Original Article

Optical aberrations in three different intraocular lens designs of a same platform

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Abstract:

PURPOSE: To compare internal optical aberrations between three different intraocular lenses (IOL) of the same Tecnis platform: monofocal ZCB00, multifocal ZMB00, and enlarged depth-of-focus (EDoF) Symfony ZXR00.

METHODS: We included in this study 236 eyes of 118 patients who had been bilaterally implanted either with the monofocal, the multifocal, or the EDoF IOL. They were examined with the K1-RW wavefront analyzer (Topcon Medical Systems) 2 months after surgery. Patients with any ocular pathology were excluded from the study. Only high-order aberrations (HOA) of the third and fourth orders of the Zernike polynomials were considered.

RESULTS: Forty-three patients (86 eyes) were implanted with the monofocal IOL, 45 patients (90 eyes) with the ZMB00 IOL, and 30 patients (60 eyes) with the EDoF Symfony IOL. Mean age was 62.42 ± 7.38, 63.60 ± 6.01, and 64.74 ± 5.84 years, respectively. Mean axial length was 23.37 ± 1.00, 23.49 ± 1.00, and 23.54 ± 0.73 mm, respectively. For a 6-mm pupil, internal total HOA in the monofocal group was 1.01 ± 1.75 µm; in the bifocal group was 1.35 ± 2.12 µm; and in the Symfony group was 0.72 ± 0.63 µm. No optical aberration differences were found among the three groups ($P > 0.05$).

CONCLUSION: There are no differences regarding internal optical aberrations between these three IOLs when analyzing them with optical aberrometry. Patients' pupil size should be considered for the selection of the most appropriate IOL to be implanted, because despite a same optical platform, every IOL implies a different increase of HOA with larger pupil sizes.

Keywords:

Enlarged depth-of-focus, intraocular lens, multifocal, optical aberrations, wavefront analyzer

Introduction

Intraocular lenses (IOLs) have been greatly developed in recent times. Thus far, the most common IOLs implanted in cataract surgery are monofocal IOLs, with all their possible variations. Their main disadvantage is that the total loss of the accommodation power implies the necessity of spectacles for near vision. The following generation of IOLs is the bifocal, which restores an excellent near visual acuity. However, their main disadvantages are presence of halos at night, difficulties in intermediate vision, and sometimes a poor contrast sensitivity.[1-3] Finally, the recent last generation of IOLs is the trifocal and enlarged depth-of-focus (EDoF) lenses, which are able to restore near and intermediate visual acuity.[4-7]

Visual acuity is a popular quantitative measurement in clinical practice which is also useful in scientific studies. It is the main parameter used to quantify the eventual effectiveness of a refractive cataract surgery. However, vision quality should be taken into account, too. Contrast sensitivity is usually used for assessing vision quality, but it should not be forgotten that there are lots of tests that examine other aspects about vision quality, such as color discrimination, reading ability, or halo vision. Optical aberrations are not usually measured in daily routine but may affect visual quality, as it has been proven in cases of corneal refractive surgery.[8] In the same way, implanted IOLs may lead to variations in optical aberrations, which could be even more interesting when comparing monofocal with premium ones. Total ocular

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aberrations are made up by corneal and internal aberrations. The former are a consequence of corneal features, and the latter are mainly due to the crystalline lens or the IOL in cases of pseudophakia. Therefore, internal aberrations are the ones which should be considered when comparing different IOLs *in vivo*.

Optical aberrations can be measured with wavefront analyzers. These may be classified according to the methods they use, such as Hartmann-Shack, ray tracing, or Tscherning. The KR-1W (Topcon Medical Systems) is a wavefront analyzer using Hartmann-Shack technology which also combines corneal topography and autorefraction. Hence, it allows discrimination between internal and corneal aberrations.

Our aim in this study is to compare high-order aberrations (HOAs) among three generations of IOLs from the same family: monofocal Tecnis ZCB00, multifocal Tecnis ZMB00, and EDoF Tecnis Symfony (Abbott Medical Optics).

Methods

Patients

This study included 236 eyes of 118 patients who had undergone bilateral cataract surgery. Inclusion criteria were age <75, corneal astigmatism less than 1 diopter (D), and IOL power between +17 and +27 D. Exclusion criteria were previous intraocular or corneal surgery, zonular weakness, intraoperative problems, endophthalmitis, high refractive errors, patients with only one useful eye, deep amblyopia, and the presence of any other ocular or systemic pathology which could alter final visual outcomes. This study adhered to the tenets of the Declaration of Helsinki and was approved by the local ethics committee. Informed consent was obtained from all patients, and they had time to submit any inquiries regarding the intervention and posterior examinations.

Patients underwent a full ophthalmic examination before being enrolled in the study that included refraction, corrected distance visual acuity (CDVA), slit lamp examination, tonometry, fundus examination, and ocular biometry (500 Carl Zeiss IOL-master, Mediatec AG).

Cataract surgery was performed by four different surgeons, who used the same technique and whose surgical induced astigmatism was 0.25 D. Two months after cataracts surgery, an aberrometric analysis was performed with the KR-1W wavefront analyzer (Topcon Medical Systems). The KR-1W wavefront analyzer uses an integrated Placido-disk topography and Hartmann-Shack wavefront system. It is able to measure optical aberrations depending on the pupil size. It measures minimal and maximal pupil diameters and then aberrations considering a 4-mm pupil and a 6-mm pupil. Patients were analyzed under scotopic conditions to reach the maximal pupil diameter for both the 4- and 6-mm pupil examinations. Those patients with a pupil size smaller than 4 mm or higher than 7 mm were excluded from the study. They were examined three times, but only the best measurement was taken for the analysis. The Zernike polynomials considered for the study were the third and fourth orders, and all of them were measured as root mean square (RMS) in µm. Although we collected data from total HOAs, we only considered internal aberrations in this study as a main result of implantation of IOLs. Hence, the optical aberrations considered in this study were trefoil, coma, tetrafoil, secondary astigmatism, and spherical aberration. Furthermore, these values were summarized in HOA, third-order aberrations, and fourth-order aberrations.

Intraocular lenses

These three Tecnis IOLs are biconvex acrylic hydrophobic IOL with an ultraviolet filter and an aspheric anterior surface that results in a spherical aberration of − 0.27 µm for a 6-mm pupil.[9] They are designed with wavefront aberrations analyses and molded monoblock. Their total diameter is 13 mm and the diameter of the optics is 6 mm.

The multifocal Tecnis ZMB00 is a posterior diffractive lens and its light distribution is equivalent in all the focal points,[10] with an addition of +4.00 D in lens plane for its near vision focus, as measured from the IOL plane. The Symfony ZXR00 has an EDoF which is based on diffractive achromatic technology. It has an achromatic diffractive pattern on its posterior surface that elongates the focus and compensates for the chromatic aberration of the cornea.[11]

Statistical analysis

The statistical analysis was done with SPSS software for Windows (IBM Corporation, Somers, NY, USA). Mean values and standard deviations were calculated for every parameter. First, it was checked if samples adjusted to normality with the Kolmogorov–Smirnov test and to homoscedasticity with Levene's test. Then, the one-way ANOVA and Bonferroni *post hoc* tests were used. In case they did not adjust to normality or homoscedasticity, the Kruskal–Wallis and the Tamhane *post-hoc* tests were performed. The significance level was $P < 0.05$.

Results

A total of 118 patients were enrolled in this study: 43 patients were implanted with the monofocal ZCB00 IOL, 45 patients with the multifocal ZMB00 IOL, and 30 patients with the EDoF Symfony IOL. All groups were comparable in age, axial length, power of the implanted IOL, and best corrected visual acuity under photopic conditions. All these parameters are displayed in Table 1.

When comparing aberrometric outcomes, we found no differences neither considering a 4-mm pupil nor a 6-mm pupil. All these outcomes are displayed in Tables 2 and 3. When analyzing 6-mm pupil outcomes, despite no statistical differences, the bifocal diffractive ZMB00 IOL showed a tendency toward higher HOA levels than others and the EDoF Symfony IOL toward lower HOA levels. We found no tendencies like the previous stated when analyzing 4-mm pupil outcomes.

Table 1: Descriptive data

Variable±SD	ZCB00 group	ZMB00 group	Symfony group	P
Gender (male/female)	17/26	20/25	13/17	
Eyes (patients)	86 (43)	90 (45)	60 (30)	
Age, years old	62.42±7.38	63.60±6.01	64.74±5.84	0.10
AL (mm)	23.37±1.00	23.49±1.00	23.54±0.73	0.52
ACD (mm)	3.20±0.40	3.17±0.38	3.20±0.34	0.85
IOL power (D)	21.90±2.75	22.35±2.83	21.51±1.98	0.15
Sphere (D)	−0.03±0.31	−0.01±0.36	−0.03±0.13	0.95
Cylinder (D)	−0.23±0.38	−0.20±0.30	−0.10±0.22	0.06
SE (D)	−0.14±0.30	−0.11±0.34	−0.07±0.20	0.31
Pupil diameter (mm)	4.85±1.02	4.79±9.15	4.95±0.82	0.61
CDVA				
Monocular (logMAR)	−0.03±0.08	−0.02±0.08	0.00±0.12	0.30
Monocular (snellen)	20/21.43±0.82	20/20.94±0.83	20/20±1.20	0.30
Binocular (logMAR)	−0.07±0.07	−0.07±0.06	−0.06±0.11	0.57
Binocular (Snellen)	20/23.50±0.78	20/23.50±0.63	20/22.96±1.12	0.57

SD=Standard deviation; AL=Axial length; ACD=Anterior chamber depth; CDVA=Corrected distance visual acuity; LogMAR=Logarithm minimum angle of resolution; IOL=Intraocular lenses; SE=Spherical equivalent

Table 2: Aberrometric outcomes evaluating a 4-mm pupil

Variable±SD	ZCB00 group	ZMB00 group	Symfony group	P
Ocular aberrations				
Total HOA (μm)	0.18±0.12	0.15±0.06	0.17±0.07	0.05
Third order (μm)	0.16±0.10	0.13±0.06	0.15±0.06	0.08
Fourth order (μm)	0.08±0.08	0.06±0.03	0.07±0.04	0.10
Trefoil (μm)	0.13±0.09	0.10±0.05	0.12±0.07	0.06
Coma (μm)	0.08±0.06	0.08±0.06	0.08±0.05	0.69
Tetrafoil (μm)	0.06±0.07	0.04±0.02	0.05±0.04	0.08
Secondary astigmatism (μm)	0.03±0.03	0.03±0.02	0.03±0.02	0.37
Spherical aberration (μm)	0.02±0.05	0.01±0.04	0.01±0.05	0.24
Internal aberrations				
Total HOA (μm)	0.14±0.10	0.14±0.06	0.14±0.08	0.88
Third order (μm)	0.11±0.08	0.10±0.06	0.12±0.07	0.63
Fourth order (μm)	0.08±0.07	0.08±0.04	0.08±0.04	0.98
Trefoil (μm)	0.07±0.08	0.06±0.04	0.08±0.08	0.27
Coma (μm)	0.07±0.04	0.08±0.05	0.07±0.04	0.51
Tetrafoil (μm)	0.05±0.07	0.04±0.03	0.04±0.03	0.66
Secondary astigmatism (μm)	0.03±0.03	0.03±0.02	0.03±0.03	0.86
Spherical aberration (μm)	−0.03±0.05	−0.04±0.05	−0.04±0.04	0.37

SD=Standard deviation; HOA=High-order aberration

Discussion

According to the current literature, the KR-1W is an aberrometer whose repeatability and reproducibility have already been proven,[12] and its outcomes have been compared with other devices, too.[13] It provides reliable measures, but these outcomes are not interchangeable between devices.[12,14,15] Some articles about optical aberrations among premium IOLs have been published so far, but as far as we know, this is the first article comparing IOL aberrations of the Tecnis platform *in vivo*. There is only one study – performed by Kim *et al*., who made comparisons among multifocal IOLs with different near-distance vision additions.[16]

Spherical and aspheric IOLs imply differences in scattering light and HOA.[17] The fact that all IOLs belong to the Tecnis platform reduces possible bias[18] and makes outcomes more comparable and reliable because they are made of the same material, and so, any possible competition element is eliminated. Hence, we are analyzing visual quality results as a consequence of the different optical inner characteristics of the lenses, which lead them to provide one or more visual foci. In our study, we did not find any differences regarding internal aberrometric outcomes. We did not consider a deep analysis of preoperative internal optical aberrations because it is well known that cataracts significantly increase internal HOA, and it is the crystalline lens or the IOL the major responsibles for internal HOA.

The values of ocular total HOA with either 4- or 6-mm pupil sizes were very close to those of internal total HOA. Hence, implantation of an IOL has a major importance on visual quality, as optical aberrations caused by this IOL would play a major role in comparison with corneal ones.[19]

Table 3: Aberrometric outcomes evaluating a 6-mm pupil

Variable±SD	ZCB00 group	ZMB00 group	Symfony group	*P*
Ocular aberrations				
Total HOA (μm)	1.10±1.32	1.26±1.93	0.86±0.61	0.34
Third order (μm)	0.70±0.93	0.77±1.51	0.57±0.28	0.61
Fourth order (μm)	0.69±0.92	0.83±1.17	0.52±0.55	0.20
Trefoil (μm)	0.52±0.61	0.49±0.94	0.44±0.24	0.86
Coma (μm)	0.44±0.72	0.55±1.20	0.30±0.24	0.29
Tetrafoil (μm)	0.36±0.43	0.44±0.68	0.28±0.31	0.23
Secondary astigmatism (μm)	0.32±0.56	0.34±0.65	0.21±0.32	0.43
Spherical aberration (μm)	0.40±0.67	0.52±0.77	0.27±0.43	0.12
Internal aberrations				
Total HOA (μm)	1.01±1.75	1.35±2.12	0.72±0.63	0.13
Third order (μm)	0.60±1.25	0.82±1.61	0.42±0.35	0.20
Fourth order (μm)	0.66±1.20	0.85±1.26	0.46±0.49	0.13
Trefoil (μm)	0.35±0.78	0.49±1.10	0.25±0.24	0.27
Coma (μm)	0.46±0.98	0.61±1.21	0.31±0.29	0.24
Tetrafoil (μm)	0.33±0.54	0.49±0.79	0.26±0.33	0.10
Secondary astigmatism (μm)	0.33±0.73	0.41±0.73	0.19±0.29	0.18
Spherical aberration (μm)	0.18±0.78	0.22±0.83	0.03±0.40	0.35

SD=Standard deviation; HOA=High-order aberration

However, there is an important difference between 4-mm and 6-mm internal total HOA. It is well known that wider pupil sizes imply higher values of HOA, but we found that not all the groups experienced the same increase. The bifocal group experienced the biggest increase, being followed by the monofocal group, and the smallest increase was for the EDoF group. Interestingly, all of them were really similar in the 4-mm pupil analysis (around 0.14 μm). This means that despite a same optical platform, the optical design of every IOL may affect differently visual quality and that patients' pupil size should be considered for the selection of the most appropriate lens. Nevertheless, none of the patients included in our study had any complaints about visual acuity or quality, nor they referred subjective dysphotopsia or photic phenomena, and they were satisfied with the IOL implanted.

The study by Kim *et al*. which made comparisons among diffractive multifocal IOLs with different near-distance vision additions did not find any differences among the ZKB00, ZLB00, and ZMB00 Tecnis IOLs in regard to internal optical aberrations.[16] A study which compared the Symfony IOL with the trifocal Acrysof Panoptix (Alcon) and the monofocal Acrysof SN60WF (Alcon) used the OPD-Scan II (NideK Co., Ltd.) and it was found that at a 5-mm pupil, the RMS of HOA was higher in the Symfony than in the trifocal or the monofocal group and that primary spherical aberration was higher in the Symfony group, too.[20] However, it is not said whether these aberrations are ocular, corneal, or internal and compared IOLs are not from the same family, and so, their optical properties are different. Cochener compared aberrations with the WaveScan aberrometer (Abbott Medical Optics) between the ZMB00 IOL and the trifocal FineVision IOL, finding no statistical differences between them.[21] Pilger *et al*. did not find any difference in total ocular aberrations between Tecnis ZCB00 and Symfony IOLs.[22] As far as we can compare, all these results are consistent with ours.

In conclusion, there are no differences in internal optical aberrations between Tecnis ZCB00, ZMB00, and Symfony ZXR00 IOLs when measuring with the KR-1W wavefront analyzer. Therefore, the optical designs of these premium IOLs, which make patients achieve a better near vision, do not imply higher wavefront aberrations, and so, visual quality is not highly worsened. Internal HOA plays a major role on total HOA, and patients' pupil size should be considered for the selection of the most appropriate IOL to be implanted, as the largest increase of HOA is experienced with the bifocal and the lowest with the EDoF IOL. Thus, patients with a large pupil sizes should not be considered to be implanted with a purely diffractive IOL such as the ZMB00, and other options such as Symfony could be a better option instead.

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Conflicts of interest

There are no conflicts of interest.

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