrected visual acuity (BCVA). Subgroup 1A comprised 17 patients (34 eyes) with a baseline difference in BCVA between the two eyes not more than 0.1. Subgroup 1B comprised 11 patients (22 eyes) with a baseline difference in BCVA between the two

eyes more than 0.1. Group 2 comprised 12 patients (24 eyes) in whom the dominant eye was operated on first and the amblyopic eye was operated second.

Major inclusion criteria were bilateral immature cataract, concomitant moderate to high hyperopia ($\geq +3.0$ diopters [D]) and moderate to high amblyopia (with a persistent unilateral reduction in BCVA in the absence of organic pathology of the visual system since the early childhood). Mild amblyopia was defined as a BCVA of 0.6–0.8, and moderate amblyopia was defined as a BCVA of 0.3–0.5. Patients with manifest strabismus, concomitant retinal or optic nerve disease, history of eye surgery, psychoemotional instability, or postoperative non-compliance were excluded. The presence of signs of psychoemotional instability (anxiety, aggressiveness, inattention and non-cooperation) was determined during the completion of the clinical questionnaire and the examination of behavioral and emotional manifestations.

Patients underwent standard phaco with monofocal IOL implantation under multimodal anesthesia. IOL power calculations were performed on ultrasound and biometry devices to meet the emmetropic refractive target. Toric IOLs were used in all patients with astigmatism exceeding 0.75 D. The time between the first and second phases of surgery ranged from 1 to 3 months depending on postoperative changes in visual functions with time and patient's postoperative adjustment. Uncorrected visual acuity (UCVA), BCVA, refractive status and the state of binocular vision at three months after surgery were compared with baseline values to evaluate the efficacy of treatment.

Statistical analyses were conducted using Statistica 10.0 (StatSoft, Tulsa, OK, USA) software. A non-parametric Mann-Whitney test was used for preoperative comparison among the eyes. A paired Wilcoxon signed rank test was used to compare postoperative and preoperative values. The level of significance $p \leq 0.05$ was assumed.

Results

We reviewed visual outcomes of cataract surgery with IOL implantation in eyes with various severity of hyperopia and amblyopia. A patient was considered to have anisometropic amblyopia if there was more than 1.0 mm difference in the axial length and/or more than 2.0 D difference in the refractive error between the two eyes (Table 1).

The median difference in the axial length between the two eyes was 0.84 mm for group 1 ($P = 0.00001$) and 0.64 mm ($P = 0.0005$) for group 2, and, in all cases, the axial length was shorter than 22 mm, indicating that the eyes were hyperopic (Table 1). The median difference in the IOL spherical power between the two eyes was 3.0 D for group 1 and 2.54 D for group 2, and this difference was significant. No significant difference was, however, observed for the axial length in dominant eyes, axial length in amblyopic eyes, IOL spherical power in dominant eyes, or IOL spherical power in amblyopic eyes between the two groups at baseline, indicating similar tendencies in the formation of presumptive anisometropic amblyopia. No intraoperative or postoperative complication was observed in either group. Additionally, in both groups, the mean error of predicted refraction did not exceed 0.5 D (range,

Table 1. Biometric characteristics of study groups (median \pm standard deviation [interquartile range])

Parameters	Group 1		Group 2	
	Amblyopic eye	Dominant eye	Amblyopic eye	Dominant eye
Axial length (mm)	20.91 \pm 0.84 (19.13–22.36)	21.75 \pm 0.56 (20.21–22.84) $P=0.00001$	20.98 \pm 0.66 (19.89–22.36) $P1=0.84$	21.62 \pm 0.12 (20.21–22.36) $P=0.0005$ $P1=0.82$
Anterior chamber (mm)	2.21 \pm 0.14 (2.07–2.76)	2.62 \pm 0.18 (2.22–3.15) $P=0.0000$	2.17 \pm 0.08 (2.04–2.36) $P1=0.86$	2.52 \pm 0.04 (2.12–2.88) $P=0.00000$ $P1=0.78$
Lens (mm)	5.31 \pm 0.41 (3.5–5.91)	5.04 \pm 0.19 (4.66–5.56) $P=0.00005$	5.27 \pm 0.48 (3.5–5.91) $P1=0.78$	5.04 \pm 0.04 (4.8–5.56) $P=0.0004$ $P1=0.84$
Calculated IOL power (D)	30.72 \pm 3.54 (23.5–36.0)	27.72 \pm 02.18 (24.0–32.5) $P=0.0004$	30.61 \pm 2.76 (25.0–34.5) $P1=0.83$	28.07 \pm 0.55 (24.0–34.0) $P=0.0027$ $P1=0.97$

Note: P, Mann-Whitney test P-value for the difference between the amblyopic eye and the dominant eye; P1, P-value for the difference between group 1 and group 2

Table 2. Uncorrected visual acuity values in groups (mean \pm standard deviation)

Eye	Before surgery	After surgery	P-value
Group 1A			
amblyopic	0.15 \pm 0.09	0.71 \pm 0.11	\leq 0.00001
dominant	0.29 \pm 0.07	0.96 \pm 0.05	\leq 0.00001
Group 1B			
amblyopic	0.15 \pm 0.09	0.51 \pm 0.08	=0.000006
dominant	0.51 \pm 0.07	0.96 \pm 0.06	=0.00004
Group 2			
amblyopic	0.22 \pm 0.09	0.32 \pm 0.07	=0.0014
dominant	0.50 \pm 0.11	0.95 \pm 0.05	=0.000018

Note: P-value, Wilcoxon test P-value

Table 3. Best-corrected visual acuity values in groups (mean \pm standard deviation)

Eye	Before surgery	After surgery	P-value
Group 1A			
amblyopic	0.25 \pm 0.08	0.76 \pm 0.13	\leq 0.00001
dominant	0.33 \pm 0.06	0.98 \pm 0.03	\leq 0.00001
Group 1B			
amblyopic	0.33 \pm 0.09	0.54 \pm 0.07	= 0.00007
dominant	0.81 \pm 0.10	0.99 \pm 0.03	= 0.00011
Group 2			
amblyopic	0.32 \pm 0.07	0.33 \pm 0.06	= 0.0678
dominant	0.58 \pm 0.08	0.99 \pm 0.02	= 0.000018

Note: P-value, Wilcoxon test P-value

0.11-0.75 D), and it was this that caused the difference between BCVA and UCVA.

It was of interest to evaluate the efficacy of surgical strategy depending on whether the amblyopic eye or the dominant eye received phaco with IOL implantation first, with UCVA and BCVA serving as major efficacy outcome measures (Tables 2 and 3).

After surgery, mean UCVA improved significantly in all groups (1A, 1B and 2), with the greatest improvement observed in the amblyopic eye in group 1A ($\Delta=+0.56$), indicating the greatest vision improvement with a smaller baseline difference in BCVA between the two eyes. The smallest improvement in UCVA ($\Delta= + 0.10$) was observed in Group 2 (comprising patients in whom the amblyopic eye was operated second). The postoperative improvement in BCVA in the amblyopic eye was statistically significant also only in group 1A, supposing a favorable effect of early intervention in the weakest eye. Additionally, there was actually no postoperative change in BCVA ($p = 0.0678$) in the amblyopic eye in group 2.

Taking into account that, in all groups, cataract surgery in the dominant eye resulted in complete UCVA and BCVA recovery, a question arose on the quantitative extent of improvement in visual function compared to baseline in amblyopic eyes. To address this question, we analyzed cumulative visual acuity (UCVA and BCVA) in all amblyopic eyes; visual outcome was categorized as good (0.7 or better), moderate (0.6-07) or poor (0.3-04). The data obtained are presented in Figs 1 and 2.

Group 1A showed the greatest postoperative improvements (0.5 or larger) in cumulative UCVA and cumulative BCVA (Figs 1 and 2), with a good visual outcome achieved in 67% and 77% of patients, respectively and a moderate visual outcome, in 33% and 23% of patients, respectively. Therefore, patients with a smaller baseline difference in visual acuity between the two eyes have higher plasticity of the binocular system. Additionally, performing cataract surgery first on the amblyopic eye creates the preconditions for integrating it into the visual system before the brain will overcome

the dominant eye. These data indicate that, with a proper surgical strategy and the presence of moderate amblyopia and minimal anisometropia, visual function can be restored even in adults. In group 1B the improvements in cumulative UCVA and cumulative BCVA, although statistically significant, were smaller than in group 1A, with moderate UCVA outcome and moderate BCVA outcome seen in 68% and 86% of patients, respectively and poor UCVA outcome and poor BCVA outcome, in 34% and 23% of patients, respectively. A good VA outcome was seen in no patient in group 1B. That is, with a large baseline difference in VA between the two eyes, the amblyopic eye has a lower capacity for activation. Even under these conditions, however, performing cataract surgery first on such an eye allows partial implementation of the potential of adult brain neuroplasticity. This is important for the patients in whom the postoperative VA in the dominant eye approached that in the amblyopic eye. In such cases, it

was reasonable to perform the second intervention 1 to 3 months after the first intervention.

Group 2 (comprising patients in whom the dominant eye was operated on first) showed the smallest postoperative improvement in visual acuity in the amblyopic eye, with moderate UCVA outcome and moderate BCVA outcome seen in 4% and 8% of patients, respectively and poor UCVA outcome and poor BCVA outcome, in 96% and 93% of patients, respectively. Therefore, with cataract surgery performed first on the dominant eye, it is from this eye that visual information becomes steadily processed. However, thereafter, the amblyopic eye becomes increasingly suppressed by the CNS, even if the emmetropic refractive target in this eye has been met. It is especially important to take this into account in patients with anisometric amblyopia who have not used spectacle or contact lens correction previously (their brain is accustomed to processing information from one eye).

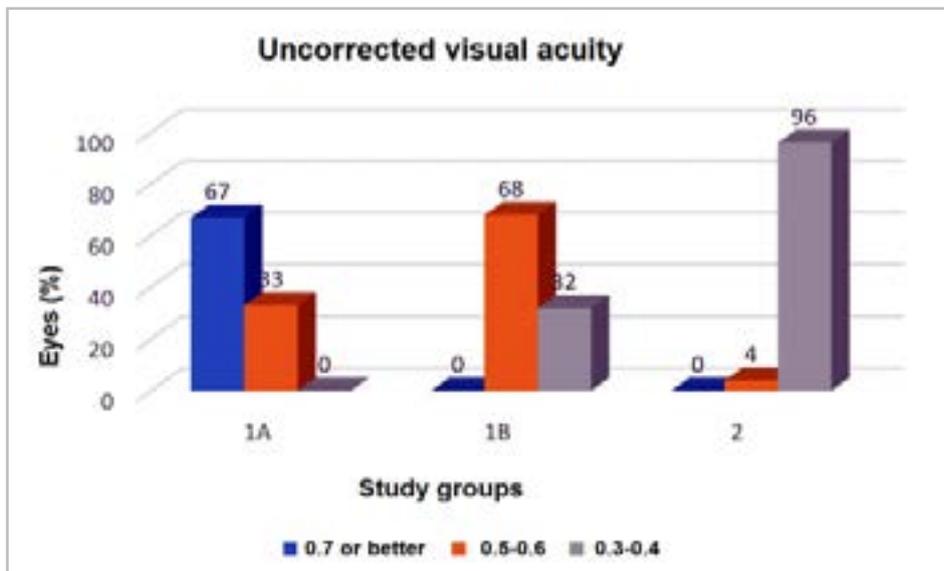


Fig. 1. Postoperative cumulative uncorrected visual acuity in amblyopic eyes

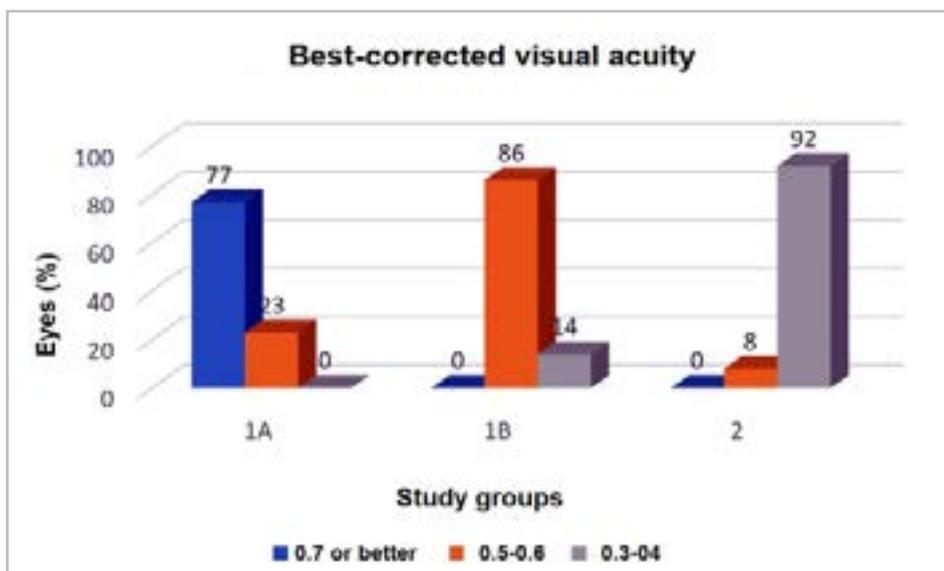


Fig. 2. Postoperative cumulative best-corrected eyes visual acuity in amblyopic eyes

Discussion

Although phaco in patients with cataract is technically successful, functional recovery of the amblyopic eye is still unpredictable [10, 11]. This can be explained by several factors. First, cerebral sensory dominance is formed in childhood and is preserved even with an improved visual signal. In such cases, the amblyopic eye is not involved in the visual process even after surgery due to binocular suppression [12]. Second, the ability of the visual cortex to adapt to the new conditions of visual perception after IOL implantation is preserved in a portion of patients, whereas in the rest it has been suppressed for years, and the visual cortex cannot adapt to new sensory inputs [13]. Finally, there are no clear criteria for predicting (1) the potential for a particular patient to restore vision and (2) the stability of the visual outcome obtained [14]. In the current study, we did not investigate the predictive criteria for the restoration of visual function after surgery on the amblyopic eye, but demonstrated the surgical eye sequence in surgery for bilateral cataract is important for the final visual outcome in patients with amblyopia or hyperopia. The best UCVA outcome and BCVA outcome were seen in group 1A in which patients the amblyopic eye was operated on first and a baseline difference in BCVA between the two eyes was not more than 0.1.

Our findings are in agreement with the literature data on the possibility of functional recovery of the amblyopic eye in adult patients [11,15,16]. A systematic review and narrative synthesis reported on spontaneous recovery from amblyopia following fellow eye vision loss due to enucleation, injury, or disease [14]. It is believed that, in such cases, the brain has to switch over to using the weaker eye, which results in partial reactivation of visual function. These cases of spontaneous recovery from amblyopia, however, were unpredictable, and the degree of improvement in amblyopic eye visual acuity ranged from minimal to clinically meaningful and depended on the baseline visual function. In contrast to the above scenario with a spontaneous improvement in amblyopic eye visual acuity, in the current study, the improvement in the visual function of the amblyopic eye was achieved through a purposeful intervention. That is, phaco with IOL implantation in the non-dominant eye enabled achieving a statistically significant improvement in UCVA and BCVA. Thus, in group 1A, the UCVA in the amblyopic eye increased after surgery from 0.15 ± 0.09 to 0.71 ± 0.11 ($p \leq 0.0001$); however, the change in group was minimal and less significant statistically.

Therefore, our findings confirmed those of previous studies on the presence of residual neuroplasticity in the adult visual system, but also demonstrated that this mechanism can be activated under controlled conditions using a properly selected surgical strategy. This provides new prospects for the treatment of amblyopic patients with cataract, which in the past was believed to hold little promise for visual rehabilitation. A relatively small sample size was a limitation of this study.

In conclusion, cataract surgery by phacoemulsification in adults with amblyopia provides a clinically significant improvement in visual acuity. An improvement in visual acuity in the amblyopic eye indicates the preservation of residual neuroplasticity in the adult visual system. The surgical eye sequence is critical in cataract surgery: operating on the amblyopic eye first creates the preconditions for its more active involvement in the visual process, which improves the chances for functional rehabilitation, especially in the presence of a small baseline difference in visual acuity between the two eyes.

Author Contributions

LNS: Conceptualization, Methodology, Supervision, Investigation, Data Analysis and Interpretation, Writing – original draft, Writing – review & editing; IOA: Methodology, Supervision, Investigation, Data Analysis and Interpretation, Writing – original draft, Writing – review & editing; ROA: Data Analysis and Interpretation, Writing – review & editing; MTS: Investigation and Data Analysis. All authors reviewed the results and approved the final version of the manuscript.

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Conflict of interest

The authors state that they have no conflict of interest that could influence their view on the subject matter or materials described and discussed in this manuscript.

Study subjects

This study involved human subjects, was approved by the local bioethics committee, and followed ethical standards as outlined in the Declaration of Helsinki. Informed consent was obtained from all subjects. This study did not include animal experiments.

Abbreviations

BCVA, best-corrected visual acuity; D, diopter; IOL, intraocular lens; phaco, phacoemulsification; UCVA, uncorrected visual acuity; Δ , absolute change in visual acuity.

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