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ORIGINAL PAPER

The impact of multifocal intraocular lens in retinal imaging with optical coherence tomography

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Abstract Multifocal intraocular lenses (MF IOLs) have concentric optical zones with different dioptric power, enabling patients to have good visual acuity at multiple focal points. However, several optical limitations have been attributed to this particular design. The purpose of this study is to access the effect of MF IOLs design on the accuracy of retinal optical coherence tomography (OCT). Cross-sectional study conducted at the Refractive Surgery Department of Central Lisbon Hospital Center. Twenty-three eyes of 15 patients with a diffractive MF IOL and 27 eyes of 15 patients with an aspheric monofocal IOL were included in this study. All patients underwent OCT macular scans using Heidelberg Spectralis®. Macular thickness and volume values and image quality (Q factor) were compared between the two groups. There were no statistically significant differences between both groups regarding macular thickness or volume measurements. Retinal OCT image quality was significantly lower in the MF IOL group ($p < 0.01$). MF IOLs are associated with a significant decrease in OCT image quality. However, this fact does not seem to compromise the accuracy of spectral domain OCT retinal measurements.

Keywords Image quality · Macular thickness · Multifocal intraocular lens · Optical coherence tomography

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Introduction

Cataract surgery has evolved from a visual rehabilitating procedure to become a refractive surgery in which the independence of corrective lenses is seen as a criterion of quality and satisfaction [1]. In this regard, monofocal intraocular lens (IOL) usually provides excellent visual function; however, its limited depth of focus does not allow simultaneous clear vision for both distance and near. On the other hand, multifocal (MF) IOLs have multiple focal lengths within the optical zone, which results in a more acceptable range of near through distance vision as well as increased spectacle independence [2, 3]. Consequently, MF IOLs are becoming an increasingly popular option for the correction of presbyopia. Although eyes with ophthalmic pathology such as vitreoretinal diseases or glaucoma are not candidates for implantation of a MF IOL, the incidence of these pathologies in patients with previously implanted MF IOLs will probably rise, given the increasing popularity of this type of lens.

Optical coherence tomography (OCT) has assumed a major role in the study of retinal and optic nerve pathology in the last years. However, to date, very few studies evaluated the effect of MF IOLs design on the accuracy of retinal imaging and measurements performed by OCT devices. The objective of this study is to compare retinal OCT measurements in patients with two different types of diffractive MF IOLs with a control group with monofocal aspheric IOLs.

Materials and methods

Cross-sectional study conducted at Central Lisbon Hospital Center, a university-based tertiary center. Twenty-three eyes of fifteen patients who underwent uneventful phacoemulsification with implantation of Acrysof ReSTOR SA60D3 apodized diffractive multifocal IOL (Alcon Laboratories) or Tecnis ZM900 aspheric diffractive multifocal IOL (Abbott Medical Optics) were enrolled in this study. Twenty-seven eyes of fifteen patients who underwent uneventful phacoemulsification with monofocal aspheric IOL implantation, either Acrysof IQ SN60WF (Alcon Laboratories) or Tecnis ZCB00 (Abbott Medical Optics) served as a control group. All eyes enrolled in the study had a post-operative follow-up superior to one month. Eyes with posterior capsular opacification, corneal or vitreoretinal pathologies, ocular hypertension, optic neuropathies, pre-operative spherical equivalent higher than ±6.0 D or astigmatism higher than ±3.0 D were excluded from the study. A written informed consent was obtained from all subjects and this investigation adhered to the tenets of the Declaration of Helsinki. Ethics Committee approval was obtained.

Every patient was submitted to a complete ophthalmological evaluation that included best corrected visual acuity (BCVA) assessment, refraction, biomicroscopy, fundoscopy, Goldmann applanation tonometry, and macular imaging using OCT Heidelberg Spectralis® (Heidelberg Engineering, Heidelberg, Germany). Twenty-five sections, each comprising 100 averaged scans, were obtained in a 20° × 20° (5.8 mm × 5.8 mm) square centered on the fovea. Macular thickness and volume parameters were automatically calculated by existing Heidelberg OCT software (version 5.3.2). Three concentric zones centered on the foveal center were evaluated and compared between the two study groups: central (1 mm), parafoveal (2 mm), and perifoveal (3 mm) (Fig. 1). The Q factor—a measure of OCT signal strength—was also obtained and compared between both groups.

The data were statistically analyzed using *SPSS for Windows, version 20.0; IBM/SPSS, Chicago, IL.* Student's *t* test was performed to compare the mean differences between continuous variables, with a p value of 0.01 being considered as statistically significant.

Results

In the MF IOL group, we studied 23 eyes of 15 patients (4 men and 11 women); in the monofocal IOL group, we studied 27 eyes of 15 patients (3 men and 12 women). Table 1 presents the parameters analyzed in this study. There were no statistically significant differences between both groups regarding age, post-operative distance BCVA, and axial length. The mean post-operative refractive cylinder was 0.72 ± 0.46 D in the MF IOL group and 0.83 ± 0.48 D in the monofocal IOL group ($p = 0.223$). The mean macular thickness in zone 1 in the MF IOL group was 280.00 µm, and in the monofocal group it was 283.00 µm ($p = 0.373$); the mean macular thickness in zone 2 in the MF IOL group was 331.60 µm, and in the monofocal group it was 334.68 µm ($p = 0.372$); the mean macular thickness in zone 3 in the MF IOL group was 337.35 µm, and in the monofocal group it was 336.20 µm ($p = 0.453$). The mean macular volume in zone 1 in the MF IOL group was 0.22 mm^3, and in the monofocal group it was 0.22 mm^3 ($p = 0.388$); the mean macular volume in zone 2 in the MF IOL group was 0.21 mm^3, and in the monofocal group it was 0.20 mm^3 ($p = 0.221$); the mean macular volume in zone 3 in the MF IOL group was 0.38 mm^3, and in the monofocal group it was 0.33 mm^3 ($p = 0.141$). Thus, OCT analysis did not reveal significant differences in macular thickness or

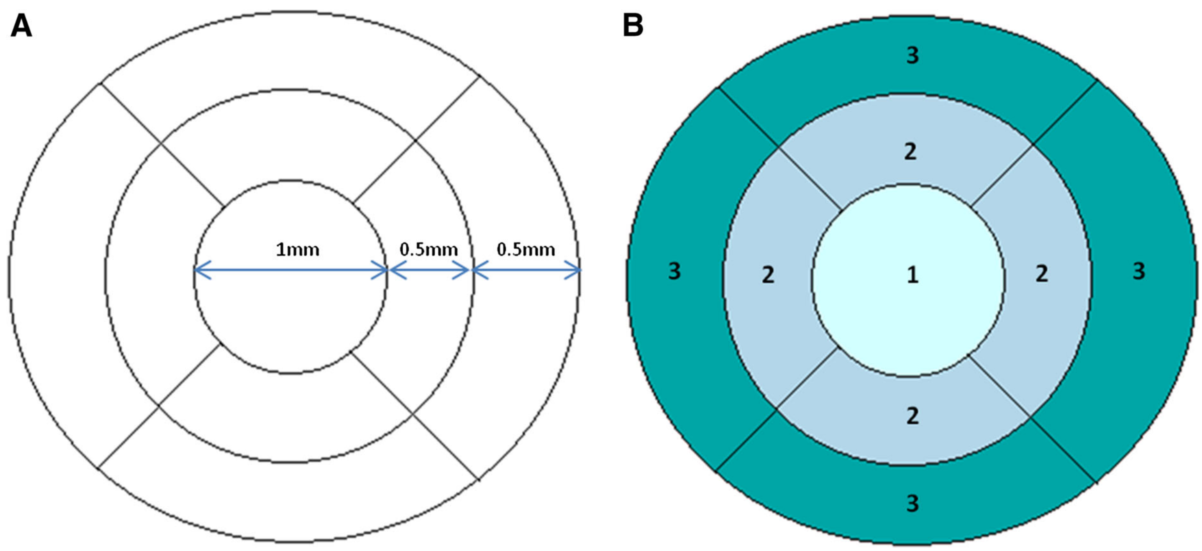

Fig. 1 Diagrammatic representation of the different concentric macular areas analyzed in the study: central (*zone 1*), parafoveal (*zone 2*), and perifoveal (*zone 3*)

macular volume measurements in any of the macular zones analyzed. The mean Q factor was 23.13 dB in the MF IOL group and 26.84 dB in the monofocal group ($p = 0.003$). The Q factor was significantly higher in the monofocal IOL group, indicating better image quality in this group.

No wavy horizontal artifacts were seen in OCT images or in confocal scanning-laser ophthalmoscopy images in both groups.

Discussion

This study demonstrates that OCT measurements in the macular area are not affected by the optical design of diffractive MF IOLs. These measurements were comparable to those performed in patients implanted with monofocal aspheric IOL. However, MF IOL reduces OCT image quality by more than 3 dB. This reduction was statistically significant.

MF IOLs provide good distance and near visual acuity, being a good solution for implantation following cataract surgery as well as following refractive lens exchange [4–7]. Diffractive MF IOLs have concentric optical zones with different dioptric power, enabling patients to have good visual acuity at multiple focal points [3]. The drawbacks associated with this type of IOL design are loss of contrast sensitivity, increase in higher order aberrations, and night-time glare and halos [8, 9]. Aychoua et al. [10] recently reported a clinically relevant reduction of visual sensitivity as assessed with standard automated perimetry in patients with MF IOL. Another published paper reported wavy horizontal artifacts on OCT line-scanning ophthalmoscopy images in patients with two different types of diffractive MF IOLs, tested with 4,000 Cirrus HD-OCT® device (Carl Zeiss Meditec). The authors, however, found no differences in retinal thickness, retinal volume, or fundoscopic photographs [11]. Skiadaresi et al. evaluated retinal measurements following implantation of LENTIS Mplus, an asymmetrically powered refractive MF IOL, with a surface-embedded section for near vision that occupies only a segment of the optic. In this study, the authors used Topcon 3D OCT 1000® (Topcon, Oakland, NJ) and found neither image artifacts nor alterations in retinal thickness or volume measurements [12]. It has also been reported a decrease in OCT signal strength and image quality (Q factor) in patients with multifocal contact lenses, which was found to reduce more with increased reading add of the multifocal contact lens [13]. Our study, as far as we know, is the first to demonstrate a decrease in OCT signal strength in patients with diffractive MF IOLs. We also accessed the impact of this IOL design in retinal imaging using another OCT device, Heidelberg Spectralis®. To test if

Table 1 Patients' age, post-operative distance best corrected visual acuity (BCVA), axial length, post-operative refractive cylinder, type of implanted intraocular lens (IOL), and optical coherence tomography parameters

Parameter	MF IOL	Monofocal IOL	*p* value
IOL type	9 AcrySof ReSTOR SA60D3/ 14 Tecnis Multifocal ZMB00	12 Acrysof IQ SN60WF/ 15 Tecnis ZCB00	–
Age (years)	68.80 ± 11.74	76.07 ± 7.16	0.025
Post-operative distance BCVA	0.93 ± 0.11	0.93 ± 0.10	0.389
Axial length (mm)	22.57 ± 1.44	22.90 ± 1.11	0.196
Post-operative astigmatism (D)	0.72 ± 0.46	0.83 ± 0.48	0.223
Macular thickness in zone 1 (μm)	280.00 ± 29.80	283.00 ± 33.17	0.373
Macular thickness in zone 2 (μm)	331.60 ± 26.34	334.68 ± 36.66	0.372
Macular thickness in zone 3 (μm)	337.35 ± 34.27	336.20 ± 32.81	0.453
Macular volume in zone 1 (mm^3)	0.22 ± 0.02	0.22 ± 0.03	0.388
Macular volume in zone 2 (mm^3)	0.21 ± 0.06	0.20 ± 0.02	0.221
Macular volume in zone 3 (mm^3)	0.38 ± 0.22	0.33 ± 0.03	0.141
Q factor (dB)	23.13 ± 5.24	26.84 ± 3.44	0.003*

* Statistically significant difference between both groups

the optical rings with different dioptric powers have influence in retinal measurements, we evaluated the average thickness and volume in three concentric macular regions in patients with diffractive MF IOL and compared with patients implanted with monofocal IOL. In accordance to the previous studies on diffractive and refractive MF IOLs, we found no significant changes in retinal measurements [11, 12]. However, contrary to a previous work on diffractive MF IOLs [11], we found no artifacts on fundoscopic images captured by the OCT device. This fact is probably related to different OCT device technologies. The 4,000 Cirrus HD-OCT® device uses a line-scanning ophthalmoscopy system based on a "semi" confocal principle, which produces horizontal artifacts in eyes with diffractive MF IOLs [14]. On the other hand, the Heidelberg Spectralis® OCT, utilized in our study, uses a scanning-laser ophthalmoscopy system, which produces confocal imaging. A confocal system uses a pinhole to remove light from adjacent voxels in order to improve the image details, while a flying-spot camera scans a focused spot in one dimension with a high-speed optical element [11]. Therefore, scanning-laser ophthalmoscopy generates no artifacts in eyes with diffractive MF IOLs.

It is important to note that there is a slight difference regarding the mean age of the two study groups, which was higher in the monofocal IOL group. This difference, however, did not reach the threshold for statistical significance adopted in this study. Taking into account the highly significant difference in retinal image quality between the two groups ($p < 0.01$), we believe that this fact does not compromise the major conclusions of this study. Moreover, previous studies suggest that increasing age can have a negative impact in OCT image quality in phakic patients [15], but, to date, there are no studies evaluating the effect of age in OCT image quality in pseudophakic patients.

In conclusion, the optical design of diffractive MF IOLs may affect OCT imaging by reducing signal strength and image quality. However, this finding does not seem to impair the potential of this important diagnostic tool in the diagnosis and follow-up of vitreoretinal disorders.

Conflicts of interest No conflicting relationship exists for any author.

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