Wavefront-guided Excimer Laser Vision Correction After Multifocal IOL Implantation

Bettina B. Jendritza, MD; Michael C. Knorz, MD; Steve Morton

ABSTRACT

PURPOSE: To investigate the use of wavefront-guided LASIK after multifocal intraocular lens (IOL) implantation to correct residual ametropia and higher order aberrations.

METHODS: In a prospective, nonrandomized case series, wavefront-guided LASIK was performed in 27 eyes (19 patients) after multifocal IOL implantation (Tecnis diffractive IOL, n=20; ReSTOR diffractive IOL, n=4; ReZoom refractive IOL, n=3) using the VISX STAR S4 IR excimer laser. Visual acuity, manifest refraction, and wavefront error were examined pre- and 3 months postoperatively.

RESULTS: In the Tecnis group, results before (after) LASIK were: sphere +1.06±0.77 diopters (D) (−0.03±0.28 D; *P*=.0001), cylinder −1.13±0.73 D (−0.14±0.25 D; *P*=.00004), distance uncorrected visual acuity (UCVA) 20/45±0.09 (20/29±0.16; *P*=.00004), near UCVA 20/30±0.24 (20/25±0.16; *P*=.001), and higher order aberrations (4-mm pupil) 0.14±0.05 μm (0.18±0.03 μm; *P*=.02). Distance and near best spectacle-corrected visual acuity (BSCVA) did not change. In the ReSTOR group, results before (after) LASIK were: sphere +0.75±0.56 D (+0.13±0.22 D), cylinder −1.50±0.47 D (−0.13±0.22 D), distance UCVA 20/40±0.07 (20/26±0.07), near UCVA 20/44±0.05 (20/25±0.0), and higher order aberrations (4-mm pupil) 0.14±0.03 μm (0.20±0.02 μm). Distance and near BSCVA did not change. In the ReZoom group, results before (after) LASIK were: sphere +0.08±1.20 D (0.00 D), cylinder −0.83±0.120 D (0.00 D), distance UCVA 20/40±0 (20/25±0), near UCVA 20/60±0.09 (20/150±0.18), and higher order aberrations (4-mm pupil) 0.43±0.04 μm (0.39±0.03 μm). Patients lost one line of distance BSCVA and two lines of near BSCVA.

CONCLUSIONS: Wavefront-guided LASIK is safe and effective in diffractive multifocal IOLs to correct residual refractive error, but higher order aberrations did not improve. It is not recommended in refractive multifocal IOLs, as these cannot be measured reliably with current wavefront sensors. [*J Refract Surg*. 2008;24:274-279.]

Bioptics is a surgical procedure to correct refractive errors by combining corneal and lenticular surgical techniques. The term "bioptics" was originally developed to correct high or extreme ametropia that could not be corrected by one procedure alone. In the early days of bioptics, the implantation of a phakic intraocular lens (IOL) was followed by intended LASIK approximately 1 to 3 months later.[1]

Today, a sequential or, in some cases, simultaneous combination of a corneal refractive procedure and implant technology is suitable, depending on the patient's need for spectacle independence.[2] Refractive lens exchange or cataract surgery with a monofocal implant cannot provide good distance and near vision without correction. Therefore, we were interested in multifocal IOLs, designed to provide spectacle independence after refractive lens exchange in ametropic and presbyopic patients. Furthermore, we offered the patient an additional LASIK procedure approximately 1 to 3 months after refractive lens exchange or cataract surgery in case of a residual refractive error to achieve full spectacle independence. The LASIK procedure was wavefront-guided to possibly provide higher precision of astigmatism correction due to on-axis treatment achieved by iris registration and to possibly reduce higher order aberrations.[3,4]

PATIENTS AND METHODS

Multifocal Intraocular Lenses

Three multifocal IOLs were used in this study. Two designs were diffractive and one was refractive. The Tecnis aspheric

From FreeVis LASIK Center, University of Heidelberg, Medical Faculty Mannheim, Germany (Jendritza, Knorz); and Eye Services, Bourne End, United Kingdom (Morton).

Dr Knorz is a consultant of AMO Inc, Santa Ana, Calif. Dr Jendritza and Mr Morton have no financial interest in the materials presented herein.

Presented in part at the American Academy of Ophthalmology Annual Meeting; November 11-14, 2006; Las Vegas, Nev.

Correspondence: Bettina B. Jendritza, MD, FreeVis LASIK Zentrum, Klinikum Mannheim, Theodor-Kutzer-Ufer 1-3, 68167 Mannheim, Germany. Tel: 49 621 383 3410; Fax: 49 621 383 1984; E-mail: bjendritza@freevis.de

Received: September 19, 2007

Accepted: December 6, 2007

diffractive multifocal IOL (Advanced Medical Optics [AMO], Santa Ana, Calif) is a foldable three-piece silicone IOL. The optic incorporates a prolate anterior shape with 0.27 µm of negative spherical aberration, designed to compensate for the spherical aberration of the average cornea, and a diffractive back side. Light distribution to far and near focus is approximately 42%, independent of pupil size, and approximately 16% in higher diffractive orders. The ReSTOR diffractive multifocal IOL (Alcon Laboratories Inc, Ft Worth, Tex) offers the use of a foldable hydrophobic acrylic platform, apodization of the anterior diffractive optic, and transition to a refractive optic outside a 3.6-mm diameter. It is therefore pupil dependent, and light distribution is shifted towards distance vision for larger pupil sizes. Both lenses have effective near additions of +4.00 diopters (D), which translates to approximately 3.20 D at the spectacle plane.

The ReZoom (AMO) is a refractive multifocal IOL and was developed to re-engineer the optics of AMO's previously approved Array IOL. It is a three-piece, hydrophobic acrylic IOL that distributes light over five optical zones. The ReZoom is both distance-dominant and pupil dependent. Intermediate vision is lower than distance vision, and near vision is lower than that generated by diffractive multifocal IOLs. The near addition is 3.50 D, which translates to approximately 2.80 D at the spectacle plane.

Patient Population

From January 2006 to January 2007, 27 eyes of 19 patients (9 men [12 eyes] and 10 women [15 eyes]) underwent wavefront-guided (CustomVue, AMO/VISX) LASIK after previous implantation of one of the described multifocal IOLs to correct residual ametropia. Mean patient age was 53±10.3 years (range: 36 to 68 years).

The eyes were divided into three groups, depending on the type of multifocal IOL used. The IOL type was chosen depending on the patient's needs (preferred reading distance or intermediate vision for computer work). The first group consisted of 20 eyes that were implanted with a Tecnis multifocal IOL (Tecnis group). The second group consisted of 4 eyes with a ReSTOR multifocal IOL (ReSTOR group), and the third group of 3 eyes with a ReZoom multifocal IOL (ReZoom group). Statistical analysis was performed in the Tecnis group only due to the small number of eyes in the other groups (paired samples *t* test, alpha 0.05).

Refraction and Other Examinations

Preoperative examination included manifest refraction, slit-lamp microscopy, non-contact tonometry (non-contact tonometer NT-2000; NIDEK Co Ltd, Gamagori, Japan), corneal topography (TMS-2N; Tomey, Erlangen, Germany), corneal tomography and pachymetry (Orbscan IIz; Bausch & Lomb, Rochester, NY), and measurements of uncorrected visual acuity (UCVA) and best spectacle-corrected visual acuity (BSCVA) for distance and near. Outcome measures were UCVA and BSCVA for distance and near, manifest refraction, and changes in higher order aberrations before and after LASIK (WaveScan aberrometer, AMO/VISX). Postoperative examinations were performed at 1 day, 1 to 3 and 6 to 8 weeks, and 3 months postoperatively. All data presented were measured at 3 months.

Aberrometry and Treatment Calculation

Aberrometry was performed using the WaveScan aberrometer. Three or more measurements were obtained before LASIK with an undilated pupil. One of the three measurements that best matched the manifest refraction was chosen to calculate the treatment. If manifest sphere differed by ±0.50 D or more from the wavefront sphere, manifest sphere was used to calculate the treatment. If wavefront cylinder differed by more than 0.50 D or more than 15° from the manifest cylinder, wavefront-guided treatment was not performed. No other adjustments were made.

A VISX STAR S4 IR excimer laser (AMO) was used. The eye tracker and iris registration were used in all eyes. As the WaveScan aberrometer does not allow calculation of wavefront errors for pupil sizes other than the one measured, we calculated wavefront errors for a 4-mm pupil in all eyes as described elsewhere.[5] These 4-mm values allow for a comparison between groups. In addition, we calculated wavefront error for each individual eye for the same pupil size pre- and postoperatively, using the largest possible pupil size for which data were available at both examinations. As pupil size was not the same in different patients, we cannot compare the pre- and postoperative values in this approach. We therefore subtracted the postoperative values from the preoperative values and averaged the change. This change will reflect the change of higher order aberrations at pupil sizes greater than 4 mm.

LASIK Flap

The mean postoperative period between multifocal IOL implantation and CustomVue LASIK was 4.4 months (range: 6 weeks to 12 months). The Amadeus microkeratome (AMO) with a 140-µm head and a 9.0-mm suction ring was used to create the flap in 18 eyes. In 9 eyes with a preoperative astigmatism of ⩾2.50 D, the LASIK flap was created using the IntraLase FS 60 (AMO) immediately prior to lens surgery without lifting the flap. In patients with astigmatism of ⩾2.50 D,

TABLE 1

Subjective Refraction, Aberrometer-derived Refraction, Uncorrected Visual Acuity, and Best Spectacle-corrected Visual Acuity Before and 3 Months After Wavefront-guided LASIK Following Implantation of Three Different Multifocal IOLs

	Tecnis (n=20)			ReSTOR (n=4)		ReZoom (n=3)	
	Before LASIK	After LASIK	*P* Value*	Before LASIK	After LASIK	Before LASIK	After LASIK
Sphere (D)	+1.06±0.77 (−0.75 to +2.25)	−0.03±0.28 (−0.5 to +0.5)	.0001	+0.75±0.56 (0.00 to +1.5)	+0.13±0.22 (0.00 to +0.5)	+0.08±1.2 (−1.00 to +1.75)	0.00±0.00 (0.00 to 0.00)
Cylinder (D)	−1.13±0.73 (−2.75 to 0.00)	−0.14±0.2 (−0.75 to 0.00)	.00004	−1.50±0.47 (−2.25 to −1.00)	−0.13±0.22 (−0.50 to 0.00)	−0.83±0.12 (−1.00 to −0.75)	0.00±0.00 (0.00 to 0.00)
WaveScan							
Sphere (D)	+1.51±0.49 (0.79 to 2.63)	+0.64±0.4 (0.00 to 1.41)	.006	+0.41±0.24 (0.13 to 0.72)	+1.01±0.15 (0.89 to 1.23)	−1.59±1.13 (−2.72 to −0.04)	−0.67±0.21 (−0.96 to −0.44)
Cylinder (D)	−1.27±0.76 (−2.73 to −0.26)	−0.36±0.20 (−0.85 to −0.12)	.003	−1.70±0.55 (−2.4 to −1.03)	−0.64±0.30 (−0.99 to −0.24)	−0.67±0.21 (−0.96 to −0.44)	−0.33±0.23 (−0.65 to −0.07)
UCVA distance	20/45±0.09 (20/60 to 20/30)	20/29±0.16 (20/50 to 20/20)	.00004	20/50±0.07 (20/60 to 20/40)	20/26±0.07 (20/30 to 20/25)	20/40±0.00 (20/40 to 20/40)	20/25±0.00 (20/25 to 20/25)
BSCVA distance	20/27±0.12 (20/40 to 20/20)	20/26±0.1 (20/50 to 20/20)	.43	20/26±0.07 (20/30 to 20/25)	20/26±0.07 (20/30 to 20/25)	20/21±0.09 (20/25 to 20/20)	20/25±0.00 (20/25 to 20/25)
UCVA near	20/30±0.24 (20/60 to 20/20)	20/25±0.16 (20/40 to 20/20)	.001	20/44±0.05 (20/50 to 20/40)	20/25±0.00 (20/25 to 20/25)	20/60±0.09 (20/100 to 20/50)	20/153±0.18 (0 to 20/50)
BSCVA near	20/27±0.22 (20/50 to 20/20)	20/25±0.15 (20/30 to 20/20)	.001	20/34±0.05 (20/40 to 20/30)	20/25±0.00 (20/25 to 20/25)	20/22±0.17 (20/30 to 20/20)	20/30±0.14 (20/40 to 20/25)

UCVA = uncorrected visual acuity, BSCVA = best spectacle-corrected visual acuity
**t test.*

we deemed it unlikely that the corneal incision during the lens replacement surgery alone could correct the astigmatism. We therefore created the flap with the IntraLase to shorten the wait for wound stability. Hence, enhancements in eyes that had an IntraLase flap were performed earlier, with the earliest approximately 6 weeks after lens implantation.

RESULTS

Mean refraction, aberrometer-derived refraction, visual acuity, and higher order aberrations before and after LASIK are given in Tables 1 and 2. Three-month postoperative data are reported.

In the Tecnis group, sphere and cylinder as well as distance and near UCVA improved significantly after LASIK. No eye lost distance or near BSCVA. Aberrometer-derived refractions matched the manifest values well and also improved significantly, but showed a slightly larger variability than manifest refraction. Before LASIK, 45% of eyes in the Tecnis group needed an additional near add for reading. After LASIK, all patients could read without any correction. Overall higher order aberrations increased slightly after LASIK for a 4-mm pupil (from 0.14 to 0.18 µm; P=.02) but decreased slightly (0.07 µm) when comparing change of higher order aberrations for larger pupil sizes. Coma, trefoil, and spherical aberration also increased for a 4-mm pupil and when comparing change of higher order aberrations for the same pupil size pre- and postoperatively.

In the ReSTOR group, results were similar. Refraction and visual acuity improved after LASIK. No eye lost distance or near BSCVA. Aberrometer-derived refractions matched well with manifest values but showed a somewhat greater variability than manifest values. Higher order aberrations also increased slightly after LASIK for a 4-mm pupil (0.14 to 0.20 µm) but improved slightly (0.10 µm) when comparing change of higher order aberrations for the same pupil size pre- and postoperatively. The results for coma, trefoil, and spherical aberration were similar to those in the Tecnis group.

In the ReZoom group, refraction and distance UCVA improved, but distance BSCVA worsened by one line, near BSCVA worsened by two lines, and near UCVA worsened by four lines. In addition, a considerable difference was noted between manifest and aberrometer-derived refraction, with the aberrometer-derived refraction being on average 1.50 D more myopic than the manifest values, indicating inaccurate measurements of the aberrometer in eyes with a refractive multifocal

IOL. Higher order aberrations were much higher than in the other two groups, most likely indicating the inability of the wavefront sensor used to measure refractive multifocal IOLs.

DISCUSSION

An increasing number of patients undergoing cataract and refractive surgery want to achieve not only good unaided vision for distance but also want to be able to read without spectacles. As any residual ametropia would negate the goal of spectacle independence with a multifocal IOL, we offered our patients an additional LASIK procedure to achieve spectacle independence, if emmetropia was not achieved after IOL implantation. We used wavefront-guided LASIK, intending to further improve quality of vision and to optimize the ablation due to iris registration. Compensation of eye rotation and pupil centroid shift using iris registration of the VISX STAR S4 IR excimer laser in customized treatments provides a match for wavefront measurements and laser ablation and therefore corrects astigmatism more precisely than a standard ablation without iris registration. In addition, customized wavefront-guided treatments with iris registration induce significantly less higher order aberrations than treatments without iris registration and provide a higher predictability and improved contrast sensitivity.[6-8]

In this case series, we used three different multifocal IOLs. Two IOL designs were diffractive, one refractive. The Tecnis aspheric diffractive multifocal IOL was used in 74% of cases (n=20). The Tecnis has excellent near vision,[9] good distance vision, but somewhat lower intermediate vision. Because of the diffractive optic, which extends to the periphery of the lens, the lens is not pupil dependent. The lens gives a measurable improvement in mesopic contrast sensitivity and reduced night vision symptoms especially compared to first- and second-generation bifocal and multifocal IOLs.[10-12] Our results confirmed the good near vision achievable with the Tecnis IOL: 100% of patients after LASIK could read without glasses. Mean UCVA improved significantly after LASIK (Table 1).

The ReSTOR diffractive multifocal IOL was used in four eyes. Mesopic contrast sensitivity loss and night vision symptoms, especially halos, are significantly reduced compared to older multifocal or bifocal IOLs.[13,14] Due to the design featuring a central near zone only, near vision is lower with a larger pupil than with a smaller pupil, and

TABLE 2

Higher Order Aberrations (Mean±Standard Deviation) Before and 3 Months After Wavefront-guided LASIK Following Implantation of Three Different Multifocal IOLs*

HOA (µm)†	Tecnis (n=20) 4-mm Pupil Before LASIK	Tecnis (n=20) 4-mm Pupil After LASIK	Tecnis (n=20) *P* Value‡	Tecnis (n=20) Change for Same Pupil Size	ReSTOR (n=4) 4-mm Pupil Before LASIK	ReSTOR (n=4) 4-mm Pupil After LASIK	ReSTOR (n=4) Change for Same Pupil Size	ReZoom (n=3) 4-mm Pupil Before LASIK	ReZoom (n=3) 4-mm Pupil After LASIK	ReZoom (n=3) Change for Same Pupil Size
Coma	0.08±0.03 (0.03 to 0.13)	0.09±0.03 (0.04 to 0.13)	.23	−0.04±0.08 (−0.16 to 0.05)	0.06±0.04 (0.01 to 0.10)	0.13±0.05 (0.05 to 0.17)	−0.10±0.12 (−0.25 to 0.05)	0.14±0.10 (0.07 to 0.29)	0.06±0.05 (0.01 to 0.13)	0.04±0.04 (−0.01 to 0.07)
Trefoil	0.07±0.03 (0.04 to 0.14)	0.09±0.04 (0.03 to 0.16)	.10	−0.02±0.08 (−0.12 to 0.14)	0.08±0.02 (0.06 to 0.10)	0.11±0.02 (0.08 to 0.13)	−0.04±0.05 (−0.10 to 0.02)	0.10±0.08 (0.03 to 0.21)	0.15±0.02 (0.14 to 0.18)	−0.05±0.06 (−0.12 to 0.03)
SA	0.04±0.01 (0.02 to 0.07)	0.05±0.02 (0.01 to 0.06)	.06	0.04±0.03 (−0.09 to 0.01)	0.07±0.01 (0.06 to 0.07)	0.07±0.01 (0.06 to 0.08)	0.02±0.04 (−0.02 to 0.07)	0.32±0.04 (0.27 to 0.38)	0.30±0.04 (0.27 to 0.35)	0.03±0.02 (0.01 to 0.05)
All HOA	0.14±0.05 (0.07 to 0.24)	0.18±0.03 (0.14 to 0.23)	.02	0.07±0.08 (−0.22 to 0.04)	0.14±0.03 (0.11 to 0.17)	0.20±0.02 (0.17 to 0.22)	0.10±0.45 (−0.15 to 0.04)	0.43±0.04 (0.38 to 0.49)	0.39±0.03 (0.36 to 0.43)	0.02±0.05 (−0.02 to 0.09)

HOA = higher order aberrations, SA = spherical aberration

**Higher order aberrations given for a 4-mm pupil size pre- and postoperatively; in addition, the difference of higher order aberrations for each individual eye was calculated for the same pupil size pre- and postoperatively, using the largest possible pupil size for which data were available at both exams, and mean differences are shown as "change for same pupil size" (a positive value indicates fewer higher order aberrations, a negative value indicates an increase in higher order aberrations).*

†Root-mean-square values.

‡t-test.

some night vision symptoms still may occur.[15-17] In the ReSTOR group, all eyes were spectacle independent and within ±0.50 D of emmetropia after wavefront-guided LASIK.

The ReZoom IOL, a refractive multifocal IOL, is distance-dominant and pupil dependent. Intermediate vision is weaker than distance but slightly better than that generated by diffractive multifocal IOLs.[18] In our series, three eyes of two patients with a ReZoom IOL were treated. All eyes were plano after LASIK but their distance and near BSCVA as well as their near UCVA were reduced after LASIK (Table 1). Comparing wavefront-derived and manifest refraction in the ReZoom group, it was noted that wavefront refraction of all three ReZoom eyes differed by >1.50 D from the manifest refraction (Table 1). We had modified the wavefront-derived sphere to match the manifest sphere for calculation of the treatment. However, this still resulted in a reduction of near vision and a reduction of corrected near vision, which indicates that current wavefront-measuring devices are not able to correctly measure the wavefront aberrations in an eye after implantation of the ReZoom multifocal IOL. This was later confirmed by experimental studies in an artificial eye conducted by Campbell.[19] Campbell concluded that the WaveScan aberrometer could not reliably measure distance refraction and higher order aberrations in the ReZoom IOL, whereas the Tecnis multifocal IOL could be measured reliably.[19] This explains our results and indicates that wavefront-guided ablations should not be used after implantation of a refractive multifocal IOL such as the ReZoom IOL.

In diffractive multifocal IOLs such as the Tecnis or ReSTOR, the success rate of wavefront-guided LASIK was high: all patients were spectacle-free after LASIK compared to 45% before LASIK. Both in the Tecnis and ReSTOR groups, overall higher order aberrations increased slightly after LASIK for a 4-mm pupil, but decreased slightly when comparing change of higher order aberrations for larger pupil sizes (Table 2). Coma, trefoil, and spherical aberration increased for a 4-mm pupil and when comparing change of higher order aberrations for the same pupil size pre- and postoperatively in the Tecnis and ReSTOR group; however, differences were small (Table 2).

It may be argued why wavefront-guided ablations should be used with multifocal IOLs, and if so, whether a wavefront-guided treatment affects the multifocality. We used wavefront-guided treatments for two reasons. First and most important, we believe that the use of iris registration, which is a part of the wavefront-guided treatment, offers higher precision of the laser ablation as astigmatism is treated on-axis and as pupil centroid shift is compensated, potentially providing a better centration. Second, a decentration of the IOL in reference to the pupil might induce some higher order aberration, and a wavefront-guided treatment might be beneficial in addressing these higher order aberrations. Our results showed that wavefront-guided treatment was efficient in addressing residual refractive errors with both diffractive multifocal IOLs tested, and there was no clear trend regarding the effect on higher order aberrations. Higher order aberrations increased with a 4-mm pupil, but decreased if larger pupil sizes were analyzed (Table 2). In addition, multifocality of the diffractive multifocal IOLs was not impaired by a wavefront-guided treatment, as all patients in the Tecnis and ReSTOR group could read very well. These findings are confirmed by wavefront-measurements in a model eye with both diffractive multifocal IOLs,[19] which showed that both refraction and higher order aberrations could be measured reliably. On the other hand, we observed that a refractive multifocal IOL such as the ReZoom could not be measured reliably, and a wavefront-guided treatment should therefore not be used with refractive multifocal IOLs.

Wavefront-guided LASIK is effective in correcting residual refractive errors after implantation of diffractive multifocal IOLs. Higher order aberrations seem to be largely unaffected. However, wavefront-guided LASIK should not be used after implantation of refractive multifocal IOLs.

REFERENCES

1. Zaldivar R, Davidorf JM, Oscherow S. Posterior chamber phakic intraocular lens for myopia of -8 to -19 diopters. *J Refract Surg.* 1998;14:294-305.
2. Leccisotti A. Secondary procedures after presbyopic lens exchange. *J Cataract Refract Surg.* 2004;30:1461-1465.
3. Chandhrasri S, Knorz MC. Comparison of higher order aberrations and contrast sensitivity after LASIK, Verisyse phakic IOL, and Array multifocal IOL. *J Refract Surg.* 2006;22:231-236.
4. Dai GM. Scaling Zernike expansion coefficients to smaller pupil sizes: a simpler formula. *J Opt Soc Am A Opt Image Sci Vis.* 2006;23:539-543.
5. Kasper T, Bühren J, Kohnen T. Visual performance of aspherical and spherical intraocular lenses: intraindividual comparison of visual acuity, contrast sensitivity, and higher order aberrations. *J Cataract Refract Surg.* 2006;32:2022-2029.
6. Chernyak DA. From wavefront device to laser: an alignment method for complete registration of the ablation of the cornea. *J Refract Surg.* 2005;21:463-468
7. Partal A, Manche EE. CustomVue laser in situ keratomileusis for myopia and myopic astigmatism using the Visx S4 excimer laser. Efficacy, predictability, and safety. *J Cataract Refract Surg.* 2006;32:475-479.
8. Tuan KM, Liang J. Improved contrast sensitivity and visual acuity after wavefront-guided laser in situ keratomileusis: in-depth statistical analysis. *J Cataract Refract Surg.* 2006;32:215-220.
9. Hütz WW, Eckhardt HB, Röhrig B, Grolmus R. Reading ability

with 3 multifocal intraocular lens models. *J Cataract Refract Surg*. 2006;32:2015-2021.

10. Knorz MC, Claessens D, Schäfer RC, Seiberth V, Liesenhoff H. Evaluation of contrast acuity and defocus curve in bifocal and monofocal intraocular lenses. *J Cataract Refract Surg*. 1993;19:513-523.
11. Knorz MC. Results of a European multicenter study of the True Vista bifocal intraocular lens. *J Cataract Refract Surg*. 1993;19:626-634.
12. Brydon KW, Tokarewicz AC, Nichols BD. AMO Array multifocal lens versus monofocal correction in cataract surgery. *J Cataract Refract Surg*. 2000;26:96-100.
13. Kohnen T, Allen D, Boureau C, Dublineau P, Hartmann C, Mehdorn E, Rozot P, Tassinari G. European multicenter study of the AcrySof ReSTOR apodized diffractive intraocular lens. *Ophthalmology*. 2006;113:584.
14. Gimbel HV, Sanders DR, Raanan MG. Visual and refractive results of multifocal intraocular lenses. *Ophthalmology*. 1991;98:881-888.
15. Chiam PJ, Chan JH, Aggarwal RK, Kasaby S. ReSTOR intraocular lens implantation in cataract surgery: quality of vision. *J Cataract Refract Surg*. 2006;32:1459-1463.
16. Blaylock JF, Si Z, Vickers C. Visual and refractive status at different focal distances after implantation of the ReSTOR multifocal intraocular lens. *J Cataract Refract Surg*. 2006;32:1464-1473.
17. 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 eye in non-presbyopic patients. *J Refract Surg*. 2006;22:303-305.
18. Lane SS, Morris M, Nordan L, Packer M, Tarantino N, Wallace RB III. Multifocal intraocular lenses. *Ophthalmol Clin North Am*. 2006;19:89-105.
19. Campbell C. Wavefront measurements of diffractive and refractive multifocal intraocular lenses in an artificial eye. *J Refract Surg*. 2008;24:308-311.