Distance and Near Visual Acuity Improvement After Implantation of Multifocal Intraocular Lenses in Cataract Patients With Presbyopia: A Systematic Review

Blaise Agresta, MPH; Michael C. Knorz, MD; Thomas Kohnen, MD, PhD, FEBO; Christina Donatti, ClinPsyD, MSc; Daniel Jackson, MSc

ABSTRACT

PURPOSE: To evaluate uncorrected distance visual acuity (UDVA) as well as uncorrected near visual acuity (UNVA) as outcomes in treating presbyopic cataract patients to assist clinicians and ophthalmologists in their decision-making process regarding available interventions.

METHODS: Medline, Embase, and Evidence Based Medicine Reviews were systematically reviewed to identify studies reporting changes in UDVA and UNVA after cataract surgery in presbyopic patients. Strict inclusion/exclusion criteria were used to exclude any studies not reporting uncorrected visual acuity in a presbyopic population with cataracts implanted with multifocal intraocular lenses (IOLs). Relevant outcomes (UDVA and UNVA) were identified from the studies retrieved through the systematic review process.

RESULTS: Twenty-nine studies were identified that reported uncorrected visual acuities, including one study that reported uncorrected intermediate visual acuity. Nine brands of multifocal IOLs were identified in the search. All studies identified in the literature search reported improvements in UDVA and UNVA following multifocal IOL implantation. The largest improvements in visual acuity were reported using the Rayner M-Flex lens (Rayner Intraocular Lenses Ltd) (UDVA, binocular: 1.05 logMAR, monocular: 0.92 logMAR; UNVA, binocular and monocular: 0.83 logMAR) and the smallest improvements were reported using the Acri.LISA lens (Carl Zeiss Meditec) (UDVA, 0.21 decimal; UNVA, 0.51 decimal).

CONCLUSIONS: The results of this systematic review show the aggregate of studies reporting a beneficial increase in UDVA and UNVA with the use of multifocal IOLs in cataract patients with presbyopia, hence providing evidence to support the hypothesis that multifocal IOLs increase UDVA and UNVA in cataract patients. [*J Refract Surg*. 2012;28(6):426-435.]

doi:10.3928/1081597X-20120518-06

Cataract surgery is one of the most commonly performed surgeries in the National Health Services (NHS). In the United Kingdom, 10% of persons aged ⩾65 years have received cataract surgery and 30% of the population have been found to have a visually impairing cataract in one or both eyes.[1] In this population (people aged ⩾65 years in the United Kingdom), it is estimated that 2.4 million people have a visually impairing cataract in one or both eyes and 225 000 new cases are predicted annually.[2]

Presbyopia is an age-related loss of lens accommodation that results in an inability to focus at near distances. The global prevalence of presbyopia has been estimated to be 1.04 billion (in 2005)[3] and is expected to rise to 1.8 billion by 2050. An estimated 9.9 million people in Europe and North America, 4.8 million people in Japan, and 1.2 million people in Australia and New Zealand live with uncorrected or undercorrected presbyopia.[3] The most commonly used treatments for presbyopia include spectacles, contact lenses, and bifocal contact lenses.[4] Presbyopia and cataracts reduce patient quality of life (QOL).[5,6] The use of a multifocal intraocular lens (IOL) is designed to replace the cataract lens of an eye and reduce presbyopia by factoring a change in the focal point created by the lens (the multifocal attribute of the IOL). Thus, if multifocal IOLs are safe and efficient, an increase in QOL should be observed in cataract patients with presbyopia. This increase in QOL would not have been as significant had only cataracts or presbyopia been treated in this patient population.

From Health Economics and Outcomes Research, IMS Health, London, United Kingdom (Agresta, Donatti); FreeVis LASIK Center, Medical Faculty Mannheim of the University of Heidelberg, Mannheim, Germany (Knorz); Department of Ophthalmology, Goethe University, Frankfurt, Germany (Kohnen); and Market Access and Reimbursement, Alcon Laboratories Inc, Cointrin, Switzerland (Jackson).

The research was financially supported by Alcon Laboratories Inc UK.

Mr Agresta and Dr Donatti were paid consultants to Alcon Laboratories Inc and are employees of IMS Health. Drs Knorz and Kohnen are consultants to Alcon Laboratories Inc. Mr Jackson is an employee of Alcon Laboratories Inc.

Correspondence: Blaise Agresta, MPH, Health Economics and Outcomes Research, IMS Health, Harewood Ave, London NW1 6JB, United Kingdom. E-mail: blaise.agresta@imscg.com

Received: September 12, 2011; Accepted: May 1, 2012

Copyright © SLACK Incorporated

This systematic review attempts to identify published literature reporting the postoperative uncorrected visual acuity outcomes in patients undergoing cataract surgery with presbyopia and to show how patients can achieve virtually normal vision with the use of all multifocal IOLs.

LITERATURE SEARCH

The systematic review was conducted to evaluate the efficacy of multifocal IOLs in presbyopic cataract patients. Databases used in the search included: Medline, Medline In-Process (from 1948 to present), Embase (from 1988 to 2011), and Evidence Based Medicine Reviews (Cochrane Database of Systematic Reviews) (2005-2011), ACP Journal Club (1991-2011), Database of Abstracts of Reviews of Effects (first quarter, 2011), Cochrane Central Register of Controlled Trials (fourth quarter, 2010), Cochrane Methodology Register (first quarter, 2010), Health Technology Assessment (first quarter, 2011), and NHS Economic Evaluation Database (first quarter, 2011). These searches were accessed via the OVID platform to search for studies reporting uncorrected visual acuity in a presbyopic population with cataracts implanted with multifocal IOLs. The search terms used included: lens diseases, cataract, aphakia, cataract extraction, multifocal, lens implantation, and lenses-intraocular. The search term "bifocal" was not included in the search as the authors were only analyzing the outcomes from multifocal IOLs. An analysis of how the individual studies identified in the literature search were excluded was achieved using the Quality of Reporting of Meta-analyses (QUORUM) chart. Inclusion/exclusion criteria were used to systematically exclude any studies that did not report relevant populations (presbyopic patients with cataracts), interventions (multifocal IOL implantation), comparators (other multifocal IOL implantation), or outcomes (uncorrected visual acuity) for the review. The following types of studies were excluded from the review: those that did not report uncorrected or corrected visual acuity; those that did not report outcomes in a presbyopic cataract population; and those that reported outcomes in a language other than English. Studies using a patient population with true cataracts were included; studies with a population of refractive lens exchange patients were excluded. Studies that did not specify a cataract population were assumed to be a mixed patient population (cataract patients and refractive lens exchange) and were excluded. Likewise studies that specified a presbyopic patient group were included in the search (studies reporting refractive lens exchange patients were excluded). Although patients who undergo cataract removal become presbyopic, the authors found it imperative for a presbyopic patient group to be stated to reduce any possible underlying bias.

This analysis focused on the outcome uncorrected visual acuity. Although the World Health Organization (WHO) defines visual impairment and blindness according to visual acuity with "best possible correction," evidence suggests that uncorrected visual acuity has a significant impact on vision-related QOL.[7,8] Before QOL improvements caused by multifocal IOLs in presbyopic cataract patients are assessed, it is necessary to demonstrate the efficacy of multifocal IOLs. The safety of multifocal IOLs and the change in QOL due to multifocal IOLs were not analyzed in this review.

The unit measurement of uncorrected visual acuity varies across many studies. The Snellen scale, Jaeger scale, decimal of the Snellen scale, and logarithm of the minimum angle of resolution (logMAR) are the most commonly used units of measurement.[9] Converting these units of measurement into a standardized unit has statistical challenges where individual (patient) level data are not available.[9] When comparing changes in visual acuity in this study, conversion tables supplied by the *Journal of Refractive Surgery* were used to convert to logMAR values and visual acuity abbreviations were adopted from Kohnen.[10,11] Published literature exists to suggest that transforming group-level mean and standard deviation of visual acuity across different levels of measurement is possible.[9] But to transform group-level data, a "reasonable size" patient population ($N \geqslant 30$) is needed.[9] An a priori judgment was therefore made that if more than one third of the outcome patient groups, which were identified through the systematic review, had a patient population <30, transformation of the unit measurements would not occur.

LITERATURE SEARCH RESULTS

The systematic review identified 29 studies that measured uncorrected visual acuity in a presbyopic population with cataracts implanted with multifocal IOLs (Fig 1) with a breakdown of study type shown in Figure 2. The outcomes of these studies are reported in Table 1. A range of different outcome measurement units were reported, including Snellen measurement, decimal of the Snellen measurement, Jaeger score, and logMAR.

Some studies identified through the systematic review approach measured visual acuity as a proportion of patients who had a certain level of visual acuity or better.[24,41] Studies that reported the lowest visual acuity in the total population were included in the analysis, whereas studies that did not report the total population were excluded on the basis of incomplete data.

These 29 studies showed statistical significance of

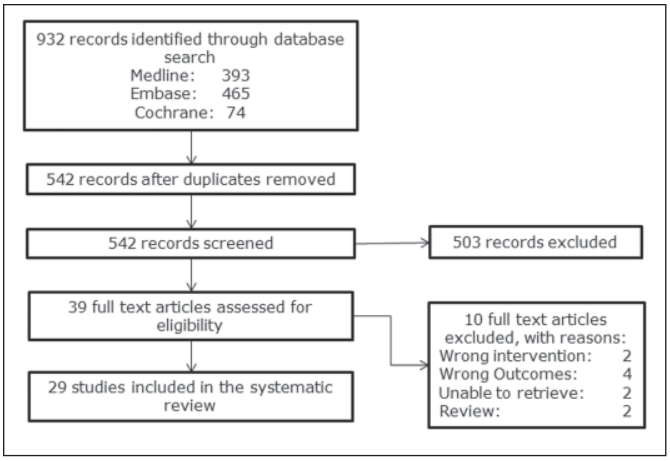

Figure 1. Quality of Reporting of Meta-analyses (QUORUM) chart of the review process.

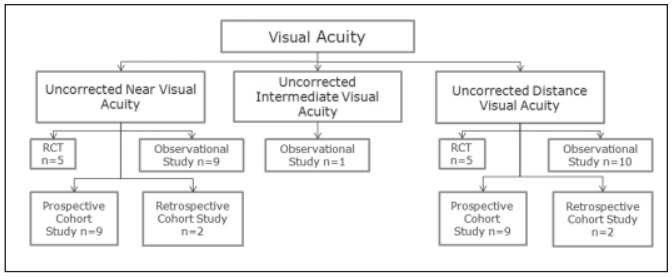

Figure 2. Breakdown of the analysis of studies identified through the systematic review. RCT = randomized controlled trial

the multifocal IOL when comparing two models of multifocal IOLs or between pre- and postoperative results. Studies that compared pre- and postoperative results reported statistical significance and provided evidence to support the efficacy of multifocal IOLs for cataract patients with presbyopia. The systematic review identified 2 randomized controlled trials, 5 observational studies, and 2 prospective cohorts that reported a comparison between pre- and postoperative visual acuity (Table 1). Every study that reported the comparison of pre- and postoperative values for UDVA and UNVA showed differences that were statistically significant postoperatively.

The systematic review identified 25 studies reporting uncorrected near visual acuity (UNVA) and 26 studies reporting uncorrected distance visual acuity (UDVA). One study reported uncorrected intermediate visual acuity (UIVA) (Table 2). Nine brands of multifocal IOLs were identified in these studies: ReSTOR (SA60D3, SN6AD1; Alcon Laboratories Inc, Ft Worth, Texas), ReZoom (NXG1; Abbott Medical Optics [AMO], Santa Ana, California), CeeOn (811E; Pharmacia & Upjohn, Kalamazoo, Michigan), Array (SA40N; AMO), Tecnis (ZM900; AMO), Acri.LISA (366D; Carl Zeiss Meditec, Jena, Germany), Rayner M-Flex (630F; Rayner Intraocular Lenses Ltd, East Sussex, United Kingdom), PA154N (AMO), and MS612 (HumanOptics, Erlangen, Germany). A limitation of the results exists because of a mix between outcomes measured using the Snellen method, Jaeger method, or decimal or logMAR scores. Using the Snellen scale, visual acuity closest to 20/20 (in feet) or 6/6 (in meters) represents standard or normal sight.[42] Using the decimal scale, standard or normal sight is 1.00. In the logMAR scale, 20/20 is equivalent to 0.00. The Jaeger scale defines standard or normal sight at J1+.

This analysis, both in terms of reported outcomes of UNVA and UDVA, shows that the gains in improvement for UDVA appear to be greater than gains in UNVA. Postoperative UDVA values were closer to a normal sight score (20/20 Snellen) in 28 models of multifocal IOLs tested across the 36 models in 29 studies. Uncorrected near visual acuity was closer to normal sight in 6 models and postoperative UNVA was equivalent to UDVA in 2 studies.

Greater improvements in UDVA were also reported compared to UNVA. The greatest increase in visual acuity was reported by Cezón-Prieto and Bautista,[20] being the only identified study that reported UIVA. The smallest improvements in visual acuity were reported by Alió et al[18] when measuring binocular visual acuity. De Vries et al[30] reported the mean visual acuity with the closest value to normal visual acuity (20/20) when measuring both UDVA and UNVA. Yang et al[27] reported the least gain in UNVA. Akaishi et al[17] reported the least gain in UDVA. The greatest improvements in UNVA were observed by De Vries et al.[30]

Twenty-one of the 29 studies reported different measures of QOL,[12,13] spectacle independence,[39] and visual disturbances such as halos[23] or glare.[36] There was no consistency across studies in reporting these outcomes. Methods included individually designed questionnaires[14]; the Vision Function (VF) -14,[16] VF-7,[38] or VF25[43] questionnaire; reporting in four dimensions (eg, satisfied, dissatisfied, very satisfied, not satisfied[32] or none, mild, moderate, severe[24]); reporting different outcomes as patient numbers,[20] percentage of patients,[30] or mean values[26]; and reported outcomes on different scales (scoring with a lower number representing a better value[15] or a higher number indicating a better value[14]). Considering these limitations, QOL measured by Gunenc and Celik[13] resulted in 100% satisfaction in overall vision with the CeeOn and Array multifocal IOLs. Rekas and Zelichowska[25] reported the worst outcomes with 60% of patients (6 of 10) reporting a mild halo effect with the ReSTOR multifocal IOL.

Copyright © SLACK Incorporated

TABLE 1

Results of the Systematic Review of Patients With Cataract and Presbyopia With Multifocal IOL Implantation

Study Type/ Study (y)	Lens	Unit of Measure (Study Length)	No. of Eyes	Monocular/ Binocular	Patient Age (y)	UDVA			UNVA		
						Preop	Postop	*P* Value	Preop	Postop	*P* Value
Randomized Controlled Trial											
Chiam et al[12] (2007)	ReSTOR SA60D3	Snellen (6 mo)	100	Binocular	67.8±8.1	—	20/23	NR	—	20/26	NR
	ReZoom NXG1	Snellen (6 mo)	100	Binocular	69.0±7.0	—	20/21	NR	—	20/34	NR
Gunenc & Celik[13] (2008)	CeeOn 811E	Snellen/Jaeger (6 mo)	10	Monocular	68.2	—	20/32 or better	NR	—	J2 or better	NR
	Array SA40N	Snellen/Jaeger (6 mo)	10	Monocular	64.4	—	20/32 or better	NR	—	J4 or better	NR
Javitt et al[14] (2000)	Array SA40N	Snellen (3 mo)	123	Binocular	NR	—	20/21	NR	—	20/26	NR
Lane et al[15] (2010)	ReSTOR SN6AD1	Snellen (6 mo)	147	Binocular	69±8	20/56	20/22	<.0001	20/83	20/25	<.0001
		LogMAR (6 mo)	147	Binocular		0.45±0.25	0.04±0.13	<.0001	0.62±0.31	0.1±0.16	.0001
Nijkamp et al[16] (2004)	Array SA40N	LogMAR (3 mo) for UDVA, decimal for UNVA	68	NR	72±7.7	0.53 (0.3)	0.13 (0.2)	NR	0.5 (0.3)	0.8±0.3	NR
Observational											
Akaishi et al[17] (2009)	Tecnis ZM900	LogMAR/Jaeger (3 mo)	16	NR	67.9±8.2	—	0.32±0.07	<.001	—	J1.25	NR
Alió et al[18] (2008)	Acri.LISA 366D	Decimal (6 mo)	69	Binocular	59	0.27±0.23	0.89±0.15	<.001	0.26±0.26	0.9±0.15	<.001
		Decimal (6 mo)	69	Monocular	59	0.54±0.29	0.75±0.21	<.001	0.24±0.25	0.76±0.22	<.001
Alió et al[19] (2011)	Acri.LISA 366D	LogMAR (6 mo)	48	NR	58.3±8.8	0.61±0.39	0.11±0.11	<.001	0.82±0.33	0.12±0.11	<.001
Cezón-Prieto & Bautista[20] (2010)	Rayner M-Flex 630F	LogMAR (12 mo)	32	Monocular	68.1±12.0	1.01±0.72	0.09±0.09	NR	1.11±0.42	0.28±0.11	NR
				Binocular	1.11±0.41	0.06±0.05	NR	—	1.08±0.39	0.25±0.08	NR
Lin et al[21] (2001)	Array	Decimal (3 mo)	37	NR	63	—	0.8	NR	—	0.6	NR
Mesci et al[22] (2010)	ReSTOR SA60D3	Decimal (12 mo)	20	Monocular	65.6±7.1	—	0.99±0.03	NR	—	—	NR

IOL = intraocular lens, UDVA = uncorrected distance visual acuity, UNVA = uncorrected near visual acuity, NR = not reported

TABLE 1 CONTINUED

Results of the Systematic Review of Patients With Cataract and Presbyopia With Multifocal IOL Implantation

Study Type/ Study (y)	Lens	Unit of Measure (Study Length)	No. of Eyes	Monocular/ Binocular	Patient Age (y)	UDVA			UNVA		
						Preop	Postop	*P* Value	Preop	Postop	*P* Value
Observational											
Moreno[23] (2010)	ReSTOR SN6AD3	LogMAR (6 mo)	38	NR	63.42±8.55	0.57±0.31	0.11±0.12	<.00001	0.76±0.4	0.12±0.09	.00001
Pineda-Fernandez et al[24] (2004)	Array SA40N	Snellen (3 mo)	70	NR	61.54±11	—	20/40 or better	NR	—	20/40 or better	NR
Rekas & Zelichowska[25] (2006)	ReSTOR SN60D3	Decimal (6 mo)	20	NR	64±9	0.3±0.18	0.9±0.1	NR	—	—	NR
Walkow et al[26] (1997)	811E	Snellen/Jaeger (12 mo)	40	Monocular	64.8	—	—	—	—	J1	NR
	PA154N	Snellen/Jaeger (12 mo)	40	Monocular		—	—	—	—	J4	NR
Yang et al[27] (2000)	Array SA-40N	Decimal (2 mo)	20	NR	66.0±4.4	—	0.68±0.27	NR	—	0.49±0.15	NR
Prospective Cohort											
Bi et al[28] (2008)	ReSTOR SN60D3	Decimal (6 mo)	40	NR	53.0±4.5	—	—	NR	—	—	NR
de Santhiago et al[29] (2009)	ReSTOR SN60D3	LogMAR (3 mo)	20	NR	NR	—	0.74±0.2	NR	—	0.96±0.10	NR
	Tecnis ZM900	LogMAR (3 mo)	20	NR	NR	—	0.76±0.22	NR	—	0.93±0.14	NR
De Vries et al[30] (2008)	ReSTOR SA60D3	LogMAR (3 y)	44	Binocular	74.2±8.7	—	0.115±0.173	NR	—	0.014±0.035	NR
	ReSTOR SA60D3	LogMAR (3 y)	44	Monocular		—	0.197±0.185	NR	—	0.058±0.081	NR
Gerten et al[31] (2009)	MS612+ MS714	LogMAR (3 mo)	56	Binocular	65±12	—	0.02±0.07	NR	—	0.08±0.08	NR
	MS612+ MS714	LogMAR (3 mo)	56	Monocular	65±12	—	0.10±0.11	NR	—	0.16±0.13	NR

IOL = intraocular lens, UDVA = uncorrected distance visual acuity, UNVA = uncorrected near visual acuity, NR = not reported

Copyright © SLACK Incorporated

TABLE 1 CONTINUED

Results of the Systematic Review of Patients With Cataract and Presbyopia With Multifocal IOL Implantation

Study Type/ Study (y)	Lens	Unit of Measure (Study Length)	No. of Eyes	Monocular/ Binocular	Patient Age (y)	UDVA			UNVA		
						Preop	Postop	*P* Value	Preop	Postop	*P* Value
Prospective Cohort											
Gierk-Ciaciura et al[32] (2010)	ReZoom	LogMAR (6 mo)	20	Monocular	56.0±5.2	0.79±0.16	0.11±0.01	<.001	0.73±0.18	0.20±0.04	<.001
	ReSTOR	LogMAR (6 mo)	20	Monocular	56.8±6.0	0.65±0.08	0.17±0.02	<.001	0.67±0.16	0.11±0.03	<.001
	Tecnis	LogMAR (6 mo)	20	Monocular	55.6±6.9	0.70±0.09	0.14±0.02	<.001	0.61±0.16	0.12±0.03	<.001
Mesci et al[33] (2010)	Tecnis	LogMAR (12 mo)	22	Binocular	61.7±7.4	0.13±0.13	−0.05±0.05	NR	—	0.25±0.075	NR
	ReZoom	LogMAR (12 mo)	20	Binocular	61.5±8.3	0.15±0.1	−0.05±0.05	NR	—	0.125±0.06	NR
	Tecnis ZM900	LogMAR (12 mo)	22	Monocular	61.7±7.4	0.13±0.13	0.06±0.05	NR	—	0.07±0.075	NR
	ReZoom	LogMAR (12 mo)	20	Monocular	61.5±8.3	0.15±0.1	0.06±0.05	NR	—	0.15±0.05	NR
Palomino Bautista et al[34] (2009)	Tecnis	LogMAR (7 mo)	250	Monocular	68.5±9.9	—	0.144±0.101	NR	—	0.215±0.082	NR
Renieri et al[35] (2007)	ReSTOR SA60D3	LogMAR (median) (3 mo)	18	NR	66.27±4.34	—	0.10	NR	—	0.10	NR
	Array AA50	LogMAR (median) (3 mo)	18	NR		—	0.10	NR	—	0.25	NR
Souza et al[36] (2006)	ReSTOR	LogMAR (4 mo)	50	Binocular	68.3±9.2	—	0.16±0.13	NR	—	0.09±0.10	NR
Toto et al[37] (2007)	Tecnis TM900	LogMAR (6 mo)	14	NR	60.86±6.64	—	—	NR	—	HC: 0.16±0.22 LC: 0.51±0.21	NR
	ReSTOR	LogMAR (6 mo)	14	NR	60.79±7.11	—	—	NR	—	HC: 0.13±0.12 LC: 0.50±0.11	NR
Zhao et al[38] (2010)	ReSTOR SA60D3	LogMAR (median) (6 mo)	72	Monocular	62±8	—	1.07	NR	—	0.66	NR

IOL = intraocular lens, UDVA = uncorrected distance visual acuity, UNVA = uncorrected near visual acuity, NR = not reported, HC = high contrast, LC = low contrast

TABLE 1 CONTINUED

Results of the Systematic Review of Patients With Cataract and Presbyopia With Multifocal IOL Implantation

Study Type/ Study (y)	Lens	Unit of Measure (Study Length)	No. of Eyes	Monocular/ Binocular	Patient Age (y)	UDVA			UNVA		
						Preop	Postop	*P* Value	Preop	Postop	*P* Value
Retrospective Observational											
Forte & Ursoleo[39] (2009)	ReZoom	LogMAR/Jaeger (2 y)	55	Monocular	71±7	0.5±0.3	0.04±0.08	<.001	J7.8±0.6	J2.3±0.7	<.001
Zhao et al[40] (2009)	ReSTOR SA60D3	LogMAR (31 mo)	54	Monocular	62±8	—	0.10	NR	—	0.17	NR

IOL = intraocular lens, UDVA = uncorrected distance visual acuity, UNVA = uncorrected near visual acuity, NR = not reported

TABLE 2

Results of the Systematic Review for Uncorrected Intermediate Visual Acuity

Study Type/Study (y)	Lens	Unit of Measure (Study Length)	No. of Eyes	Patient Age (y)	UIVA	
					Preop	Postop
Cezón-Prieto & Bautista (2010)[20]	Rayner M-Flex 630F	LogMAR (12 mo)	32	68.1±12.0	1.06±0.30 (monocular) 1.02±0.28 (binocular)	0.15±0.05 (monocular) 0.16±0.05 (binocular)

UIVA = uncorrected intermediate visual acuity
Note. Statistical significance was not reported in this study.

Copyright © SLACK Incorporated

DISCUSSION

The objective of this study was to evaluate published results of uncorrected visual acuity in patients with cataracts and presbyopia who received multifocal IOLs. As the goal of multifocal IOLs is to enable patients to be less dependent on spectacles following surgery,[37] uncorrected visual acuity is an appropriate surrogate marker for spectacle independence.

The aggregate results of these studies provide evidence to suggest that multifocal IOL implantation in patients with cataracts and presbyopia improves visual acuity. Although only one-third of the studies (10/30) reported pre- and postoperative values, the results of studies only reporting postoperative values were similar to the postoperative results in the studies that reported pre- and postoperative values. Of the studies that reported statistical significance, all studies reported significant differences between pre- and postoperative values. Published literature exists reporting the comparison between monofocal and multifocal IOLs and meta-analyses on multifocal IOLs,[44-46] but no systematic reviews have been published reporting the outcomes of visual acuity in multifocal IOLs for cataract patients with presbyopia. Prior to this study, there has only been one known evaluation comparing studies measuring outcomes in multifocal IOLs.[46] This study shows the collective improvement of visual acuity, both for hyperopia and myopia.

Spectacle independence and QOL are important factors when considering the use of multifocal IOLs for presbyopic patients.[47] A Cochrane review updated in 2008 identified 13 studies that measured patient satisfaction with vision associated with either multifocal or monofocal IOLs.[44] Using various QOL instruments, the review reported satisfaction with multifocal IOLs between 62.8% and 96%.[48,49] Of the 13 possible studies that were identified through the Cochrane report, 8 studies reported a preference for multifocal IOLs.[44]

A limitation of this study was that it did not measure the outcome of spectacle independence and the impact this has on the QOL of the patient population. Although it was not within the scope of this systematic review to report the outcomes of QOL studies, the literature needs to be updated with a systematic review reporting these outcomes. Furthermore, an analysis on studies reporting the association between QOL and uncorrected visual acuity is needed. A number of instruments can be used to measure QOL in multifocal IOL patients, and it is important to use a validated instrument when measuring these outcomes.[34]

Adverse events are also an important consideration when evaluating multifocal IOLs. Glare, night vision, color perception, halos, distorted vision, and blurred vision are possible adverse events that can occur with the use of IOLs.[47,50] An updated systematic review of these outcomes would also be valuable.

A limitation with the supporting evidence in the available data is the lack of consistency with regard to efficacy parameters and units of measurement among studies reporting multifocal IOL visual acuity outcomes. Mean visual acuity after cataract surgery is the most commonly reported method identified in studies measuring outcomes related to multifocal IOLs; proportion of patients achieving a minimum visual acuity level has been another highly reported method. Statistical challenges exist in comparing this proportional method of reporting with other studies. Without individual patient level data, it is not possible to combine the results of studies that measured either the distribution or the proportion of visual acuity outcomes.

This systematic review analyzed studies that reported improvements in uncorrected visual acuity in cataract patients with presbyopia. Significant improvements in UNVA and UDVA across the studies were identified. Uncorrected visual acuity is a surrogate marker for spectacle independence and thus increased QOL. Further analyses are needed on studies reporting spectacle independence and QOL in regards to multifocal IOL implantation.

AUTHOR CONTRIBUTIONS

Study concept and design (B.A., C.D., D.J.); data collection (B.A.); analysis and interpretation of data (B.A., M.C.K., T.K., C.D.); drafting of the manuscript (B.A.); critical revision of the manuscript (B.A., M.C.K., T.K., C.D., D.J.); statistical expetise (B.A., C.D., D.J.); obtained funding (B.A., C.D., D.J.); administrative, technical, or material support (B.A., C.D., D.J.); supervision (C.D.)

REFERENCES

1. Reidy A, Minassian DC, Vafidis G, et al. Prevalence of serious eye disease and visual impairment in a north London population: population based, cross sectional study. *BMJ*. 1998;316(7145):1643-1646.
2. Minassian DC, Reidy A, Desai P, Farrow S, Vafidis G, Minassian A. The deficit in cataract surgery in England and Wales and the escalating problem of visual impairment: epidemiological modeling of the population dynamics of cataract. *Br J Ophthalmol*. 2000;84(1):4-8.
3. Holden BA, Fricke TR, Ho SM, et al. Global vision impairment due to uncorrected presbyopia. *Arch Ophthalmol*. 2008;126(12):1731-1739.
4. Callina T, Reynolds TP. Traditional methods for the treatment of presbyopia: spectacles, contact lenses, bifocal contact lenses. *Ophthalmol Clin North Am*. 2006;2006(1):25-33.
5. Holzer MP, Rabsilber TM, Auffarth GU. Presbyopia correction using intraocular lenses [German]. *Ophthalmologe*. 2006;103(8):661-666.
6. Seigel K, Hopman W, tenHove M, Neves T, Groll D. Quality of life in patients undergoing cataract surgery [abstract]. Association of Health Services Research Meeting. 1999;16(350).

7. World Health Organization. *International Statistical Classification of Diseases, Injuries and Causes of Death*. 10th ed. Geneva, Switzerland: World Health Organization; 1993.
8. Bourne RR. Uncorrected refractive error and presbyopia: accommodating the unmet need. *Br J Ophthalmol*. 2007;91(7):848-850.
9. Khoshnood B, Mesbah M, Jeanbat V, Lafuma A, Berdeaux G. Transforming scales of measurement of visual acuity at the group level. *Ophthalmic Physiol Opt*. 2010;30(6):816-823.
10. Holladay JT. Proper method for calculating average visual acuity. *J Refract Surg*. 1997;13(4):388-391.
11. Kohnen T. New abbreviations for visual acuity values. *J Cataract Refract Surg*. 2009;35(7):1145.
12. Chiam PJ, Chan JH, Haider SI, Karia N, Kasaby H, Aggarwal RK. Functional vision with bilateral ReZoom and ReSTOR intraocular lenses 6 months after cataract surgery. *J Cataract Refract Surg*. 2007;33(12):2057-2061.
13. Gunenc U, Celik L. Long-term experience with mixing and matching refractive array and diffractive CeeOn multifocal intraocular lenses. *J Refract Surg*. 2008;24(3):233-242.
14. Javitt J, Brauweiler HP, Jacobi KW, et al. Cataract extraction with multifocal intraocular lens implantation: clinical, functional, and quality-of-life outcomes. Multicenter clinical trial in Germany and Austria. *J Cataract Refract Surg*. 2000;26(9):1356-1366.
15. Lane SS, Javitt JC, Nethery DA, Waycaster C. Improvements in patient-reported outcomes and visual acuity after bilateral implantation of multifocal intraocular lenses with +3.0 diopter addition: multicenter clinical trial. *J Cataract Refract Surg*. 2010;36(11):1887-1896.
16. Nijkamp MD, Dolders MG, de Brabander J, van den Borne B, Hendrikse F, Nuijts RM. Effectiveness of multifocal intraocular lenses to correct presbyopia after cataract surgery: a randomized controlled trial. *Ophthalmology*. 2004;111(10):1832-1839. Erratum in *Ophthalmology*. 2004;111(11):2022.
17. Akaishi L, Bessa T, Vaz R, Canamary F, Tzelikis PF. Multifocal intraocular lens optic anteriorization capture to correct residual refractive error. *J Cataract Refract Surg*. 2009;35(12):2077-2083.
18. Alió JL, Elkady B, Ortiz D, Bernabeu G. Microincision multifocal intraocular lens with and without a capsular tension ring: optical quality and clinical outcomes. *J Cataract Refract Surg*. 2008;34(9):1468-1475.
19. Alió JL, Pinero DP, Plaza-Puche AB, Chan MJ. Visual outcomes and optical performance of a monofocal intraocular lens and a new-generation multifocal intraocular lens. *J Cataract Refract Surg*. 2011;37(2):241-250.
20. Cezón-Preito J, Bautista MJ. Visual outcomes after implantation of a refractive multifocal intraocular lens with a +3.00 D addition. *J Cataract Refract Surg*. 2010;36(9):1508-1516.
21. Lin Z, Feng B, Liu Y, Cheng B, Zou Y. The preliminary clinical observation of array multifocal intraocular lens implantation. *Yan Ke Xue Bao*. 2001;17(1):57-60.
22. Mesci C, Erbil HH, Olgun A, Yaylali SA. Visual performances with monofocal, accommodating, and multifocal intraocular lenses in patients with unilateral cataract. *Am J Ophthalmol*. 2010;150(5):609-618.
23. Moreno LJ, Piñero DP, Alió JL, Fimia A, Plaza AB. Double-pass system analysis of the visual outcomes and optical performance of an apodized diffractive multifocal intraocular lens. *J Cataract Refract Surg*. 2010;36(12):2048-2055.
24. Pineda-Fernandez A, Jaramillo J, Celis V, et al. Refractive outcomes after bilateral multifocal intraocular lens implantation. *J Cataract Refract Surg*. 2004;30(3):685-688.
25. Rekas M, Zelichowska B. Multifocal diffractive intraocular lenses in cataract surgery—preliminary report. *Klin Oczna*. 2006;108(4-6):186-190.
26. Walkow T, Liekfeld A, Anders N, Pham DT, Hartmann C, Wollensak J. A prospective evaluation of a diffractive versus a refractive designed multifocal intraocular lens. *Ophthalmology*. 1997;104(9):1380-1386.
27. Yang HC, Chung SK, Baek NH. Decentration, tilt, and near vision of the array multifocal intraocular lens. *J Cataract Refract Surg*. 2000;26(4):586-589.
28. Bi H, Cui Y, Ma X, et al. Early clinical evaluation of AcrySof ReSTOR multifocal intraocular lens for treatment of cataract. *Ophthalmologica*. 2008;222(1):11-16.
29. de Santhiago MR, Netto MV, Barreto J Jr, Gomes Bde A, Schaefer A, Kara-Junior N. A contralateral eye study comparing apodized diffractive and full diffractive lenses: wavefront analysis and distance and near uncorrected visual acuity. *Clinics (Sao Paulo)*. 2009;64(10):953-960.
30. De Vries NE, Webers CA, Montés-Micó R, et al. Long-term follow-up of a multifocal apodized diffractive intraocular lens after cataract surgery. *J Cataract Refract Surg*. 2008;34(9):1476-1482.
31. Gerten G, Kermani O, Schmiedt K, Farvili E, Foerster A, Oberheide U. Dual intraocular lens implantation: monofocal lens in the bag and additional diffractive multifocal lens in the sulcus. *J Cataract Refract Surg*, 2009;35(12):2136-2143.
32. Gierek-Ciaciura S, Cwalina L, Bednarski L, Mrukwa-Kominek E. A comparative clinical study of the visual results between three types of multifocal lenses. *Graefes Arch Clin Exp Ophthalmol*. 2010;248(1):133-140.
33. Mesci C, Erbil H, Ozdoker L, Karakurt Y, Bilge AD. Visual acuity and contrast sensitivity function after accommodative and multifocal intraocular lens implantation. *Eur J Ophthalmol*. 2010;20(1):90-100.
34. Palomino Bautista C, Carmona González D, Castillo Gómez A, Bescos JA. Evolution of visual performance in 250 eyes implanted with the Tecnis ZM900 multifocal IOL. *Eur J Ophthalmol*. 2009;19(5):762-768.
35. Renieri G, Kurz S, Schneider A, Eisenmann D. ReSTOR diffractive versus Array 2 zonal-progressive multifocal intraocular lens: a contralateral comparison. *Eur J Ophthalmol*. 2007;17(5):720-728.
36. Souza CE, Gerente VM, Chalita MR, Soriano ES, Freitas LL, Belfort R Jr. Visual acuity, contrast sensitivity, reading speed, and wavefront analysis: pseudophakic eye with multifocal IOL (ReSTOR) versus fellow phakic eye in non-presbyopic patients. *J Refract Surg*. 2006;22(3):303-305.
37. Toto L, Falconio G, Vecchiarino L, et al. Visual performance and biocompatibility of 2 multifocal diffractive IOLs: six-month comparative study. *J Cataract Refract Surg*. 2007;33(8):1419-1425.
38. 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(2):282-285.
39. Forte R, Ursoleo P. The ReZoom multifocal intraocular lens: 2-year follow-up. *Eur J Ophthalmol*. 2009;19(3):380-383.
40. Zhao YE, Li JH, Zhu J, Wang DD, Wang QM. Evaluation of long-term visual performance following AcrySof ReSTOR lens implantation. *Chin Med J*. 2009;122(22):2705-2710.
41. Chen M, Atebara NH, Chen TT. A comparison of a monofocal Acrysof IOL using the "blended monovision" formula with the multifocal array IOL for glasses independence after cataract surgery. *Ann Ophthalmol*. 2007;39(3):237-240.
42. McNaught IE. Simple methods of eye examination. In: Crick RP, Khaw P, Crick RP, eds. *A Textbook of Clinical Ophthal-*

Copyright © SLACK Incorporated

mology: A Practice Guide to Disorders of the Eyes and Their Management. 3rd ed. Singapore: World Scientific; 2003:77-89.

43. Alió JL, Elkady B, Ortiz D, Bernabeu G. Clinical outcomes and intraocular optical quality of a diffractive multifocal intraocular lens with asymmetrical light distribution. *J Cataract Refract Surg*. 2008;34(6):942-948.
44. Leyland M, Pringle E. Multifocal versus monofocal intraocular lenses after cataract extraction [systematic review]. *Cochrane Database Syst Rev*. 2009;1.
45. Cochener B, Arnould B, Viala M, Roborel de CA, Berdeaux G. Corrected and uncorrected near and distance vision with ReSTOR compared to monofocal intraocular lens implantation after cataract surgery: a pooled analysis. *Ophthalmologica*. 2009;223(2):128-135.
46. Cochener B, Lafuma A, Khoshnood B, Courouve L, Berdeaux G. Comparison of outcomes with multifocal intraocular lenses: a meta-analysis. *Clin Ophthalmol*. 2011;(5):45-56.
47. Kohnen T, Allen D, Boureau C, et al. European multicenter study of the AcrySof ReSTOR apodized diffractive intraocular lens. *Ophthalmology*. 2006;113(4):584.
48. Sen HN, Sarikkola AU, Uusitalo RJ, Laatikainen L. Quality of vision after AMO Array multifocal intraocular lens implantation. *J Cataract Refract Surg*. 2004;30(12):2483-2493.
49. Rossetti L, Carraro F, Rovati M, Orzalesi N. Performance of diffractive multifocal intraocular lenses in extracapsular cataract surgery. *J Cataract Refract Surg*. 1994;20(2):124-128.
50. Kohnen T, Nuijts R, Levy P, Haefliger E, Alfonso JF. Visual function after bilateral implantation of apodized diffractive aspheric multifocal intraocular lenses with a +3.0 D addition. *J Cataract Refract Surg*. 2009;35(12):2062-2069.