ARTICLE

Comparative analysis of visual outcomes with 4 intraocular lenses: Monofocal, multifocal, and extended range of vision

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Purpose: To compare the visual acuity, refractive outcomes, and quality of vision in patients with bilateral implantation of 4 intraocular lenses (IOLs).

Settings: Department of Neurosciences, Biomedicine and Movement Sciences, Eye Clinic, University of Verona, Verona, and Carones Ophthalmology Center, Milano, Italy.

Design: Prospective case series.

Methods: The study included patients who had bilateral cataract surgery with the implantation of 1 of 4 IOLs as follows: Tecnis 1-piece monofocal (monofocal IOL), Tecnis Symfony extended range of vision (extended-range-of-vision IOL), Restor +2.5 diopter (D) (+2.5 D multifocal IOL), and Restor +3.0 D (+3.0 D multifocal IOL). Visual acuity, refractive outcome, defocus curve, objective optical quality, contrast sensitivity, spectacle independence, and glare perception were evaluated 6 months after surgery.

Results: The study comprised 185 patients. The extended-range-of-vision IOL (55 patients) showed better distance visual outcomes than the monofocal IOL (30 patients) and high-addition apodized diffractive–refractive multifocal IOLs ($P \leq .002$). The +3.0 D multifocal IOL (50 patients) showed the best near visual outcomes ($P < .001$). The +2.5 D multifocal IOL (50 patients) and extended-range-of-vision IOL provided significantly better intermediate visual outcomes than the other 2 IOLs, with significantly better vision for a defocus level of −1.5 D ($P < .001$). Better spectacle independence was shown for the +2.5 D multifocal IOL and extended-range-of-vision IOL ($P < .001$).

Conclusions: The extended-range-of-vision IOL and +2.5 D multifocal IOL provided significantly better intermediate visual restoration after cataract surgery than the monofocal IOL and +3.0 D multifocal IOL, with significantly better quality of vision with the extended-range-of-vision IOL.

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Modern cataract surgery with intraocular lens (IOL) implantation has achieved excellent visual results, although the extraction of the crystalline lens leads inevitably to a loss of the accommodative ability.[1] Monofocal IOLs can commonly provide excellent outcomes for unaided distance visual acuity; however, patients often require spectacle correction for near vision. In the past decade, multifocal IOLs have been designed to improve the spectacle independence after cataract surgery.[2] Different multifocal IOLs have been designed, based on different optical principles providing a significant improvement in postoperative uncorrected near visual acuity (UNVA) compared with monofocal IOLs and achieving an acceptable visual performance without decreasing uncorrected distance visual acuity (UDVA).[3,4] However, compared with monofocal IOLs, multifocal IOLs have been associated with a higher incidence of contrast sensitivity function (CSF) deterioration and subjective photic phenomena, including halos and glare, which might affect the quality of vision and patient satisfaction.[5,6] Bifocal diffractive multifocal IOLs provide good levels of visual acuity for distance and near; however, the performance at intermediate distances and the worse CSF are the limitations of these designs.[7]

To reduce these problems, there is a tendency to produce IOLs with decreased near addition (add) dioptric power, although the limitations of bifocality have not yet been addressed completely.[8] A new IOL design was recently

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developed based on the generation of an extended range of vision, and it has been presented as a promising technological advancement that results in good visual outcomes while minimizing visual disturbances commonly associated with multifocality design.

The aim of this study was to compare the visual performance of 4 IOL models (1 monofocal IOL, 2 multifocal IOLs, and 1 extended-range-of-vision IOL). The parameters evaluated were distance and near visual acuities, refractive outcomes, spectacle independence, contrast sensitivity, objective ocular optical quality, and rate of visual aberration.

PATIENTS AND METHODS

Study Design

This prospective nonrandomized comparative single-masked clinical study included patients who had cataract surgery with bilateral implantation of 1 of the following IOL models: Tecnis monofocal–aspheric 1-piece (monofocal IOL) (Abbott Medical Optics, Inc.), Tecnis Symfony (extended-range-of-vision IOL) (Abbott Medical Optics, Inc.), Restor apodized diffractive–refractive +2.5 diopter (D) (+2.5 D IOL) (Alcon Laboratories, Inc.), or Restor apodized diffractive–refractive +3.0 D (+3.0 D IOL) (Alcon Laboratories, Inc.). All patients enrolled in the study were informed about the research and written informed consent was obtained. All patients had the surgery between January 2015 and April 2016 at the Department of Neurosciences, Biomedicine and Movement Sciences, Eye Clinic, University of Verona, Verona, and Carones Ophthalmology Center, Milano, Italy. The study adhered to the tenets of the Declaration of Helsinki and was approved by the local ethical committee (Department of Neuroscience, Biomedicine and Movement Sciences, University of Verona).

Selection of the Intraocular Lens Based on Patient Requirements and Expectations

During the preoperative assessment, all patients were assessed for principle vision requirements in terms of near, intermediate, and distance vision. They were also asked about their expectations regarding postoperative spectacles or contact lens use. The choice of IOL proposed for implantation was based on their responses. Patients were implanted with the +3.0 D IOL if they required greater near vision without spectacles and with the +2.5 D multifocal IOL or the extended-range-of-vision IOL when they indicated intermediate vision was more important. The monofocal IOL was implanted in the patients who wanted a good distance vision without the risk for the potential side effects of multifocality. Specific details concerning the theoretical advantages and limitations of the IOLs were given and the final choice was always left to the patient.

Patients

Table 1 shows the preoperative patient characteristics. Inclusion criteria for the study were patients with significant bilateral cataract who were seeking spectacle independence and had a preexisting corneal astigmatism of 1.00 D or worse. Exclusion criteria included patients with only 1 functional eye and/or previous ocular surgery including corneal or refractive surgery, amblyopia, chronic or recurrent uveitis, acute ocular disease, diabetes mellitus with retinal changes, glaucoma or intraocular pressure of 24 mm Hg or higher, pseudoexfoliation syndrome, keratoconus, and corneal endothelial dystrophy.

All patients had a comprehensive preoperative ophthalmologic examination that included the measurement of uncorrected (UDVA) and corrected (CDVA) distance visual acuities, manifest refraction, optical biometry (IOLMaster, Carl Zeiss Meditec AG), biomicroscopy evaluation, Goldmann applanation tonometry, and dilated fundoscopy. The patients were treated postoperatively with the best standard of care. The patients were evaluated 1 day, 1 week, 3 months, and 6 months postoperatively. The results reported in this study refer to the last follow-up visit. The ophthalmologists who performed all postoperative functional examinations were masked to the identity of the IOL implanted.

Intraocular Lenses

The Restor +3.0 D (model SN6AD1) and the Restor +2.5 D are foldable aspheric multifocal IOLs that combine the functions of an apodized diffractive and a refractive region. Both IOLs are made of the same hydrophobic acrylic material. The Restor +3.0 D IOL consists of 9 concentric gradual diffractive steps from the center to the periphery within the central 3.6 mm optical zone, providing a near add of +3.0 D at the lens plane. The Restor +2.5 D IOL has the same design with a near add of +2.5 D at the lens plane.[9]

The Tecnis 1-piece ZCB00 is a monofocal foldable hydrophobic IOL with an anterior aspheric surface designed according to an average cornea eye model to compensate for the spherical aberration of the cornea.

The Tecnis Symfony ZXR00 is made of the same hydrophobic acrylic material as the Tecnis 1-piece IOL and has an achromatic echelette design that extends the range of vision and compensates for the chromatic aberration of the cornea. In particular, the lens has a wavefront-designed anterior aspheric surface and a posterior achromatic diffractive surface.[10]

Surgical Technique

Three experienced surgeons (G.M., E.P., F.C.) performed all surgeries using a standard sutureless phacoemulsification technique. In all cases, topical anesthesia was administered and pharmacological mydriasis was induced using a combination of tropicamide 1.0% and phenylephrine 10.0%. A clear cornea microincision of 2.4 mm was placed at the steep meridian in all cases. The IOL was implanted using a specific injector for each IOL model.

Intraocular lens power and predicted postoperative refraction were based on biometric data measured with the biometry device. Intraocular lens dioptric power was selected targeting emmetropia, using the IOL power corresponding to the negative (myopic) predicted refractive outcome closest to zero. The SRK/T[11] biometry formula was used in IOL power calculations for all eyes with an axial length longer than 22.0 mm. The Holladay biometry formula was used for all other eyes.[12] All patients received the same postoperative treatment, which was a combination of topical netilmicin 0.3% and dexamethasone 0.1% (Netildex) 4 times a day for 2 weeks and then tapered off by 1 drop per week. Likewise, nonsteroidal antiinflammatory ketorolac 0.5% drops (Acular) were prescribed 3 times a day for 4 weeks to prevent macular edema in all patients.[13]

Outcome Measurements

Binocular UDVA and CDVA were measured using the Early Treatment Diabetic Retinopathy Study (EDTRS) charts under photopic conditions and 100% contrast (ESV-3000 ETDRS System, Vectorvision, Inc.) at 4 m.

Binocular uncorrected (UIVA), corrected (CIVA), and distance-corrected (DCIVA) intermediate visual acuities were measured using EDTRS near acuity charts (Sloan EDTRS format near vision, Precision Vision) with 100% contrast at 60 cm.

Binocular UNVA, and corrected (CNVA) and distance-corrected (DCNVA) near visual acuities, were measured with the same near chart at 40 cm.

The visual performance was also evaluated by measuring the distance contrast sensitivity function under photopic conditions (85 candelas [cd]/m^2) with the CSV-1000 device (Vectorvision, Inc.) and by obtaining the defocus curve. The latter provides an objective measure of expected vision at different distances. It was evaluated by assessing the binocular visual acuity at 4 m. Measurements were performed after correcting the patients for distance visual acuity in both eyes while viewing a distant chart.