Impact of Trifocal and Trifocal Toric Intraocular Lenses on Spectral-domain OCT Retinal Measurements

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Precis: Monofocal, trifocal, and trifocal toric intraocular lenses (IOLs) induce similar changes on overall retinal optical coherence tomography (OCT) measurements.

Purpose: The purpose of this study was to assess whether trifocal and trifocal toric IOLs affect the measurement of retinal parameters using spectral-domain OCT.

Methods: This cross-over study included patients undergoing implantation of a trifocal IOL: AcrySof IQ PanOptix, a trifocal toric IOL: AcrySof IQ PanOptix Toric, and a monofocal IOL: AcrySof IQ. The monofocal group was considered as the control group. The refractive target was emmetropia in all cases. Mean average macular thickness, macular volume, and retinal nerve fiber layer (RNFL) thickness were measured with the Cirrus HD-OCT. All measurements were performed before and 3 months after the surgery.

Results: The study analyzed 150 eyes of 150 patients (50 for each IOL group). Macular thickness and macular volume showed statistically significant differences before and after the surgery for the 3 groups ($P<0.05$ in all cases). RNFL thickness was found to be similar before and after the surgery in all groups ($P>0.05$ in all cases). Mean difference values (before and after the surgery) in the monocular, trifocal, and trifocal toric group for macular thickness, macular volume, and RNFL thickness were $4.9 \pm 7.8$, $7.9 \pm 10.0$, and $7.7 \pm 13.7 \mu m$, respectively; $0.1 \pm 0.2$, $0.2 \pm 0.4$, and $0.2 \pm 0.3 \text{mm}$, respectively; and $0.8 \pm 5.5$, $1.3 \pm 6.0$, and $0.8 \pm 6.7 \mu m$, respectively. Mean differences were found to be similar for the 3 groups.

Conclusion: The trifocal and the trifocal toric IOLs under study did not induce an additional impact on spectral-domain OCT retinal measurements compared with monofocal IOLs.

Key Words: trifocal, trifocal toric, intraocular lenses, cataract surgery, optical coherence tomography

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Population ageing will surely be the distinctive trait of populations during the 21st century. In fact, it is expected that by 2050, 1 in 6 people in the world will be over 65 years of age.¹ One of the major consequences of population ageing related to visual health is that retinal conditions are already a significant and increasing problem worldwide.² Another critical consequence is presbyopia, representing one of the 2 most common human ocular afflictions in the world.³

Aiming to compensate the visual symptoms of presbyopia, multifocal intraocular lenses (IOLs) have been a widespread solution for patients who want to have spectacle independence.⁴,⁵ Trifocal IOLs distribute the light into 3 different foci (far, intermediate, and near). Furthermore, today it is possible to find novel designs of trifocal IOLs, including trifocal designs that compensate the corneal astigmatism of patients who undergo cataract surgeries.

Optical coherence tomography (OCT) is the most commonly used technique in the exploration and follow-up of the posterior pole.⁶–¹² Some authors have suggested that multifocality could induce some artifacts or changes in OCT retinal measurements.¹³,¹⁴ In addition, regardless of multifocal and/or monofocal lens designs, the distortion of the image induced by moderate amounts of astigmatism has also showed to affect OCT measurements.¹⁵,¹⁶

Related to this, only a few studies have analyzed the impact of trifocal IOLs on OCT retinal measurements.¹⁷–¹⁹ and no studies have analyzed the potential impact of toxicity in trifocal IOLs on OCT measurements. Therefore, the aim of this study was to determine whether trifocality and astigmatic compensation combined with trifocality may have an effect on the measurement of retinal parameters through a widely used spectral-domain OCT device.

METHODS

This cross-over study was conducted in Clinica Rementeria, Madrid, Spain, and included patients undergoing routine cataract surgery and implantation of 2 different versions (nontoric and toric) of the same model of diffractive trifocal IOL. Patients implanted with a monofocal IOL were also included in the study.

The study followed the tenets of the Declaration of Helsinki and was reviewed and approved by the pertinent Ethics Committee. Informed consent was obtained from all patients after the nature of the study had been explained.

As in previous similar studies performed at the clinic, all subjects underwent an ophthalmological examination, which included refraction, screening for ocular conditions and/or systemic diseases, slit-lamp biomicroscopy, and fundus examination. Exclusion criteria were amblyopia, abnormal iris, ocular pathologies other than cataracts, or previous ocular surgery. Patients with intraoperative or postoperative complications were also excluded. Toric IOLs were implanted in patients with 1 D or more preoperative corneal astigmatism.²⁰ Only 1 eye of each patient was evaluated in this study.

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Patients who met the inclusion criteria underwent cataract surgery with phacoemulsification routine and IOL implantation previously described. All surgeries were carried out by 2 experienced surgeons (L.A.R.-C. and J.L.G.-P.), and the 3 groups had surgeries performed by both surgeons. Toric IOL implantation was guided by the VERION System (Alcon Laboratories). The monofocal IOL considered for the study was the Alcon AcrySof IQ SN60WF (Alcon Laboratories). This is a single-piece hydrophobic acrylic IOL with ultraviolet and blue light filtration. At the same time, it presents a refractive index of 1.55 at a wavelength of 550 nm. The optical zone has a negative spherical aberration. In this case, the optical zone of the IOL is diffractive in the central 4.5 mm of the anterior surface with 15 diffractive annuli. It has an outer refractive annulus (from 4.5 to 6.0 mm). This lens has been described as panfocal with quadrifocal IOL technology. This quadrifocal design distributes the incoming light into 4 foci: distance, 120, 60, and 40 cm. However, the optical design of the diffractive zone has been modified to redistribute the energy of the 120 cm focus to the distance focus. Therefore, the quadrifocal design actually offers a trifocal function for far, intermediate (60 cm/2.17 D add), and near distance (40 cm/+3.25 D add). The third lens considered in the study was the AcrySof IQ PanOptix Toric IOL (Alcon Laboratories). This lens is the toric version of the AcrySof IQ PanOptix IOL and presents the same material trifocal concepts. However, the posterior surface of the lens is biconical, creating a toricity to correct corneal astigmatism. The AcrySof IQ Panoptix Toric is available in 5 ranges from model T2 to T6 (from 1.0 to 3.75 D of astigmatism).

Finally, all patients were evaluated before, 1 day after each procedure, 1 week, 1 month, and 3 months after the surgery. This study presents the results before and 3 months after the surgery. All eyes were scanned on a single Cirrus HD-OCT instrument (Carl Zeiss Meditec, Dublin, CA). The procedure was performed in 1 eye of each participant, and all measurements were obtained by the same experienced ophthalmic technician. According to the study protocol, a correct retinal layer segmentation was visually confirmed after each examination. Any incorrect segmentation implied a repetition of the OCT scan until a perfect automatic segmentation was reached. At the same time, the scan signal strength on the OCT device is displayed on a scale of 0 to 10, with 10 being maximum. Owing to the normality of the data, the preoperative and postoperative data of each parameter were compared by means of the Student t test. A repeated measures analysis of variance was used to gauge any statistically significant difference of the data within the 3 groups. Differences were considered to be statistically significant when the P-value was <0.05 (ie, at the 5% level). The XL-STAT statistical software (Windows 10; 64 bits) was also employed. A Two-One-Sided-Test was used to assess the equivalence of the study population. The equivalence of 2 samples was confirmed when the P-value related to unilateral t test was <0.05.

RESULTS

The study considered 150 eyes from 150 subjects, with a mean age of 69.1 ± 7.9 years. Subjects were divided into 3 groups: 50 with monofocal IOL, 50 with trifocal IOL, and 50 with trifocal toric IOL implantation. Table 1 shows the preoperative characteristics of all the groups. The only parameter that showed statistically significant differences for the 3 groups was the mean age (P = 0.01). A multivariate regression was performed, and the estimated coefficients showed no significant influence in this particular sample for any of the parameters analyzed: macular thickness: B = 0.144 ± 0.014 μm/y, P = 0.226, 95% confidence interval (CI): −0.90 to 0.377; RNFL: B = −0.027 ± 0.01 μm/y, P = 0.708, 95% CI: −0.176 to 0.114; and macular volume: B = −0.004 ± 0.007 μm³/y, P = 0.212, 95% CI: −0.011 to 0.003.

At the same time, mean preoperative and postoperative signal strength values for the monofocal, trifocal, and trifocal toric group are shown in Table 1 (Supplemental Digital Content 1, http://links.lww.com/JIG/A497). Signal strength increased after monocular IOL implantation (P < 0.001) and was similar after trifocal (P = 0.07) and trifocal toric (P = 0.23) IOL implantation. All surgeries were successfully performed, and there were no intraoperative or postoperative complications.

Table 2 shows the results of the 3 parameters (mean average macular thickness, macular volume, and RNFL thickness) before and after IOL implantation for the 3 groups. For the 3 IOL groups, there were statistically significant differences for both macular thickness and macular volume (P < 0.0001 for all cases). The only parameter that showed no statistically significant differences before and after the surgery was RNFL thickness (P > 0.05 for the groups).

Mean values of the differences (before and after the surgery) for the 3 groups are compared and presented in Table 2 (Supplemental Digital Content 2, http://links.lww.com/JIG/A498). The differences for macular thickness, macular volume, and the RNFL thickness, measured before and after the surgery, were similar, and no statistically significant differences were observed.

Table 1. Preoperative Characteristics of the Eyes Included in the Study

| IOL Type | No. Eyes | Age (y) | Pupillar Length (mm) | Axial Length (mm) | Macular Thickness (μm) | Volumetric Thickness (μm³) | RNFL Thickness (μm) |
|----------|----------|---------|---------------------|------------------|-----------------------|---------------------------|-------------------|
| AcrySof IQ | 50 | 74.5 ± 6.7 | 3.6 ± 0.7 | 23.8 ± 1.0 | 20.9 ± 3.3 |
| PanOptix Toric | 50 | 66.2 ± 8.5 | 3.8 ± 0.9 | 23.4 ± 1.2 | 22.2 ± 3.4 |
| AcrySof PanOptix Toric | 50 | 65.7 ± 8.2 | 3.7 ± 0.8 | 23.5 ± 1.3 | 21.5 ± 4.2 |

P = 0.01

Values provided are mean ± SD. IOL indicates intraocular lens.
significant differences were found for the 3 groups ($P > 0.05$ for all cases). In addition, the study populations showed to be equivalent ($P$-values related to the unilateral $t$ test were <0.05 for all cases).

**DISCUSSION**

OCT is a noninvasive, valuable, and widespread tool for detecting and monitoring retinal diseases. Its importance relates to the current demographic situation, which means that retinal pathologies will be a key factor in eye care and global health systems. At the same time, current trifocal IOLs are becoming highly popular worldwide among surgeons who intend to offer spectacle independence to their patients after cataract surgery. As optical issues such as multifocality of the IOLs could induce artifacts in OCT measurements, the aim of the current study was to assess whether the implantation of trifocal IOLs could affect retinal parameters measured with the Cirrus HD spectral-domain OCT. In addition, a trifocal toric IOL with the same IOL platform was also considered to determine whether toricity for the astigmatic correction could induce additional changes in OCT measurements. To have a control group, patients implanted with monofocals were also analyzed.

As overall retinal parameters, macular thickness and macular volume were analyzed. Observing the results of these 2 parameters (Table 2), we can see that for the 3 groups (monofocal, trifocal, and trifocal toric IOL), the results showed a statistically significant increment of macular thickness and macular volume after the surgery. Despite the statistical differences, to assess whether trifocal and trifocal toric IOL designs may modify the measurements compared with monofocals, the differences between the preoperative and postoperative macular thickness and macular volume values for the 3 groups were compared (Table 2, Supplemental Digital Content 2, http://links.lww.com/IJG/A498).

The results showed no statistically significant differences among the 3 IOL groups. Therefore, this suggests that both trifocality and astigmatic correction with trifocal toric IOLs do not have an additional impact on OCT measurements compared with monofocal IOLs for macular thickness and macular volume values.

In relation to these parameters, a previous study assessed the impact of multifocal diffractive IOLs on macular thickness and macular volume through OCT.17 The results showed no differences between multifocal and monofocal IOL groups. As in our work this previous study suggested that, despite the fact that the image quality of the retina through multifocal differences could be lower, this issue did not affect the accuracy of the OCT measurements. However, this study did not analyze the parameters before the surgery, and the multifocal IOL design was different (it was diffractive but it was also bifocal). Direct comparisons with this study should therefore be made with caution.

Furthermore, RNFL thickness was also analyzed as a specific retinal layer. In this case, the results shown in Table 2 suggest that for the 3 groups, despite a slight increment, no statistically significant differences were found after the surgery. Previous authors have shown a higher mean RNFL thickness layer after cataract surgery,23–25 probably owing to a better image quality of the retina. Focusing on the analysis on trifocal IOLs, a research study conducted by García-Bella et al18 also reported an increment of RNFL thickness after the cataract surgery. However, in this study, the authors did not compare the trifocal IOL group results with a monofocal IOL group. Concerning this comparison, in a later study, this research group analyzed and compared RNFL values before and after cataract surgery both with a monofocal and a trifocal IOL group.19 Similarly, they reported that for both IOL groups, the mean RNFL thickness increased after the surgery, with the values being higher for the trifocal group. The study did not provide an explanation for these differences between monofocal and trifocal IOL results and suggested that future studies could confirm them. Indeed, our results do not fully confirm such significant differences. Nevertheless, it should be mentioned that the IOLs of both studies have different optical designs,20,26 and no direct comparisons should be made. Hence, it would be interesting to conduct future studies with homogeneous samples, similar devices and technicians, control groups, and different trifocal lenses to assess whether differences between IOL designs have an effective impact on RNFL thickness measurements after the surgery.

As with the other parameters, and apart from the simple comparative of presurgery and postsurgery RNFL values, our most significant analysis involved comparing the mean values of the differences (presurgery and postsurgery RNFL mean difference value) among the 3 groups. The results in Table 2 (Supplemental Digital Content 2, http://links.lww.com/IJG/A498) show that the differences in RNFL values for the 3 groups were not significant, suggesting that trifocal and trifocal toric designs do not have an additional impact on RNFL thickness measurements compared with monofocal IOLs.

We would also like to note that the impact of toricity of trifocal IOLs on OCT measurements has not been studied before and no comparisons with other studies can be made. However, astigmatism and the effect on OCT measurements were assessed by Hwang et al13 and Langenbucher et al.16 The results of these studies suggested that the distortion of the image induced by moderate amounts of astigmatism could induce changes in some retinal measurements such as RNFL. On the contrary, some authors reported that if toric lenses are well implanted, the toricity itself should not

| TABLE 2. Mean Average Values of the 3 Parameters (Macular Thickness, Macular Volume, and RNFL Thickness), Before, and 3 Months After the Surgery for the 3 Intraocular Lens Groups (Monofocal, Trifocal, and Trifocal Toric) |
|---------------------------------|---------------------------------|---------------------------------|------------------|
| Before the Surgery | After the Surgery | $P$ |
| Monofocal | | | |
| Macular thickness (µm) | 255.7 ± 23.9 | 260.3 ± 20.9 | <0.001 |
| Macular volume (mm$^3$) | 9.9 ± 0.5 | 10.0 ± 0.4 | <0.001 |
| RNFL (µm) | 86.7 ± 8.6 | 87.5 ± 8.6 | 0.13 |
| Trifocal | | | |
| Macular thickness (µm) | 256.5 ± 20.5 | 264.4 ± 20.9 | <0.001 |
| Macular volume (mm$^3$) | 10.1 ± 0.6 | 10.3 ± 0.6 | <0.001 |
| RNFL (µm) | 90.1 ± 8.5 | 91.4 ± 8.3 | 0.07 |
| Trifocal toric | | | |
| Macular thickness (µm) | 258.16 ± 23.4 | 265.1 ± 22.4 | <0.001 |
| Macular volume (mm$^3$) | 10.0 ± 0.6 | 10.1 ± 0.7 | <0.001 |
| RNFL (µm) | 91.1 ± 11.9 | 91.9 ± 11.8 | 0.20 |

Values provided are mean ± SD.
RNFL indicates retinal nerve fiber layer.
induce significant changes if compared with monofocal designs. 27 Then, a correct alignment of toric IOLs is important for avoiding errors on OCT measurements, being this alignment crucial for high cylinder IOLs.

In our study, astigmatism was corrected by the toric IOL implant, and this possibility was ruled out. In addition, as previously mentioned, this study analyzed whether the toric design itself could have an impact on the measurements, suggesting that this trifocal toric design has no impact compared with a monofocal. Thus, future studies should analyze whether high amounts of astigmatism and the different toric designs available on the market (it could include IOLs or contact lenses) could induce changes in retinal images via OCT devices.

In general, studies that considered multifocal and/or trifocal IOLs for OCT measurements are scarce and showed some variability in their results. Regarding these studies, it was suggested that differences could be owing to differences in the samples, the nature of the cataracts of the samples, and the difference in the optical designs of the IOLs, among other things. Considering both the reported variability and the potential changes in OCT measurements after cataract surgeries, it is clearly important to pay attention to retinal management of all patients who have undergone cataract surgery, 23–25 particularly those with potential or diagnosed retinal pathologies. 28 At the same time, to gain a deeper insight into the impact of trifocal and trifocal toric IOLs on OCT measurements for the management and detection of posterior pole conditions, it would be interesting to conduct future studies that analyze more retinal parameters and to complement these results with other key diagnostic tests such as visual fields.

In conclusion, some OCT measurements may undergo changes after the implantation of monofocal, trifocal, and/or trifocal IOLs. However, the results of this study suggest that trifocality and toricity for astigmatic correction with the trifocal IOLs under study do not induce additional changes in OCT measurements. Thus, the retinal management and the analysis of the retinal images of these patients by means of spectral-domain OCT devices should be similar to those of patients implanted with monofocal IOLs.

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