ARTICLE

Trifocal intraocular lens implantation in eyes with previous corneal refractive surgery for myopia and hyperopia

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Purpose: To evaluate the visual and refractive outcomes of trifocal intraocular lens (IOL) implantation in eyes previously treated with myopic and hyperopic corneal refractive laser surgery.

Setting: Clinica Baviera-AIER-Eye group, Spain.

Design: Retrospective comparative case series.

Methods: The series was divided into 2 groups according to the type of corneal laser refraction (myopic and hyperopic). The main visual and refractive outcome measures included corrected distance visual acuity (CDVA) and uncorrected distance and near visual acuity, safety, efficacy, and predictability. The secondary outcome measures were percentage of enhancement and Nd:YAG capsulotomy and influence of prelaser magnitude of myopia and hyperopia on the outcome of trifocal IOL implantation.

Results: The sample comprised 868 eyes (543 patients): myopic, n = 319 eyes (36.7%); and hyperopic, n = 549 eyes (63.2%). Three months postoperatively, visual outcomes were poorer in the hyperopic group than those in the myopic group for mean CDVA (0.06 ± 0.05 vs 0.04 ± 0.04, $P < .01$) and safety (21% vs 12% of CDVA line loss, $P < .05$) outcomes. However, precision outcomes were worse in the myopic group than those in the hyperopic group, with a mean spherical equivalent of −0.38 ± 0.3 vs −0.17 ± 0.3 ($P < .01$). Stratification by magnitude of primary laser treatment revealed poorer visual and safety results in the high hyperopia subgroup (>+3.0 diopters [D]) and poorer precision in the high myopia subgroup (<−5.0 D).

Conclusions: Trifocal IOL implantation after photorefractive surgery in eyes previously treated with myopic ablation achieved good visual outcomes but less predictability in the high myopia subgroup. However, eyes with a previous hyperopic corneal ablation achieved excellent precision but worse visual and safety outcomes in the high hyperopia subgroup.

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Lens surgery with implantation of a multifocal intraocular lens (mIOL) for presbyopia and cataracts in eyes that have previously undergone corneal photorefractive surgery remains a controversial area, in which experience continues to be limited, despite the extensive knowledge and practice acquired with both corneal and lens procedures.[1] Excimer laser in situ keratomileusis (LASIK) and photorefractive keratectomy (PRK) have demonstrated excellent safety, efficacy, and predictability in correction of myopia and low or moderate hyperopia.[2] However, corneal aberrations are introduced in the optical system leading to certain degree of contrast sensitivity and decrease in visual quality.[3,4]

In addition, mIOLs need emmetropia to achieve a maximum of effectiveness, IOL power calculation after keratorefractive surgery is less predictable than with naïve eyes, and, consequently, residual refractive errors may require an additional laser photorefractive enhancement on a previously ablated cornea, which can be similar or opposite to the primary procedure.[5] Therefore, eyes previously treated with laser refractive surgery have traditionally been considered poor candidates for subsequent implantation of mIOLs because of the accumulation of corneal and IOL aberrations.[1] Corneal laser myopic and hyperopic corrections induce opposite changes in the corneal asphericity Q value and spherical aberration (SA) (positive and negative, respectively).[3]

However, most current mIOLs have a standard aspheric profile with low negative SA, which was originally designed to imitate a young lens and compensate for the physiological

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positive SA of naïve corneas. Thus, some authors postulated that mIOLs with a negative SA would perform better in eyes with corneas ablated for myopia because they compensate for the opposite SA; by contrast, mIOLs would sum negative SA to the optical system in the posthyperopic ablated eye.[6,7]

Data on implantation of mIOLs after refractive surgery are scarce and mostly comprise generic results for bifocal outdated IOLs after myopic ablation rather than after hyperopic ablation.[6–13] Furthermore, to date, very few studies reported visual outcomes for implantation of a trifocal IOL after corneal refractive surgery.[14–17] Recent systematic reviews and clinical studies have demonstrated the advantages of trifocal IOLs over their predecessor, bifocal IOLs.[18–20] Therefore, in appropriately selected eyes, trifocal IOLs could become an alternative for patients with presbyopia and cataracts who have previously undergone corneal refractive laser surgery. We must then ask whether the same mIOL profile fits equally a myopic and a hyperopic postkeratorefractive eye. The objectives of this study were to investigate the performance of trifocal IOLs in eyes previously treated with laser refractive surgery and to compare visual and refractive outcomes in eyes that underwent corneal ablation for myopia and hyperopia.

METHODS

Design

This multicenter, multisurgeon, single-protocol, retrospective, comparative case series study enrolled consecutive eyes that had undergone a lensectomy procedure with a trifocal IOL implantation, with a previous corneal laser refractive surgery at the authors' institution (all preoperative data known).

Subjects

Data were recorded from the central computerized clinical records system at Clinica Baviera, Spain, from 2003 to date. The study was approved by the institutional legal and ethics committee. All patients received detailed information preoperatively and gave their written informed consent for multifocal lensectomy after corneal surgery and for the use of their anonymous and aggregated medical data for clinical research.

The study inclusion criteria were as follows: (1) spherical trifocal IOL surgery (clear lens or cataracts) with a previous refractive corneal laser procedure (LASIK or surface ablation/PRK) for correction of myopia or hyperopia; (2) good potential visual acuity (baseline pre-LASIK logMAR corrected distance visual acuity [CDVA] <0.5); and (3) at least 3 months of follow-up after lens surgery. The exclusion criteria included the following: (1) eyes with subnormal optics, such as corneal topographic abnormalities (small optical zones, decentered ablations, and ectasia suspicion) and (2) any baseline anatomical disorder (vitreoretinal or surface/anterior segment disorder) or any perioperative anatomical complications (corneal and/or lens surgeries) to rule out organic disease that could mask the functional outcomes of both refractive procedures.

Intraocular Lenses

The diffractive trifocal IOLs implanted during the study period were the FineVision Micro-F, FineVision Pod-F (both from Physiol S.A.), and the AT Lisa tri 839MP (Carl Zeiss Meditec AG) IOLs. Table 1 summarizes the homogeneous distribution of the 3 trifocal IOLs in both groups. All 3 IOLs are made of foldable hydrophilic acrylic material. The FineVision Micro-F (single-piece 4-loop haptics) and FineVision Pod-F (single-piece, double-C loop haptics) combine 2 diffractive structures adjusted to offer a +3.50 diopters [D] addition for near vision and a +1.750 D addition for intermediate vision; both have a negative aspheric profile of −0.11 μm. The AT Lisa tri 839MP IOL comprises a single piece with a plate haptic design and +3.33 D near and +1.66 D intermediate additions in the IOL plane and a negative aspheric profile of −0.18 μm.

Surgical Procedures

Corneal and lens surgical procedures were performed by experienced surgeons based on homogeneous perioperative protocols. Primary corneal refractive surgery was mainly by LASIK; surface alcohol-assisted PRK was used in only 3% of patients. During the study period, LASIK was performed with 2 microkeratomes with nasal hinges (Moria LSK-ONE and Moria ONE-USE-PLUS-SBK, Microtech, Inc., Moria Ophthalmic Instruments) and 3 excimer laser models: Technolas 217C, 217-Z-100 (Bausch & Lomb, Inc.), Mel-80 (Carl Zeiss Meditec AG), and WaveLight-Allegretto Wave-Eye-Q (Alcon Laboratories, Inc.).

After a mean time of 9.3 ± 3 years, former LASIK patients retuned to the clinic for lens surgery because of a reduction in distance visual acuity, near visual acuity, or both (presbyopia and/or cataracts). Standard uneventful phacoemulsification was performed with implantation of a trifocal IOL in the capsular bag.

As all corneal refractive procedure data were available, the IOL calculation was performed using the online ASCRS calculator by entering the refractive, keratometric, topographic, and biometric data, based on a multiformula approach. The postoperative target for the IOL power calculation was emmetropia in all cases.

An additional secondary corneal laser enhancement after trifocal IOL implantation was performed in the case of a postoperative refractive error that resulted in unsatisfactory visual outcome (uncorrected distance visual acuity [UDVA] or uncorrected near visual acuity [UNVA]) at 3 months after lens surgery. Enhancement laser procedures were mainly performed using an alcohol-assisted PRK technique (97%), and the corneal flap was relifted in only 3% of cases. The postoperative pharmacologic treatment protocol consisted of a combination of antibiotic and steroidal anti-inflammatory drops and additional nonsteroidal anti-inflammatory drops.

Clinical Evaluation

Both surgical procedures (corneal and lensectomy) were performed at the authors' institution with homogeneous preoperative assessment protocols: all patients underwent a complete ophthalmologic examination that included measurement of visual acuity data, namely, distance vision (Snellen Auto Chart Projectors, Topcon Corp.), near vision (Runge Near Vision Card, Good-Lite Co.), refraction (uncorrected and corrected, manifest, and cycloplegic), topography, slitlamp biomicroscopy, ocular surface and tear film evaluation, and fundoscopy.

However, because of diversity in practice locations and development of devices over time, the preoperative evaluation was not standardized. Different corneal topographers were used during the study period (Orbscan II [Bausch & Lomb, Inc.], Pentacam HR [Oculus Optikgerate GmbH], and the WaveLight-Oculyzer [Alcon Laboratories, Inc.]). Assessment of the quality and regularity of previous corneal myopic and hyperopic ablation and evaluation of spherical and higher-order aberrations (WFA Z40 in the 6.0 mm zone and WFA HO root mean square in the 4.0 mm zone) were performed.

The preoperative examination for lens surgery also included endothelial cell count (SP 3000P, Topcon Europe Medical B.V.) and macular optical coherence tomography (SOCT Copernicus-REVO, Optopol Technology SA). Depending on the study timepoint, biometric parameters were assessed using an ultrasonic immersion biometer (Ocuscan-RPX, Alcon Laboratories, Inc.) or an optical biometer (IOLMaster 500, Carl Zeiss Meditec AG).

Table 1. Evolution of Refractive and Visual Data of Myopic vs Hyperopic Groups in Corneal Laser Surgery, Postlaser Lensectomy and Postlensectomy Periods.

Parameter	Myopic group (N = 319 eyes)	Hyperopic group (N = 549 eyes)	*P* value[a]
	Mean ± SD; range		
Primary refractive data			
CDVA prelaser (logMAR)	0.02 ± 0.02; 0, 0.46	0.02 ± 0.03); 0, 0.5	>.05
Sphere (D)[b]	−2.85 ± 1.20; +0.50, −10.75	+2.3 ± 0.76; +0.75, +7.5	<.001
Cylinder (D)[b]	−0.86 ± 0.57; 0, −4.5	−0.69 ± 0.54; 0, −6.75	>.05
MRSE (D)[b]	−3.32 ± 1.20; −0.25, −12.50	+2.20 ± 0.77; −0.75, +6.25	<.001
Mean K (D)	43.60 ± 1.40; 39.5, 48.00	43.30 ± 1.50; 37.50, 48.75	>.05
Postlaser data			
MRSE (D)	−0.25 ± 0.30; −4.40, +0.75	−0.19 ± 0.40; −3.20, +1.90	>.05
CDVA postlaser (logMAR)	1.1 ± 0.01; 0, 1.5	1.2 ± 0.03; 0, 0.5	<.05
Lensectomy data			
Time from laser to lensectomy (y)	9.6 ± 4; 0.5, 15	9.6 ± 3; 0.4, 16	>.05
Axial length (mm)	25.2 ± 1.3	22.7 ± 1.6	<.001
IOL power (D)	20.30 ± 2.30	21.80 ± 2.30	<.001
IOL model, %			
FineVision MicroF	66	60	>.05[d]
FineVision PodF	14	17	>.05[d]
AT Lisa tri 839MP	20	23	>.05[d]
Postlensectomy outcomes (3 mo)			
CDVA (logMAR)	0.04 ± 0.04; 0, 0.52	0.06 ± 0.05; 0, 0.52	<.001
UDVA (logMAR)	0.09 ± 0.08; 0, 0.82	0.1 ± 0.08; 0, 0.7	>.05
UNVA (logMAR)[c]	0.15 ± 0.14; 0, 0.8	0.16 ± 0.12; 0, 0.8	>.05
MRSE (D)[c]	−0.38 ± 0.30; −2.50, +1.50	−0.17 ± 0.30; −2.50, +2.00	<.001
Predictability (% eyes within ±0.50 D)	63.5	73.5	<.01[d]
Post-IOL enhancement (%)	17	13	>.05[d]
Postlensectomy outcomes (final visit, postenhancement)			
Mean follow-up (mo)	14 ± 10	16 ± 13	
CDVA (logMAR)[c]	1.3 ± 0.04; 0, 0.4	0.06 ± 0.05; 0, 0.52	<.001
UDVA (logMAR)[c]	0.08 ± 0.06; 0, 0.7	0.09 ± 0.06; 0, 1.1	>.05
UNVA (logMAR)[c]	0.15 ± 0.14; 0, 0.9	0.17 ± 0.15; 0, 0.9	>.05
MRSE (D)[c]	−0.34 ± 0.30; −2.50, +1.00	−0.07 ± 0.24; −2.25, +3.50	<.001
Predictability, %			<.01[d]
Eyes within ±0.50 D	68	78	
Eyes within ±1.00 D	89	95	

K = keratometry; MRSE = manifest refractive spherical equivalent
[a]Yuen test for trimmed means of independent samples.
[b]Laser treatment refraction
[c]Postlensectomy final visual outcomes measured in the final visit
[d]The χ^2 test

Refractive and Visual Measures

The main measurements were visual and refractive outcomes obtained from the visit at the third month and from the final available visit, with at least 3 months of follow-up after lensectomy (Table 1). Visual results included mean logMAR UDVA, CDVA, and UNVA; refractive data included postoperative sphere, cylinder, manifest refraction spherical equivalent (MRSE), and accuracy (percentage of eyes within ±0.25 D, ±0.50 D, and ±1.00 D).

The safety outcomes were defined as the percentage of eyes with a loss of 1 or more and 2 or more lines of CDVA between the time after lens surgery and after corneal surgery. The efficacy outcomes were measured as the percentage of eyes with a difference between postlensectomy UDVA and postcorneal surgery CDVA of 0 or more lines.

Secondary measurements were the percentage of Nd:YAG laser capsulotomy procedures and corneal laser enhancement after lens surgery for residual refraction. In addition, both myopic and hyperopic cohorts were stratified into 1.00 D steps of corneal laser treatment, by analyzing the distribution of postoperative mean CDVA and root mean square error variables.

Bivariant comparisons were performed between the low and high myopic (>−5.00 vs ≤−5.00 D) and hyperopic (≤+3.00 D vs >+3.00 D) subgroups regarding corneal laser treatment. Although the conventional definition of high myopia is −6.00 D, a cutoff value of −5.00 D was collected to avoid a disproportionate sample size (N) in both the low and high myopic subgroups as there were only 29 eyes with a less than −6.00 D range of initial laser correction.

Statistical Analysis

The statistical analysis was performed using R Development Core Team (2008) software.[21] The Shapiro test was used to test the normality of the series. After analyzing the distributions of variables, a robust approach was chosen to describe data and test the differences in mean values. Ranges and trimmed means with winsorized standard deviations, using 20% winsorization, as suggested by Wilcox are reported.[22] To compare winsorized means, the Yuen test was performed as described by Wilcox. When comparing discrete variables, the χ^2 or the Fisher exact test was applied, depending on the distribution of the expected

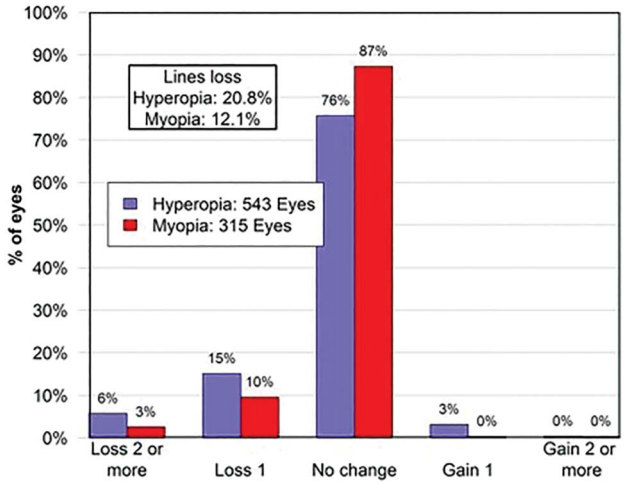

Figure 1. Trifocal IOLs in postkeratorefractive eyes: visual (safety) outcomes in myopic vs hyperopic groups. Change in CDVA lines. Postlensectomy/post-LASIK timepoints. $P < .01$, χ^2 test.

frequencies. A *P* value of less than 0.05 was considered statistically significant.

RESULTS

The study sample comprised 868 eyes from 543 patients who had undergone lens surgery with a trifocal IOL during the period 2012 to 2019 and had previously undergone corneal laser refractive surgery at the authors' institution. The series was divided into 2 groups according to the laser refractive treatment performed: the myopic group (n= 319 eyes of 215 patients [36.7%]), and the hyperopic group [which included hyperopic and mixed-astigmatism defects, n= 549 eyes of 328 patients, [63.2%]).

Regarding demographic data, the mean age and sex were distributed as follows: 99 women out of 215 patients (46%) vs 181women out of 328 patients (55%) in myopic and hyperopic groups respectively. The percentage of eyes with cataractous and clear lens was similar in both groups (myopic group, 65.1% cataract and 34.9% clear lens; hyperopic group, 60.3% cataract and 39.7% clear lens [$P > .05$]). The mean follow-up time was 14 ± 10 months and 16 ± 13 months after lensectomy in the myopic and hyperopic groups, respectively, and the main corneal laser technique was LASIK in both groups (94% in the myopic group and 98% in the hyperopic group). Table 1 displays the main refractive and visual data from baseline to postlensectomy, including the distribution of trifocal IOLs in both groups. Table 1 also displays a comparison of postoperative visual and refractive outcomes for the myopic and the hyperopic groups at the third-month visit and at the final visit (postenhancement data included), with a total mean follow-up of 15 ± 12 months.

At 3 months after lens surgery, the hyperopic group had significantly worse visual outcomes than the myopic group, measured as mean CDVA (0.06 ± 0.05 vs 0.04 ± 0.04, $P < .01$); by contrast, the myopic group achieved worse predictability outcomes measured as mean MRSE (−0.38 ± 0.30 D vs −0.17 ± 0.30 D, in hyperopic and myopic groups, respectively, $P < .001$) and percentage of eyes within ±0.50 D (73.5% vs 63.5% in hyperopic and myopic groups, respectively, $P < .01$). However, UDVA and UNVA were similar between the groups. These outcomes improved slightly at the final visit after enhancement, although the statistically significant differences remained similar between both groups.

As for safety outcomes and risk for vision loss (Figure 1), the hyperopic group had a statistically significant higher percentage of eyes that lost more than 1 line of CDVA (21% vs 12%, respectively, $P < .01$) compared with the myopic group. However, there were no statistically significant differences regarding efficacy between the groups (61% in both groups, $P > .05$).

As for predictability outcomes, the myopic group achieved a worse postoperative mean MRSE and a lower percentage of eyes with postoperative MRSE within the interval of ±0.50 D (63.5% vs 73.5%, $P < .01$) (Table 1). However, the enhancement rate was similar between the groups (myopic 17% and hyperopic 13%, $P > .05$) (Table 1).

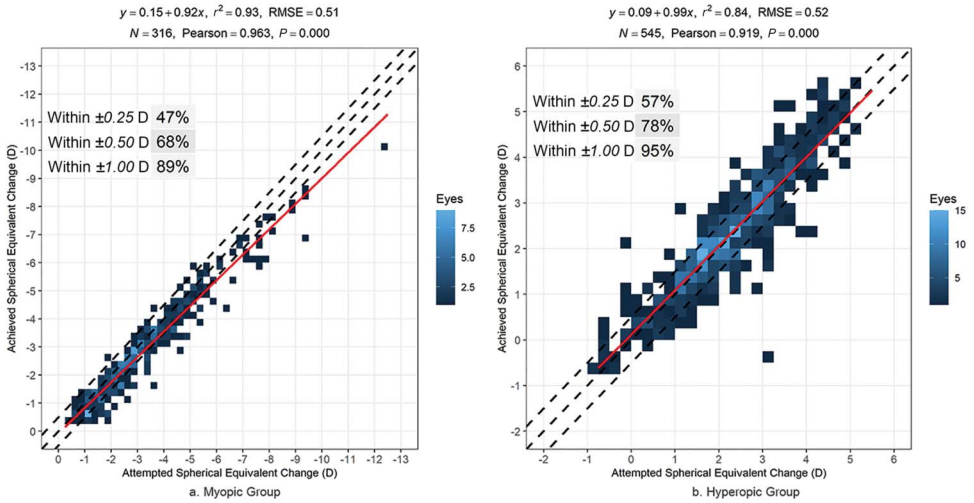

Figure 2. Trifocal IOL in postkeratorefractive eyes. Predictability outcomes in myopic vs hyperopic groups. Refractive accuracy histogram of the myopic group (*A*) and hyperopic group (*B*). *A*: The higher the corneal laser refractive correction, the higher the undercorrection with a myopic shift (enhancement included). Percentage of eyes with postoperative manifest refraction spherical equivalent within ±0.25 D, ±0.50 D, and ±1.00 D. Percentage comparisons $P < .01$, χ^2 test. RMSE = root mean square error

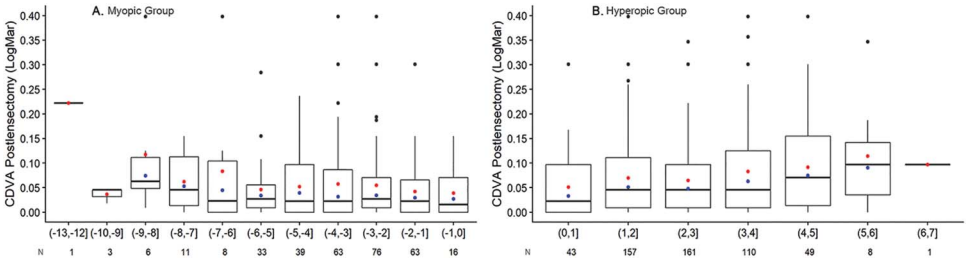

Figure 3. Postoperative CDVA stratified by diopter step in myopic and hyperopic groups. Box plot diagram (*central black horizontal line* = median, *red point* = mean; *blue point* = trimmed mean). *A*: Mean postoperative CDVA in myopic group by diopter step. *B*: The mean postoperative CDVA in hyperopic group by diopter step (eyes with mixed astigmatism not included).

At the final visit, predictability continued to be worse in the myopic group despite enhancement (Figure 2), with a myopic shift related to the magnitude of laser refraction.

Stratification of both cohorts by the initial corneal laser treatment refraction is represented in Figures 3 and 4, which illustrate postoperative mean CDVA and MRSE, respectively. As for eyes with a previous myopic ablation, Figure 4, A shows that the higher the degree of myopic corneal laser refraction, the higher the residual postlensectomy myopic defect, although postoperative mean CDVA remains unchanged with an increasing initial refractive myopic error (Figure 3, A). By contrast, eyes with hyperopic ablation show a significant decrease in postlensectomy CDVA values, with increasing magnitude of laser hyperopia correction (Figure 3, B). Nevertheless, postoperative precision outcomes were good for these eyes, even in the high range of laser correction (Figure 4, B).

Both cohorts were also divided into low or high subgroups with a cutoff value of −5.00 D and +3.00 D for the myopic and hyperopic groups, respectively (see Methods section) (Figures 5 and 6). Figures 5, A and 6, A show the bivariate comparison between low and high myopic subgroups regarding mean postlensectomy root mean square error and CDVA, respectively, with statistically significant poorer precision in the high myopic subgroup but similar postlensectomy mean CDVA between the subgroups.

Similarly, Figures 5, B and 6, B show the results of a bivariate comparison between the low and high hyperopic subgroups regarding mean postlensectomy MRSE and CDVA, respectively, with a statistically significant poorer postoperative mean CDVA in the high hyperopic subgroup but a similar postlensectomy MRSE between the subgroups.

As for the enhancement rate, there were no statistically significant differences between the low and high myopic subgroups (19.7% vs 13%, respectively, $P = .1$) and the hyperopic subgroup (14% vs 12%, respectively, $P = .6$) at a mean time of 5.7 ± 3.4 and 5.4 ± 3.9 months after trifocal phacoemulsification in the hyperopic and myopic groups, respectively ($P > .05$).

Nd:YAG laser capsulotomy was performed in 21% of the hyperopic group compared with 13.7% in the myopic group ($P < .05$); however, no statistically significant differences were detected in intragroup comparison of low and high myopic eyes (13.8% and 13.9%, respectively, $P = 1.0$) and low and high hyperopic eyes (20.2% and 22%, respectively, $P = .7$). Although the IOL model was homogeneously distributed between the myopic and hyperopic groups, the percentage of capsulotomies according to the kind of IOL was also analyzed and found that the AT Lisa tri 839MP IOL had a higher rate of capsulotomies (37%) than the FineVision MicroF (11%) and PodF (20%) trifocal IOLs (Table 1). However, the time from lens surgery to Nd:YAG capsulotomy was significantly shorter in both FineVision IOL groups than that in the AT Lisa IOL group (14 vs 24 months).

DISCUSSION

The decision to implant an mIOL after previous corneal refractive laser surgery is controversial. However, the significant improvement in visual quality and patient satisfaction that trifocal IOLs provided over their predecessor (bifocal IOLs) increased our confidence in this approach, leading us to gradually extend the implantation of trifocal IOLs to eyes previously treated with LASIK.

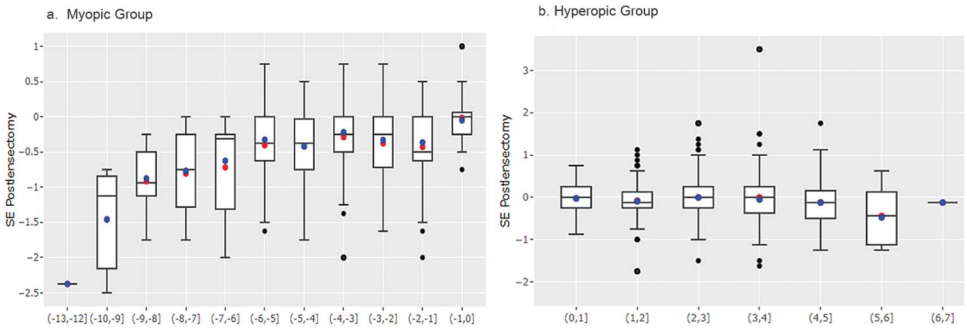

Figure 4. Postoperative spherical equivalent stratified by diopter step in myopic and hyperopic groups. Box plot diagram (*central black horizontal line* = median, *red point* = mean; *blue point* = trimmed mean). *A*: Mean SE in myopic group by diopter step. *B*: Mean SE in hyperopic group by diopter step (eyes with mixed astigmatism not included). SE = spherical equivalent

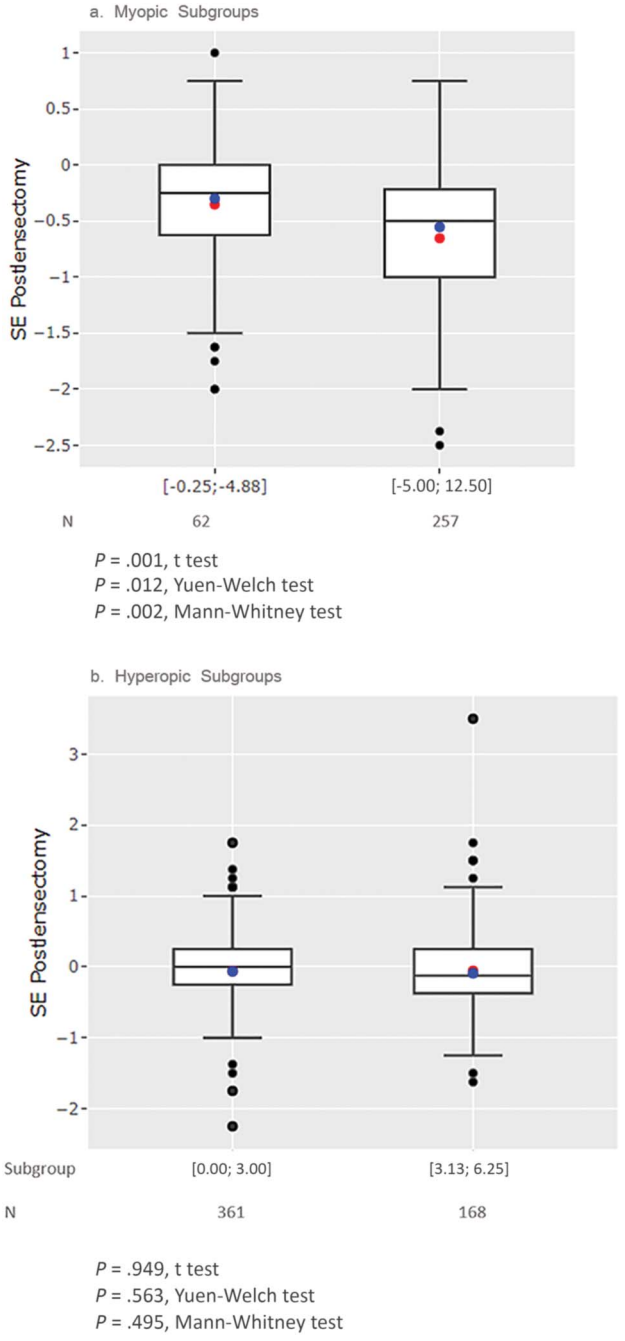

Figure 5. Comparison of postoperative spherical equivalent achieved according to low and high magnitude of preoperative error in myopic and hyperopic groups. *A*: Comparison of mean spherical equivalent in high (≤−5.00 D) and low (>5.00 D) myopic subgroups. *B*: Comparison of mean spherical equivalent in high (>+3.00 D) and low (≤+3.00 D) hyperopic subgroups (eyes with mixed astigmatism not included). SE = spherical equivalent

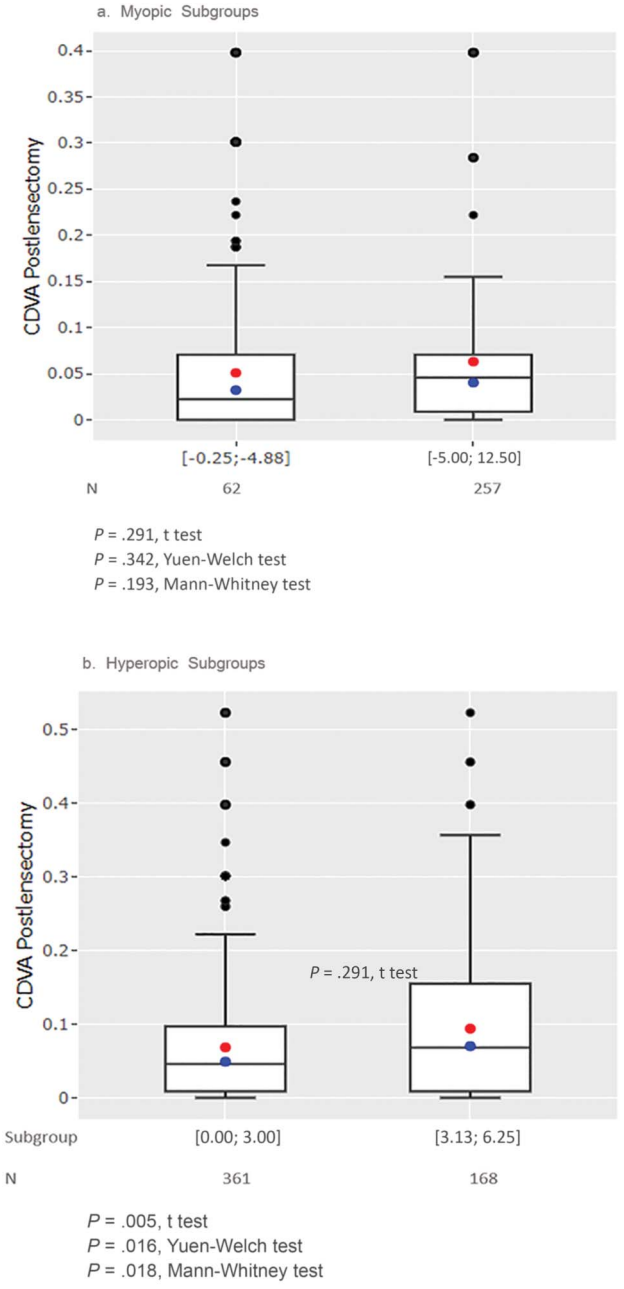

Figure 6. Comparison of postoperative CDVA achieved according to low and high magnitude of preoperative error in myopic and hyperopic groups. *A*: Comparison of mean CDVA in high (≤−5.00 D) and low (>5.00 D) myopic subgroups. *B*: Comparison of mean CDVA in high (>+3.00 D) and low (≤+3.00 D) hyperopic subgroups (eyes with mixed astigmatism not included).

MIOLs implantation in postkeratorefractive eyes was first reported in 4 small prospective comparative studies performed in 2008 by Alfonso et al.[6,7,11,12] The authors examined bifocal diffractive IOLs (AcrySof ReSTOR SN60D3 [Alcon Laboratories, Inc.] and AcriLISA-366 [Carl Zeiss Meditec AG] IOLs) in eyes previously treated with LASIK for myopia and hyperopia and provided the first evidence that implantation of mIOLs after corneal refractive surgery was well-tolerated, safe, and predictable.[6,7,11,12] This study corroborated these outcomes as mean logMAR CDVA after implantation of a trifocal IOL was 0.03 and 0.06 in myopic and hyperopic eyes, respectively. In addition, we found that only 2.6% of myopic eyes and 5.8% of hyperopic eyes lost more than 2 lines of CDVA. Precision was also reasonable, with the final postoperative MRSE within ±0.50 D in 67% and 79% of eyes and within ±1.00 D in 89% and 95% after an

enhancement rate of 17% and 13% of myopic and hyperopic groups, respectively. However, when comparing visual and refractive outcomes of trifocal IOLs in eyes previously treated with myopic and hyperopic corneal refractive ablations, we found visual outcomes to be good but precision worse in the myopic eyes, with a postoperative myopic shift related to the degree of initial myopic refraction of corneal laser surgery. By contrast, refractive precision was higher but visual and safety outcomes worse in the hyperopic ablation eyes. These results are concordant with those of similar studies with bifocal IOLs.[9,13] Nevertheless, few data have been reported on the performance of the current trifocal IOLs in these specific eyes.[14–17]

Regarding the performance of trifocal IOLs in postkeratorefractive eyes, the only published article with which to draw comparisons is that of Brenner et al., who studied a series of 241 eyes from 143 patients.[17] The authors reported the results of the FineVision MicroF and PodF IOLs after corneal laser surgery in myopic eyes (n = 155) and hyperopic eyes (n = 86) and found outcomes similar to those of this study, such as better precision of trifocal IOLs in the hyperopic group (which achieved a statistically significant lower postlensectomy MRSE).

Vrijman et al. recently published 2 retrospective descriptive studies to determine the outcome of the AcrySof-ReSTOR IOL after LASIK for myopia and for hyperopia.[9,13] Both studies reported poorer predictability in postmyopic eyes than in posthyperopic eyes.

Brenner et al. explained the higher precision of the hyperopic ablation group regarding the more reliable measurements of central keratometry in these eyes, resulting from less intense geometric changes than those in myopic cases, in which the calculation for the IOL is more difficult.[17] Furthermore, in eyes that have previously undergone high myopic ablations leaving an extremely thin cornea, it may be unfeasible to perform further postlensectomy enhancements. This may explain the poorer precision recorded in the myopic group in this study, which was maintained until the final postoperative visit, despite the enhancement procedure. Although the enhancement rate was similar in both groups, a higher enhancement rate could have been necessary in the myopic group, although the procedure could not be performed because of insufficient pachymetry. A correction factor (such as the Wang-Koch adjustment) should be considered in long postmyopic eyes when planning further implantation of a trifocal IOL.[23]

Regarding visual outcomes, which are one of the main concerns affecting the interaction between an ablated cornea and mIOL aberrations in the optical system, we found a worse postoperative mean CDVA in eyes treated with hyperopic ablation, which lost more CDVA lines than those treated with myopic ablation. However, near vision (UNVA) was not affected, with similar good outcomes in the postmyopic and posthyperopic groups. Brenner et al. also reported better visual results, measured as mean postlensectomy CDVA, in the myopic group than those in the hyperopic group ($P < .03$) at 6 months postoperatively, although safety and efficacy indexes were similar in both groups.[17] This finding contrasts with ours, which show worse safety outcomes and loss of postoperative CDVA in the hyperopic group (and specifically the high hyperopic subgroup). The differences regarding safety outcomes between these studies may be due to differences in the change in CDVA values.

Alfonso et al. put forward the first hypothesis about the interaction between the SA of previously treated corneas and mIOLs and found that aspheric IOLs performed better in eyes with corneas ablated for myopia, whereas spherical IOLs were more successful in those ablated for hyperopia.[6,7,11,12] Chang et al. reported on visual performance and quality of life in a prospective study of 27 eyes with previous myopic LASIK and subsequent implantation of the TECNIS ZMA00/ZMB00 IOL (Johnson & Johnson Vision).[10] The excellent visual safety results (no eye lost a single line of CDVA) were explained by the good match for the negative aspheric profile of the TECNIS IOL, which can compensate for +0.27 μm of SA on corneas ablated for myopia. Future research on topographic corneal aberrations (such as coma and SA) in postkeratorefractive eyes and their influence on outcomes after implantation of an mIOL will help surgeons to decide on the IOL model to implant. Finally, Ferreira et al. reported good outcomes for the Symfony IOL (Johnson & Johnson Vision) in myopic eyes treated with LASIK.[24]

Taking into account visual and refractive outcomes, we also stratified eyes by degree of corneal laser treatment in both the myopic and hyperopic groups to ascertain whether the higher ablations would be more poorly matched with trifocal IOLs than the lower ones. These subgroup comparisons are shown in Figures 3 to 6 and can be summarized as follows: high myopic ablations lead to poorer precision but maintain good visual outcomes, which are similar to those observed for lower ablations, whereas high hyperopic ablations may achieve good predictability outcomes but worse visual outcomes and loss of CDVA lines.

The findings of this study are relevant since they support the safety of implantation of trifocal IOLs in eyes with prior low and moderate myopic and hyperopic photorefractive surgery. However, in eyes previously treated with high hyperopic ablation, the risk for vision loss is increased, and another IOL model should be considered. In addition, a careful calculation should be made for the trifocal IOL in eyes treated with high myopic ablation. Other authors have also reached this conclusion about lower precision that tends toward myopic shift in eyes treated with high myopic ablation; Vrijman et al. reported that eyes with a prelaser MRSE less than −6.00 D had a less predictable outcome (also in myopic shift) after implantation of the bifocal AcrySof Restor IOL.[9]

Finally, our study revealed a significantly higher percentage of Nd:YAG capsulotomies in the hyperopic group (21% vs 13% $P < .05$). The published percentage of

capsulotomy after mIOL lensectomy in post-keratorefractive eyes is relatively high compared with naïve eyes and is fairly heterogeneous, ranging from 20% to 51%.[8–10,13] Vrijman et al. also described a higher rate of Nd:YAG capsulotomies after implantation of the bifocal AcrySof ReSTOR IOL after hyperopic corneal ablation (27.5%) than that after myopic corneal ablation (18.2%).[9,13] These results might be interpreted as an indirect indicator of poorer visual quality because of complex visual phenomena associated with the interaction of multifocal optics and posterior capsule opacification, as suggested by Shah et al., who, after comparing with monofocal IOLs, reported a significantly higher rate of Nd:YAG capsulotomies in a large series of mIOLs (ReSTOR SN60D3 and SA60D3 IOLs).[25] In a previous study by our group, analysis of capsulotomy rates using the trifocal IOL model revealed a significantly higher percentage with the AT Lisa tri 839MP IOL model than that with the FineVision models, although this is not relevant in this study as the 3 IOL models were homogeneously distributed in both the myopic and the hyperopic groups (Table 1).[26]

This study is limited by its retrospective design, which excludes specific measurements, such as subjective assessment (patient-reported satisfaction), spectacle dependence, and objective quality parameters (aberrometry, contrast sensitivity, and topographic corneal aberrations). However, the study was designed mainly to evaluate objective visual and refractive data. It is possible that the poorer safety outcomes in the hyperopic group do not correlate with real-life patient-perceived outcomes, which would probably be better, as patients may be prepared to tolerate some distance vision loss in exchange for intermediate and near vision independence. Future studies with additional surveys on patient quality of life and spectacle dependence will clarify this issue. In addition, the heterogeneity resulting from a large group of surgeons using various excimer lasers and measurement devices during the study period has also proven to be an unavoidable shortcoming in a retrospective multicenter study with a long follow-up that includes different surgical procedures. Nevertheless, ours is one of the largest series in the literature, reporting real-life outcomes of the interaction between refractive procedures.

In conclusion, implantation of a trifocal IOL is compatible with previous corneal refractive laser surgery since it provided appropriate objective visual and refractive outcomes, although the procedure was less precise in post-myopic eyes. Trifocal IOLs performed significantly better in visual outcomes in eyes that had previously undergone corneal ablation for myopia than in those treated for hyperopia (mainly in the range more than +3.00 D), in which we recorded worse safety results, loss of CDVA lines, and more frequent Nd:YAG capsulotomy.

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WHAT WAS KNOWN

- Implantation of multifocal IOLs (mIOLs) in post-keratorefractive eyes remains controversial, to the extent that some surgeons consider it a relative contraindication because of the higher risk for decreased quality of vision due to interaction between the optics of a diffractive mIOL and an ablated cornea.
- Previous studies have postulated the hypothesis that mIOLs would perform better with corneas ablated for myopia than for hyperopia because of the unfavorable interaction between the negative corneal spherical aberration induced by a hyperopic ablation and an mIOL with a negative aspheric profile.

WHAT THIS PAPER ADDS

- Current diffractive trifocal IOLs are compatible with a photoablated cornea in adequate predictability, efficacy, and safety outcomes.
- Implantation of trifocal IOLs in eyes that had previously undergone photorefractive surgery led to better visual outcomes in eyes with previous myopic and low hyperopic corneal ablation (<+3.00 D). However, eyes that had previously undergone high hyperopic corneal laser surgery had worse safety outcomes and loss of CDVA.
- Implantation of trifocal IOLs in eyes previously treated with photorefractive surgery led to better refractive outcomes in eyes previously treated with hyperopic corneal ablation than in those treated with myopic ablation.

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