

Binocularity Enhances Visual Acuity of Eyes Implanted With Multifocal Intraocular Lenses

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ABSTRACT

PURPOSE: To investigate the effect of binocularity on long-term visual acuity in patients who have undergone bilateral implantation of a presbyopia-correcting diffractive multifocal intraocular lens (IOL).

METHODS: Twenty patients (9 men and 11 women) with an average age of 70 ± 7 years (range: 56 to 78 years) underwent bilateral implantation of a diffractive multifocal IOL (AcrySof IQ ReSTOR IOL, SN60D3; Alcon Laboratories, Inc., Fort Worth, TX). Uncorrected visual acuity was measured monocularly and binocularly on average 26 ± 6 months following implantation in the second eye (range: 17 to 40 months) using the University of Crete European-wide modified Early Treatment Diabetic Retinopathy Study charts at the following distances: (1) 4 m, uncorrected distance visual acuity (UDVA), (2) 66 cm, uncorrected intermediate visual acuity (UIVA), and (3) 33 cm, uncorrected near visual (UNVA).

RESULTS: Mean \pm standard deviation UDVA was 0.07 ± 0.10 and 0.21 ± 0.12 logMAR (20/23 and 20/32 Snellen) in the better and worse eye, respectively, improving to 0.00 ± 0.09 logMAR (20/20 Snellen) binocularly. Mean \pm standard deviation UIVA was 0.18 ± 0.14 and 0.32 ± 0.15 logMAR (20/30 and 20/42 Snellen) in the better and worse eye, respectively, improving to 0.08 ± 0.15 logMAR (20/24 Snellen) binocularly. Mean \pm standard deviation UNVA was 0.20 ± 0.09 and 0.32 ± 0.12 logMAR (20/32 and 20/42 Snellen) in the better and worse eye, respectively, improving to 0.11 ± 0.10 logMAR (20/26 Snellen) binocularly. Binocular summation, defined as the difference between the binocular and better eye visual acuity, was found to be statistically significant at all distances: 0.07 ± 0.05 logMAR at 4 m, 0.10 ± 0.11 logMAR at 66 cm, and 0.09 ± 0.08 logMAR at 33 cm.

CONCLUSIONS: The results confirm that there is substantial benefit of binocular vision in individuals with bilateral multifocal IOL implantation in terms of increased visual acuity. This effect is evident at all distances.

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Several surgical procedures can potentially satisfy the needs of the presbyope by counteracting the effects of reduced amplitude of accommodation in the aging eye. These are based on three principal approaches: (1) monovision,¹ which uses the capacity of the brain to process the focused retinal image from one eye, (2) accommodative IOLs,² which target to recover true accommodation by producing ocular/lens power changes, and (3) simultaneous vision (image) correction (ie, an increase in the ocular depth of focus) through lens multifocality, which can provide functional distance and near vision for every visual task.^{3,4} Simultaneous image correction achieved with diffractive IOL designs (offering a bifocal effect) or multifocal/refractive designs (offering a smooth transition in power between distance and near corrections) has significantly reduced spectacle dependence.^{5,6}

One phenomenon that may play an important role in the success of the simultaneous-image designs to aid presbyopes is neural adaptation.⁷ The idea that patients can, over time, adapt to their somewhat blurred retinal images so that their visual performance improves with time is not new. Previous studies have referred to this,^{8,9} but comparatively few studies have attempted to explore its characteristics. An interesting issue is the role of binocular integration on such forms of plasticity. It is well established that vision with two eyes is enhanced over what would be expected with just one eye¹⁰ when conditions of binocular overlap and fusion are achieved. This phenomenon, called “binocular summation,” is mainly attributed to the existence of neurons in the visual cortex that “summate” the signals from the two eyes.¹¹

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Interestingly, a recent study¹² has shown that binocular vision ameliorates the effect of blur.

Unexpectedly, although most of the aspects of visual performance with IOLs have been thoroughly studied, there are no reports regarding the amount of gain in visual acuity as a result of binocular vision. The aim of the current study was to investigate the effect of binocularity on visual performance following bilateral implantation of a diffractive multifocal IOL.

PATIENTS AND METHODS

PARTICIPANTS

The eligibility criteria for inclusion in the observational case study were: age between 55 and 80 years, uncomplicated phacoemulsification, independence from spectacle use following cataract surgery, implantation of the same IOL bilaterally, and at least 15 months following the operation in the second eye. Exclusion criteria were any type of fundus pathology, corneal astigmatism of more than 1.50 diopters (D), and deviation from the target refraction of more than 1.00 D.

The study protocol adhered to the tenets of the Declaration of Helsinki and was approved by the Institutional Review Board of the Aristotle University of Thessaloniki, Thessaloniki, Greece. All participants were informed verbally about the nature of the study and provided written informed consent. Anonymity and confidentiality were guaranteed.

SURGICAL TECHNIQUE

The IOL used in all cases was the AcrySof IQ ReSTOR IOL (SN60D3; Alcon Laboratories, Inc., Fort Worth, TX) with 4.00 D (3.20 D at spectacle plane) and a nonaspheric profile. One experienced surgeon (ITT) performed all surgeries using topical anesthesia and a 2.4- to 2.75-mm clear corneal incision.

VISUAL ACUITY RECORDINGS

Visual acuity (VA) measurements were performed without any refractive correction at the following distances: (1) 4 m uncorrected distance visual acuity (UDVA) (corresponding to 0.25 D vergence), (2) 66 cm uncorrected intermediate visual acuity (UIVA), corresponding to 1.50 D vergence, and (3) 33 cm uncorrected near visual acuity (UNVA), corresponding to 3.00 D vergence. For distance recordings, VA was assessed monocularly (for each eye) and binocularly, using the three versions of the high-contrast modified Early Treatment of Diabetic Retinopathy Study logMAR charts for European-wide use (Precision Vision, La Salle, IL).¹³ Room lights were turned off. A back-illuminated slim stand (Cat No. 392; Sussex Vision Ltd., Rustington, West Sussex, UK) held the acuity charts. Luminance values were within the

recommendations for standardizing the measurement of VA (160 cd m⁻²). For intermediate and near distance recordings, the mixed-contrast “European-wide” near vision logMAR cards (Cat No: 2831; Precision Vision) were used. Accurate testing distances were ensured with special attached cords. Intermediate/near recordings were performed with room lights on (chart background luminance was 70 cd m⁻²; illuminance at cornea was 75 lux).

All participants were asked to identify each letter in each row starting from the top left corner and proceeding row by row until they could no longer name at least one letter in a row correctly. They were instructed to read slowly and guess the letters when they were unsure. The termination rule for stopping was making four or five mistakes on a line. VA was derived from the calculation of missed letters up to the last readable line. The order of VA testing regarding the viewing condition (monocularly vs binocularly) and the distance (distance vs intermediate vs near) was counterbalanced among the participants.

STATISTICAL ANALYSIS

Analyses of variance with two-sided paired Student's *t* tests were performed. The level of statistical significance for the *P* value was set to less than .05. All analyses were performed with SPSS (version 16.0; SPSS, Inc., Chicago, IL) and MedCalc for Windows (version 9.5.0.0; MedCalc Software, Mariakerke, Belgium).

RESULTS

Twenty patients (9 men and 11 women) participated in the study with an average age of 70 ± 7 years (range: 56 to 78 years). Mean time from the operation in the second eye was 26 ± 6 months (range: 17 to 50 years).

Figure 1 presents mean VA for all distances tested under monocular (averaged between the two eyes) versus binocular condition. Mean ± standard deviation UDVA was 0.07 ± 0.10 and 0.21 ± 0.12 logMAR (20/23 and 20/32 Snellen) in the better and worse eye, respectively, improving to 0.00 ± 0.09 logMAR (20/20 Snellen) binocularly. Mean ± standard deviation UIVA was 0.18 ± 0.14 and 0.32 ± 0.15 logMAR (20/30 and 20/42 Snellen) in the better and worse eye, respectively, improving to 0.08 ± 0.15 logMAR (20/24 Snellen) binocularly. Mean ± standard deviation UNVA was 0.20 ± 0.09 and 0.32 ± 0.12 logMAR (20/32 and 20/42 Snellen) in the better and worse eye, respectively, improving to 0.11 ± 0.10 logMAR (20/26 Snellen) binocularly. In all conditions, logMAR acuity with two eyes was always better or equal compared to the monocular acuity with the better eye.

Binocular summation, defined as the difference between the binocular and better eye VA, was found to be statistically significant at all distances: binocular

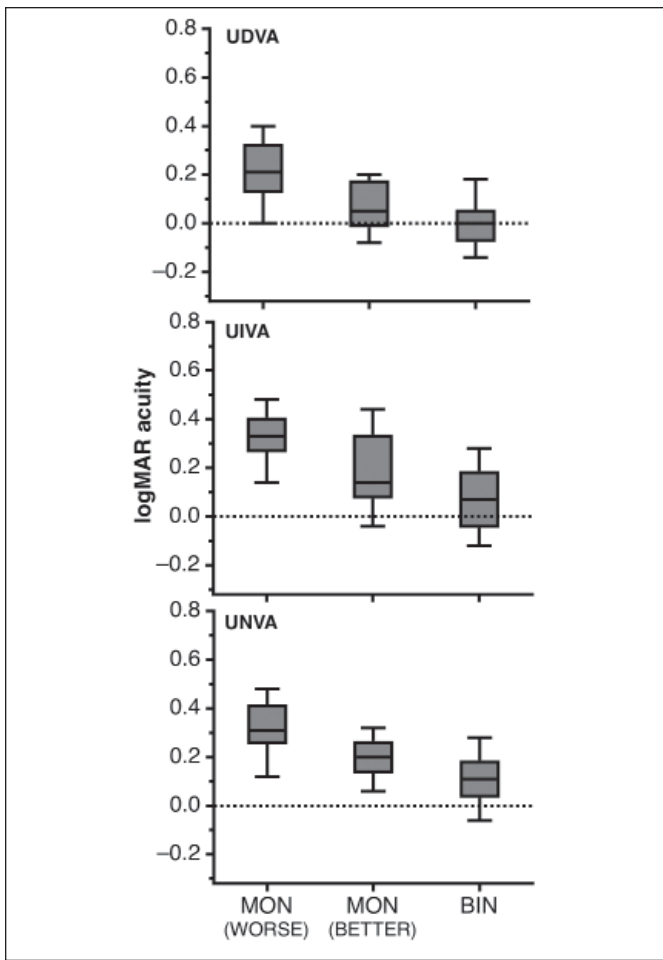


Figure 1. Box plots of visual acuity (N = 20) for uncorrected distance (upper), intermediate (middle), and near (bottom) visual acuity recordings under monocular (better vs worse eye) and binocular viewing. MON = monocular, BIN = binocular

summation was 0.07 ± 0.05 logMAR (95% confidence interval [CI] = 0.05 to 0.10, $P < .001$) at 4 m, 0.10 ± 0.11 logMAR (95% CI = 0.05 to 0.15, $P < .001$) at 66 cm, and 0.09 ± 0.08 logMAR (95% CI = 0.06 to 0.13, $P < .001$) at 33 cm.

To explore the possible impact of the interocular difference in VA (VA in better and worse eyes) on binocular summation, their correlation was tested. Although binocular summation for far and intermediate distances tended to be more pronounced the lower the difference between the two eyes, none of the regressions was significant at the $P = .05$ level (Figure 2). A statistically significant correlation was found between UIVA and the time elapsed from the first operation to the second operation ($r = 0.49$, $P = .03$). No correlation was found between binocular summation and age.

DISCUSSION

This study shows that performance with the Acrysof RESTOR SN60D3 lens in a group of patients who underwent bilateral IOL implantation is significantly improved at all distances/vergences with binocular compared to monocular observation.

VA was measured with uncorrected vision at three distances (UDVA, UIVA, and UNVA) at least 15 months following cataract extraction in the second eye, allowing enough time for any long-term adaptation effects. In the group of older patients tested, a higher binocular summation, defined as the difference in logMAR acuity between the binocular and better seeing eye, was found for all distances ranging between 0.07 and 0.10 logMAR (20/23 Snellen). However, it should be noted that if we calculate summation from the difference between binocular and average monocular acuity, the improvement in acuity would be 0.14, 0.17, and 0.15 logMAR for UDVA, UIVA, and UNVA, respectively. Although visual performance with the two eyes is expected to be enhanced at and around threshold measurements (ie, approximately 40% to 80% in contrast sensitivity),¹⁴ binocular summation is less evident for high contrast acuity (range: 5% to 13%), corresponding to 0.03 to 0.05 logMAR for younger patients¹² and decreasing with age in older patients.¹⁰ This possibly reflects deterioration in cortical activity

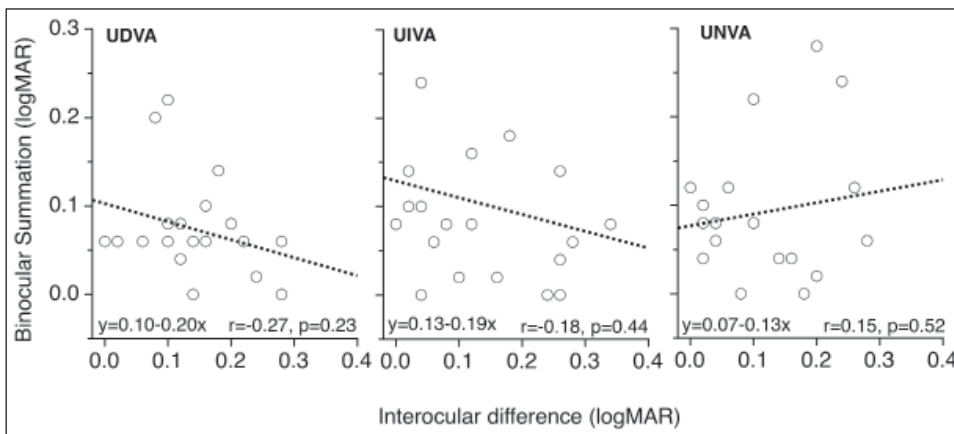


Figure 2. Plots of binocular summation for individual subjects as a function of the interocular difference in visual acuity for the three distances tested: 4 m (left), 66 cm (middle), and 33 cm (right). The parameters of linear regression fits (dotted lines) are also shown. UDVA = uncorrected distance visual acuity, UIVA = uncorrected intermediate visual acuity, UNVA = uncorrected near visual acuity

and/or an increasing interocular difference in spatial performance, with the better seeing eye dominating the overall visual performance.¹⁵ Although we would expect binocular summation to be significantly reduced in older patients, the age range in our study group was not wide enough to test such a hypothesis.

The higher amount of binocular gain, compared to younger patients, may be explained by the following mechanisms. First, recent studies have shown that it is possible to reinstate greater levels of plasticity in the adult visual system than previously suspected.^{16,17} Second, summation is enhanced as retinal blur increases,¹² whereas higher adaptation levels have also been observed in other prescriptions offering simultaneous vision correction, such as with multifocal contact lenses.¹⁸

Surprisingly, adaptation effects have not been studied with two eyes; thus, it is not established whether there were any binocular interactions in blur perception and adaptation to blur or whether these interactions change with age.¹⁹ In light of these findings, further study is desirable on adaptation in the context of presbyopic corrections, particularly the extent of its effectiveness and its time period.

The efficacy of diffractive multifocal Acrysof RESTOR lenses (Alcon Laboratories, Inc.) has been substantially studied in recent years.^{20,21} The main drawback of diffractive designs is the perception of photic phenomena, reported by patients as glare or halos, due to the diffractive boundaries intercepting with the light entering the pupil, leading to an overall dissatisfaction in approximately 20% of cases.²² Zhang et al. recently reported that satisfaction levels are higher in pseudophakes corrected with monovision than multifocal IOLs.²³ Moreover, contrast sensitivity was found compromised with diffractive multifocal IOLs,²⁴ with the effect being more pronounced at mesopic conditions and especially for higher spatial frequencies.²⁵ Previous studies have also demonstrated that diffractive multifocal IOLs do offer less satisfactory correction at intermediate distances due to their bifocal profile.²⁶

This study confirms that there is substantial benefit of binocular vision in individuals with bilateral multifocal IOL implantation in terms of increased visual acuity. This effect is evident at distance, intermediate, and near vergences.

AUTHOR CONTRIBUTIONS

Study concept and design (KTT, SP); data collection (KTT); analysis and interpretation of data (SP, ITT); drafting of the manuscript (KTT); critical revision of the manuscript (SP, SAD, ITT); statistical expertise (SP); administrative, technical, or material support (SAD, ITT); supervision (SAD, ITT)

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