Journal of Refractive Surgery

Trifocal IOL implantation in eyes that had previously undergone photorefractive surgery: The role of corneal spherical aberration on postoperative visual outcomes.

--Manuscript Draft--

Manuscript Number:	
Full Title:	Trifocal IOL implantation in eyes that had previously undergone photorefractive surgery: The role of corneal spherical aberration on postoperative visual outcomes.
Article Type:	Original Article
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Abstract:	PURPOSE: To analyze corneal aberrations and factors affecting visual outcomes after implantation of a trifocal intraocular lens (IOL) in eyes previously treated with laser corneal refractive surgery (LCRS). SETTING: Clinica Baviera/AIER-Eye, Spain DESIGN: Retrospective case-series METHODS: We studied 222 consecutive eyes implanted with a trifocal IOL (Physiol-Micro-F) after LCRS. The series was divided into 2 groups according to postlensectomy safety outcomes: the failed-eyes (FE) group (ie, eyes with a loss of ≥1 lines of corrected-distance visual acuity (CDVA), [n=59, 26.5%]); and the successful-eyes (SE) group (ie, eyes with no loss or gain in lines of CDVA, [n=163, 73.4%]). We compared the distribution of topographic corneal aberrations: spherical-aberration [Z40], coma (Z 3 +1 , Z 3 -1 , and vectorized-coma /Z31/), high-order-aberrations (RMS-HOA), kappa-angle, primary laser refractive defect, and post-LCRS CDVA, among both groups. RESULTS: Post-lensectomy median CDVA was (0.18±0.1 vs 0.04±0.05 (p<.01) in FE and SE, respectively. Comparison of failed and successful eyes showed that FE group was more hyperopic and had a statistically significant higher grade of hyperopic LCRS treatment measured as median sphere (+1.5 D vs. -0.75D), MRSE (+1.38D vs. -1.38 D), and percentage of hyperopic laser treatment (61% vs 44.2%), p<0.05. Mean Z40 was significantly more negative in FE-group (+0.07 ± 0.4 vs +0.18± 0.3 mm, p<.05). However, RMS-HOA, coma-aberrations, kappa-angle, laser-cylinder treatment, and post-laser CDVA parameters were equally distributed in both groups. CONCLUSION: Implantation of a trifocal IOL in postkeratorefractive eyes should consider topographic corneal spherical aberrations to prevent visual loss after lensectomy, particularly in eyes previously treated with hyperopic LCRS.
Author Comments:	

ABSTRACT

PURPOSE: To analyze corneal aberrations and factors affecting visual outcomes after implantation of a trifocal intraocular lens (IOL) in eyes previously treated with laser corneal refractive surgery (LCRS).

SETTING: Clinica Baviera/AIER-Eye, Spain

DESIGN: Retrospective case-series

METHODS: We studied 222 consecutive eyes implanted with a trifocal IOL (Physiol-Micro-F) after LCRS. The series was divided into 2 groups according to postlensectomy safety outcomes: the failed-eyes (FE) group (ie, eyes with a loss of ≥1 lines of corrected-distance visual acuity (CDVA), [n=59, 26.5%]); and the successful-eyes (SE) group (ie, eyes with no loss or gain in lines of CDVA, [n=163, 73.4%]).

We compared the distribution of topographic corneal aberrations: spherical-aberration [Z40], coma (Z_3^{+1}, Z_3^{-1}, and vectorized-coma /Z_{31}/), high-order-aberrations (RMS-HOA), kappa-angle, primary laser refractive defect, and post-LCRS CDVA, among both groups.

RESULTS:
Post-lensectomy median CDVA was (0.18±0.1 vs 0.04±0.05 ($p<.01$) in FE and SE, respectively. Comparison of failed and successful eyes showed that FE group was more hyperopic and had a statistically significant higher grade of hyperopic LCRS treatment measured as median sphere (+1.5 D vs. -0.75D), MRSE (+1.38D vs. -1.38 D), and percentage of hyperopic laser treatment (61% vs 44.2%), $p<0.05$. Mean Z40 was significantly more negative in FE-group (+0.07 ± 0.4 vs +0.18± 0.3 μm, $p<.05$). However, RMS-HOA, coma-aberrations, kappa-angle, laser-cylinder treatment, and post-laser CDVA parameters were equally distributed in both groups.

CONCLUSION:
Implantation of a trifocal IOL in postkeratorefractive eyes should consider topographic corneal spherical aberrations to prevent visual loss after lensectomy, particularly in eyes previously treated with hyperopic LCRS.

PRECIS:

This study analyzes the factors that influence postoperative visual outcomes in postkeratorefractive eyes that subsequently undergo trifocal lensectomy with the trifocal Finevision MicroF IOL in order to find a prognostic marker for poor outcome.

INTRODUCTION

Correction of presbyopia and cataracts with a multifocal intraocular lens (MIOL) in patients previously treated with corneal photorefractive surgery is a controversial issue of current refractive surgery, because premarket approval trials of most available MIOLs were conducted on naïve corneas. Although previous laser corneal refractive surgery (LCRS) is not an absolute contraindication for implantation of a MIOL, it does provide several challenges arising mainly from the interaction between the aberration in an ablated cornea and the optical performance of a MIOL. Furthermore, the demand to maintain spectacle independence with aging has grown in the last years in patients who have previously undergone LCRS[1-3].

The outcomes of excimer laser in situ keratomileusis (LASIK) and photorefractive keratectomy (PRK) have proven to be highly safe, effective, and predictable over more than 20 years of experience. However, modification of the shape of the cornea by laser alters natural corneal aberration and, depending on the type and degree of the ablation, may induce high-order aberrations (HOAs) in the cornea[4]. Even with a good refractive or emmetropic outcome after excimer laser treatment, patients can experience a certain loss of contrast sensitivity and a decrease in visual quality because of corneal aberrations. Some authors have estimated cut-off values for HOA leading to poorer visual quality, such as the root mean square of the HOA (RMS-HOA) and has been set at > 0.5 µm[5].

On the other hand, MIOLs are responsible for the induction of new aberrations in the optical system that require further neuroadaptation. Therefore, eyes previously treated with LCRS have traditionally been considered poor candidates for subsequent implantation of MIOLs because of the accumulation of corneal and IOL aberrations with a further risk of poorer visual quality and loss of corrected distance visual acuity (CDVA), blurred vision, glare, and ghost images. Some surgeons avoid MIOLs in patients who have undergone myopic LASIK correction greater than –4 to –6D and hyperopic LASIK corrections greater than +2 to +3D [1, A].

In addition, the kappa angle[6], the magnitude and type of primary refractive error (hyperopia vs. myopia) of the LCRS procedure, and postkeratorefractive visual outcomes should also be considered before multifocal lensectomy in order to ensure optimal postoperative outcomes.

Surprisingly, reports on preoperative HOAs in postkeratorefractive patients undergoing implantation of an MIOL are few and controversial. Most published studies report generic results with outdated bifocal IOLs [7-11], and few publications address visual outcomes with current trifocal IOLs after LCRS[12-15]. Recent clinical studies and systematic reviews have demonstrated the advantages of trifocal IOLs over bifocal IOLs [16,17]. Therefore, trifocal IOLs could become a reasonable alternative for patients with presbyopia and cataracts who have undergone LCRS and whose eyes are considered suitable candidates based on topographic or aberrometry data.

Laser refractive myopic and hyperopic corrections induce opposite changes in the corneal asphericity Q-value and spherical aberration (Z40) (positive and negative, respectively) that are proportional to the magnitude of the laser-corrected refractive error[18,19]. However, most current MIOLs have a standard aspheric profile with negative Z40, which was originally designed to imitate a young lens by compensating for the physiologically positive Z40 of naïve corneas. For this reason, some authors hypothesize that MIOLs with a negative Z40 would perform better in eyes with naïve corneas or corneas treated with a myopic ablation, as these would compensate for the opposite Z40 signs[1]. Conversely, in eyes that have previously undergone hyperopic corneal ablation, they would add negative Z40 to the optical system; consequently, spherical IOL implants with positive spherical aberration would better suit these hyperprolate corneas[1,7,8]. Consequently, the magnitude and severity of corneal aberrations should be evaluated when planning implantation of a MIOL. Wang et al[20] designed an algorithm to verify the optimal relationship between corneal aberrations and the tolerance of an IOL with the aim of identifying eyes that were good candidates for a specific MIOL after LASIK. In addition, the manufacturers of some topography devices have developed recommendations on threshold values for aberrations before implantation of a MIOL (e.g., Pentacam™, HR, Occulus Optikgerate, GmbH)[21].

Finally, it is worth mentioning the most recent review article by Moshifar et al[1], who provide a summary of published cut-off values for a series of variables that should be considered when implanting a MIOL in eyes previously treated with LCRS. The variables reported in this paper include the magnitude and type of laser corneal ablation (myopia/hyperopia), pupil diameter, kappa and alpha angles, and corneal aberrations. However, the authors advise caution with respect to nonstandardized reporting of these results (many of them drawn from non–peer-reviewed literature), thus limiting interstudy comparisons and drafting of guidelines to determine suitable postkeratorefractive candidates for MIOLs.

The purpose of this study was to identify factors that could compromise visual outcomes of trifocal lensectomy in eyes with a previously ablated cornea. We analyzed the influence of topographic corneal aberrations (Z40, coma, and total HOA) and other factors (kappa angle, primary laser refraction, and post-LASIK visual acuity) on postoperative visual outcomes after implantation of a trifocal IOL. The final objective was to identify a preoperative prognostic marker of poorer postoperative visual outcome that could help surgeons to decide whether to implant a trifocal IOL in an eye previously treated with LCRS.

PATIENTS, MATERIAL AND METHODS

DESIGN

This multicenter, multisurgeon, single-protocol, retrospective, observational case series study enrolled consecutive eyes that had undergone lensectomy with implantation of a trifocal IOL after previous LCRS at our institution (all preoperative data known).

SUBJECTS

Data were recorded from the central computerized clinical records system at Clinica Baviera, Spain from 2003 to the present. The study was approved by the institutional legal and ethics committee. All patients received detailed information before surgery and gave their written informed consent for implantation of a MIOL after LCRS 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 previous LCRS (LASIK or surface ablation/PRK) for correction of myopia or hyperopia; (2) good potential visual acuity (baseline pre-LASIK logMAR CDVA <0.5); and (3) at least 3 months of follow-up after lens surgery.

The exclusion criteria included 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 outcome of either refractive procedure.

INTRAOCULAR LENSES

The diffractive trifocal IOL implanted during the study period was the FineVision Micro-F (Physiol S.A.), which is a single-piece, 4-loop-haptic IOL that combines two diffractive structures adjusted to offer a +3.5 D addition for near vision and a +1.75 D addition for intermediate vision and has a negative aspheric profile of –0.11 μm.

SURGICAL PROCEDURES

Corneal and lens surgical procedures were performed by experienced surgeons based on homogeneous perioperative protocols. Primary corneal refractive surgery was performed between 2002 and 2018 mainly using LASIK technique; surface alcohol-assisted PRK was used in only 1% of the series. During the study period, LASIK was performed with two microkeratomes with nasal hinges (Moria LSK-ONE and Moria ONE-USE-PLUS-SBK, Microtech Inc., Moria Ophthalmic Instruments, Anthony, France) and three excimer laser models: Technolas 217C, 217-Z-100 (Bausch & Lomb, Claremont, CA, USA), Mel-80 (Carl Zeiss Meditec, Jena, Germany), and WaveLight-Allegretto Wave-Eye-Q (Alcon Laboratories, Fort Worth TX, USA).

After a mean time of 10±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). Lens surgery was carried out between the period 2013 to 2020; 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 on-line ASCRS calculator by entering 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 corneal laser enhancement was performed after implantation of the trifocal IOL in the case of a postoperative refractive error that resulted in an unsatisfactory visual outcome of 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 (63%), and the corneal flap was re-lifted in 37% of cases.

The postoperative pharmacologic treatment protocol consisted of antibiotic and steroidal anti-inflammatory drops combined with nonsteroidal anti-inflammatory drops.

CLINICAL EVALUATION

Both surgical procedures (LCRS and lensectomy) were performed at the same institution following a homogeneous preoperative assessment protocol: 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), slit-lamp biomicroscopy, ocular surface and tear film evaluation, and fundoscopy.

Topographic assessment of the quality and regularity of previous corneal myopic or hyperopic ablation and measurement of corneal aberrations were performed using the Pentacam HR (Oculus Optikgerate GmbH) topography device.

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). Biometric parameters were assessed using an optical biometer (IOLMaster 500, Carl Zeiss Meditec AG).

OUTCOME MEASURES

Visual and refractive outcomes were obtained from the last available visit with at least 3 months of follow-up after lensectomy and after LCRS. Visual results included mean and median logMAR UDVA, CDVA, and UNVA; refractive data included sphere, cylinder, and manifest refractive spherical equivalent (MRSE) and accuracy (percentage of eyes within ±0.5D).

The change in postlensectomy CDVA vs. post-LASIK CDVA was calculated to measure safety outcomes (percentage of eyes with loss of ≥ 1 and ≥ 2 lines of CDVA) and divide the series into 2 groups comparison: failed-eyes (FE) and successful-eyes (SE) groups.

As for the main outcomes of the study, we analyzed the distribution of topographical corneal aberrations between the groups. These included spherical aberration (WFA Z40 at the 6.0-mm zone, RMS-HOA at the 4.0-mm zone), 3 comatic aberrations (horizontal coma [Z_3^{+1}], vertical coma [Z_3^{-1}], and

the Pentacam value “vectorized coma” /Z31/), and kappa angle. The Laser:Nd YAG capsulotomy and postlensectomy enhancement percentages were also measured.

STATISTICAL ANALYSIS

The statistical analysis was performed by using R Development Core Team software[22]. Quantitative continuous variables were compared between independent groups using the Mann-Whitney test for median values and the chi-squared test for discrete variables.

RESULTS

The study sample comprised 222 eyes (146 patients) that met inclusion criteria. The series was divided into 2 groups according to safety outcomes measured as loss of CDVA lines between post-LCRS and post-lensectomy timepoints: the FE group (eyes with loss of ≥ 1 CVDA line) and the SE group (eyes with no change or gain in CDVA lines).

We found that 49 out of 222 (22%) eyes had lost 1 CDVA line, and 11 (5%) had lost 2 CVDA lines, that is, the FE group comprised 60 out of 222 (27%) eyes and the SE group comprised 162 eyes (73%) (Figure 1). In addition, uncorrected near visual acuity (UNVA) and uncorrected distance visual acuity (UDVA) were worse in the FE group, even though the final predictability results were similar (table 1).

Demographic data from both groups were as follows: mean age and gender were similar in both groups (FE vs. SE: 58.8 ± 7 vs. 57.7 ± 7 years; 58.8% vs. 57.7% female, $p > 0.05$). The percentage of LASIK/PRK procedures was also similar in both groups (96% LASIK), and mean follow-up time was 1.4 ± 1 years and 1.3 ± 1 years after lensectomy in the FE and SE groups, respectively.

As the purpose of the study was to identify factors associated with the poorer outcome (loss of CDVA), we investigated the statistically significant differences between the FE and SE groups regarding baseline data, laser corneal surgery, and post-laser surgery, including corneal aberrations.

Table 2 shows the refractive baseline data for both groups. The FE group was more hyperopic and had a statistically significantly higher grade of laser hyperopic treatment measured as median sphere (+1.5 D vs. –0.75D), MRSE (+1.38D vs. –1.38 D), percentage of hyperopic laser treatment (61% vs 44.2%), and axial length (23.2 mm vs. 24 mm) in the FE and SE groups, respectively (P<.05). Baseline refractive astigmatism, however, was equally distributed between the groups, without significant differences. Regarding the visual acuity achieved after the corneal photorefractive procedure, post-LASIK CDVA was also similar in both groups (table 2).

The distribution of PentaCam^{TM} corneal aberrations between the groups is shown in Table 3 and Figure 2. All aberrations and the kappa angle were distributed equally between the groups except for spherical aberration (Z40), which was statistically significantly more negative in the FE group (0.07 mm vs 0.3 mm, P<.05).

Postlensectomy YAG capsulotomies and postlensectomy enhancement procedures (FE vs. SE) were higher in the FE group, although the differences were not statistically significant (13.6% vs. 8.4% [p>0.05] and 20.3% vs.13.5% [p>0.05]).

DISCUSSION

At present, there are no guidelines on the degree and type of HOAs that preclude the use of a MIOL[1,23]. To our knowledge, this is one of the first clinical studies to address the effect of corneal aberrations and other factors on previously photoablated eyes that were subsequently implanted with a trifocal IOL. The study aimed to identify factors that are directly associated with loss of vision and, therefore, to provide predictable values for either the success or failure of the lensectomy procedure.

We analyzed a series of 222 eyes undergoing implantation of an MIOL after LCRS and identified 59 eyes with postoperative vision loss in order to compare significant differences in preoperative variables between this group (FE group) and the eyes that did not lose or gain vision after lensectomy

(SE group) (Fig 1). Table 1 shows that the FE group achieved not only a worse mean CDVA, but also worse UNVA and UDVA than the SE group despite similar accuracy outcomes.

The first finding of the present study was that, overall, implantation of a trifocal IOL is a reasonable option for a previously photoablated cornea, as only 5% of the eyes had a significant loss of CDVA (≥ 2 lines) after lensectomy. This result is concordant with those of Brenner et al[15] and previous studies[7,8,9,12,13,24], which reported good safety, efficacy, and predictability outcomes after implantation of different MIOLs in eyes that had undergone LCRS for myopia and hyperopia.

According to the main objective of the study, we compared the distribution of LCRS data, namely, postlaser visual acuity (table 2), corneal topographic aberrations, and kappa angle (table 3 and Fig 2) between the FE group and the SE group. The comparisons showed that the FE group had more frequently undergone a corneal hyperopic photorefractive procedure than the SE group (64% vs 43%, $p<.05$). The differences were statistically significant when other refractive values (mean and median sphere and MRSE) were measured. However, laser treatment for cylindrical error was similar in both groups. This result is consistent with those of a study performed by our group (in press)[25] comparing a large series of trifocal IOLs implanted after eyes that had been previously ablated for myopia versus hyperopia, where postoperative CDVA values were worse in the hyperopic group. The study by Brenner et al[15] reported the same result for the FineVision Trifocal IOL at 6 months in LCRS for myopia vs. hyperopia.

Regarding corneal aberrations, we found that the FE group had significantly more negative values for corneal spherical aberration (Z40) than the SE group as a consequence of the previous hyperopic ablation. Although this question has been hypothesized by several authors, no objective data have been reported from clinical studies to date.

Maeda et al.[21] established topographic (PentaCam™) cut-off values for several corneal aberrations, including Z40 (at the 6-mm optical zone) at +0.1 µm and total RMS-HOA (at the 4-mm optical zone) in the range +0.3 to +0.5 µm for safe implantation of an aspherical MIOL in naïve corneas. Moshifar et

al.[1] also reported a spherical aberration threshold value > +0.1μm for implantation of an aspheric MIOL in postrefractive eyes, although the authors state that their data were extracted from non–peer-reviewed literature.

Finally, since our study revealed that the kappa angle was low and equally distributed in both groups, this parameter was not associated with loss of CDVA lines. Garzon et al[6] advised against implanting MIOLs in patients with a kappa angle > 0.5 mm in order to avoid a refractive surprise or patient dissatisfaction.

Another interesting and surprising finding of the present study was that total HOA and all coma-aberrations were also homogeneously distributed between the two groups and did not correlate significantly with the decrease in visual acuity, as might initially be expected. Kohnen et al.[3] proved that the number of HOAs induced in hyperopic LASIK treatments was greater than in myopic cases and that coma aberrations were also more pronounced in the latter. The review by Moshifar et al.[1] sets a total HOA threshold of >±2.0μm and a vertical/horizontal coma of >±0.5 μm (PentaCam 6-mm zone) to caution against the use of diffractive MIOLs. The mean values of these parameters in the present series in both groups are far below from the aforementioned published reference values. Accordingly, with these results, no relationship was either found between the frequency of laser refractive cylinder treatment and postlensectomy CDVA loss. We observed that average and range cylinder values were similar in the FE and SE groups (Table 2).

The values for kappa angle and comatic and HOA aberrations are low in both groups, probably because the surgeons ruled out implantation of a trifocal IOL in postkeratorefractive eyes with subnormal optics (such as decentered corneal ablations, small optical zones, and ectasia suspicion). The reading that could be drawn from these results is that postrefractive eyes, even those with high laser cylinder ablations but high-quality topography, are adequate candidates for a trifocal implant and the main caution should be exercised in the case of previous high hyperopic ablation with a low-negative SA, which is associated with a failed outcome after lensectomy. We could not find similar studies with which to compare these results.

Besides, we found a clinically relevant higher incidence of Nd-YAG laser capsulotomy and corneal laser enhancement after trifocal IOL implantation in the FE compared to the SE groups. However, the differences were not statistically significant, but this could have been biased by a small sample size of failed eyes. Patients with a poorer visual outcome may be more prone to have undergone further procedures in an attempt to improve both corrected and uncorrected visions. This could explain such differences among groups.

Our study is limited by its retrospective design, which excludes specific measurements, such as the correlation between failed eyes (CDVA lines lost) and the patient's subjective assessment or other objective quality parameters such as contrast sensitivity or defocus curves. However, the study was designed mainly to evaluate the effect of corneal topographic aberrations on objective loss of visual acuity. In addition, the heterogeneity resulting from a large group of surgeons using various excimer lasers and measurement devices during the study period is also an unavoidable shortcoming in a retrospective multicenter study with a long follow-up that includes different surgical procedures. Nevertheless, ours is one of the first series in the literature to report real-life visual outcomes based on the interaction between the aberrations of two refractive procedures: LCRS and implantation of a trifocal IOL.

In conclusion, the present study reveals that low or negative Z40 values in topography should be considered with caution before implantation of a trifocal IOL—particularly in eyes that had undergone hyperopic corneal ablation—to avoid suboptimal outcomes and prevent loss of CDVA after lensectomy. In addition, other controversial factors, such as coma aberrations and kappa angle were not related to losing visual acuity. Further studies in this research line with more cases are needed to extract specific threshold values for indicating MIOLs in postkeratorefractive eyes.

VALUE STATEMENT:

What was known:

- Implantation of multifocal IOLs in postkeratorefractive eyes remains controversial, to the extent that some surgeons consider it a relative contraindication because of the higher risk for vision loss and decreased quality of vision due to the interaction between the aberrations of a diffractive MIOL and an photoablated cornea.
- Previous studies have postulated 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 hyperopic ablation and a MIOL with a negative aspheric profile. However, this hypothesis has not been previously tested in a clinical study.

What this paper adds:

- Topographic corneal spherical aberration should be considered before implanting a trifocal IOL in postkeratorefractive eyes. Eyes with a preoperative low-positive or negative spherical aberration value and previous laser corneal hyperopic ablation have a higher risk of loss of distance and near visual acuity after trifocal lensectomy.

REFERENCES

1. Moshifar M, Thomson AC, Thomson RJ et al. Use of presbyopia-correcting intraocular lenses in patients with prior corneal refractive surgery. Curr Opin Ophthalmol 2021:32, 45-53
2. Khor WB, Afshari NA. The role of presbyopia-correcting intraocular lenses after laser in situ keratomileusis. Curr Opin Ophthalmol 2013 Jan;24(1):35-40.
3. Alio JL, Abdelghany AA, Abdou AA, Maldonado MJ. Cataract surgery on the previous corneal refractive surgery patient. Surv Ophthalmol 2016 Nov - Dec;61(6):769-777.
4. Kohnen T, Mahmoud K, Buhren J. Comparison of corneal higher-order aberrations induced by myopic and hyperopic LASIK. Ophthalmology 2005 Oct;112(10):1692.
5. Hanna R, Mimouni M, Plaza AB, Alió JL. Factors predicting successful customized excimer laser treatment in irregular corneas. Journal of Cataract & Refractive Surgery 2020;46(2):241-249.
6. Garzón N, García-Montero M, López-Artero E, Albarrán-Diego C, Pérez-Cambrodí R, Illarramendi I, et al. Influence of angle κ on visual and refractive outcomes after implantation of a diffractive trifocal intraocular lens. Journal of Cataract & Refractive Surgery 2020;46(5):721-727.
7. Alfonso JF, Madrid-Costa D, Poo-Lopez A, Montes-Mico R. Visual quality after diffractive intraocular lens implantation in eyes with previous myopic laser in situ keratomileusis. J Cataract Refract Surg 2008 Nov;34(11):1848-1854
8. Alfonso JF, Fernandez-Vega L, Baamonde B, Madrid-Costa D, Montes-Mico R. Refractive lens exchange with spherical diffractive intraocular lens implantation after hyperopic laser in situ keratomileusis. J Cataract Refract Surg 2009 Oct;35(10):1744-1750.
9. Vrijman V, van der Linden JW, van der Meulen IJE, Mourits MP, Lapid-Gortzak R. Multifocal intraocular lens implantation after previous corneal refractive laser surgery for myopia. J Cataract Refract Surg 2017 Jul;43(7):909-914.

10. Muftuoglu O, Dao L, Mootha VV et al. Apodized diffractive intraocular lens implantation after laser in situ keratomileusis with or without subsequent excimer laser enhancement. J Cataract Refractive Surg 2010;36 (11):1815-1821.
11. Chang JS, Ng JC, Chan VK, Law AK. Visual Outcomes, Quality of Vision, and Quality of Life of Diffractive Multifocal Intraocular Lens Implantation after Myopic Laser In Situ Keratomileusis: A Prospective, Observational Case Series. J Ophthalmol 2017;1-12.
12. Li QM, Wang F, Wu ZM et al. Trifocal diffractive intraocular lens implantation in patients after previous corneal refractive laser surgery for myopia. BMC Ophthalmology (2020) 20:293.
13. Chow SSW, Chan TCY, Ng ALK, Kwok AKH. Outcomes of presbyopia-correcting intraocular lenses after laser in situ keratomileusis. International Ophthalmology 2019, 39: 1199–1204
14. Wang W, Ni S, Li X, Chen X, Zhu Y, Xu W. Femtosecond laser-assisted cataract surgery with implantation of a diffractive trifocal intraocular lens after laser in situ keratomileusis: a case report. BMC Ophthalmol 2018; 18(1):160.
15. Brenner LF, Gjerdrum B, Aakre BM, Lundmark PO, Nistad K. Presbyopic refractive lens exchange with trifocal intraocular lens implantation after corneal laser vision correction: Refractive results and biometry analysis. J Cataract Refract Surg 2019; 45:1404–1415
16. Xu ZQ, Cao DM, Chen X, Wu S, Wang X, Wu Q. Comparison of clinical performance between trifocal and bifocal intraocular lenses: a meta-analysis. PLoS One. 2017;12(10):e0186522.
17. Bilbao-Calabuig R, Llovet-Rausell A, Ortega-Usobiaga J, et al. lmplantation of Two Diffractive Trifocal Intraocular Lenses in 10 084 EyesAm J Ophthalmol 2017;179:55–66
18. Chen CC, Izadshenas A, Rana MAA, Azar DT. Corneal asphericity after hyperopic laser in situ keratomileusis. Journal of Cataract & Refractive Surgery 2002;28(9):1539-1545.
19. Bottos KM, Leite MT, Aventura-Isidro M, Bernabe-Ko J, Wongpitoonpiya N, Ong-Camara NH, et al. Corneal asphericity and spherical aberration after refractive surgery. J Cataract Refract Surg 2011 Jun;37(6):1109-1115.

20. Wang L, Pitcher JD, Weikert MP, Koch DD. Custom selection of aspheric intraocular lenses after wavefront-guided myopic photorefractive keratectomy. J Cataract Refract Surg 2010 Jan;36(1):73-81.
21. Maeda N. Assessment of corneal optical quality for premium IOLs with Pentacam. Highlights Ophthalmol 2011;39(4):2-5.
22. R Development Core Team. R: A Language and Environment for Statistical Computing. Vienna: R Foundation for Statistical Computing. ISBN 3-900051-07-0. 2008. http://www.R-project.org
23. Braga-Mele R, Chang D, Dewey S et al. Multifocal intraocular lenses: Relative indications and contraindications for implantation. J Cataract Refract Surg 2014; 40:313–322
24. Vrijman V, van der Linden JW, van der Meulen IJE, Mourits MP, Lapid-Gortzak R. Multifocal intraocular lens implantation after previous hyperopic corneal refractive laser surgery. J Cataract Refract Surg 2018 Apr;44(4):466-470.
25. Cobo-Soriano R, Ortega-Usobiaga J, Rodríguez-Gutiérrez B, Tejerina V, Llovet, F, Casco B, Baviera J. Trifocal intraocular lens implantation in eyes with previous corneal refractive surgery for myopia and hyperopia J Cataract Refract Surg. 2021. doi: 10.1097/j.jcrs.0000000000000637

OTHER SOURCES

A. Brennan K. Odd couple: multifocals and postrefractive eyes. Rev Ophthalmol 2017; Available from: https://www.reviewofophthalmology.com/article/oddcouple-multifocals-and-postrefractive-eyes. [Accessed 16 August 2020]

FIGURE LEGENDS

Figure 1:

Failed-eyes and Succesful-eyes groups classified by change of CDVA logMAR lines between post-LCRS and post-lensectomy timepoints

CDVA: Corrected distance visual acuity

LCRS: Laser corneal refractive surgery

Figure 2:

Box-plot graph with distribution of topographical corneal aberrations and kappa angle by groups

RMS HOA: right mean square of high-order aberrations;

SA-Z40: spherical aberration;

Comatic aberrations: Z3(+1) horizontal coma, Z3 (-1) Vertical Coma , /Z31/ vectorized coma.

P values, mean(horizontal line), median(red point), and range(vertical line).

Table 1

Table 1: Postlensectomy refractive and visual data of Failed-Eyes and Successful-Eyes groups.

	FAILED EYES (N=59)		SUCESSFUL EYES (N=163)		
	Mean (SD) [RANGE]	**Median (Q25/Q75)**	**Mean (SD) [RANGE]**	**Median (Q25/Q75)**	**P-Value***
POST-LENSECTOMY VISUAL AND REFRACTIVE DATA:					
CDVA (logMAR)	0.18 (±0.1) [0.04/0.52]	0.15 (0.12/0.22)	0.04 (±0.05) [0/0.22]	0.02 (0/0.06)	<0,001*
UDVA (logMAR)	0.23 (±0.21) [0.02/1.52]	0.17 (0.14/0.3)	0.1 (±0.13) [0/0.7]	0.07 (0.02/0.15)	<0,001*
UNVA (logMAR)	0.21 (±0.16) [0/0.76]	0.18 (0.1/0.3)	0.15 (±0.12) [0/0.76]	0.18 (0.1/0.18)	<0,05*
MRSE (D)	-0.2 (±0.58) [-1.75/1.5]	-0.25 (-0.5/0.12)	-0.3 (±0.67) [-2.5/3.5]	-0.25 (-0.69/0)	>0,05*
PREDICTABILITY (% eyes ±0.5D)	43 (72.9%)		109 (66.9%)		>0,05†

Note:

CDVA: Corrected distance visual acuity;
UNVA: Uncorrected near visual acuity
UDVA: Uncorrected distance visual acuity;
MRSE: Mean refractive Spherical equivalent;
D: diopters

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* Mann-Whitney test

† Chi-Square test

Table 2

Table 2. Laser refractive and visual data of Failed-Eyes and Successful-Eyes groups.

	FAILED EYES (N=59)		SUCESSFUL EYES (N=163)		
	Mean (SD) [RANGE]	**Median (Q25/Q75)**	**Mean (SD) [RANGE]**	**Median (Q25/Q75)**	**P-Value***
LASER REFRACTIVE DATA:					
SPHERE (D)	+0.71 (±3.12) [-7.75/6]	+1.5 (-1.19/+2.75)	-0.46 (±3.71) [-10.75/+6]	-0.75 (-3.0/+2.88)	<0,05
CYLINDER (D)	-0.9 (±0.78) [-3.75/0]	-0.75 (-1.25/-0.5)	-1.03 (±1.17) [-6.25/0]	-0.75 (-1.25/-0.25)	>0,05
MRSE (D)	+0.27 (±3.11) [-8/5.5]	+1.38 (-1.88/+2.25)	-0.97 (±3.66) [-12.5/+4.88]	-1.38 (-3.38/+2.38)	<0,05
HYPEROPIA (%)	38 (64%)		71 (43.5%)		<0,05†
MYOPIA (%)	21 (35,6%)		92 (56.4%)		
ALX (mm)	23.53 (±1.9) [20.22/29.13]	23.25 (22.25/24.4)	24.09 (±2.63) [0/31.41]	23.98 (22.96/25.16)	<0,01
PostLASER CDVA (LogMAR)	0.03 (±0.07) [-0.08/0.35]	0 (0/0.05)	0.03 (±0.06) [0/0.22]	0 (0/0.05)	>0,05*

Note:

MRSE: Mean refractive Spherical equivalent;
ALX: axial length; D: diopters.

* Mann-Whitney test

† Chi-Square test

Table 3

Table 3: Distribution of topographic corneal aberrations and kappa-angle among Failed-Eyes versus Successful-Eyes groups.

	FAILED EYES (N=59)		SUCESSFUL EYES (N=163)		
	Mean (SD) [RANGE]	Median (Q25/Q75)	Mean (SD) [RANGE]	Median (Q25/Q75)	P-Value*
RMS-HOA	+0.85 (±0.38) [0.3/2.21]	+0.8 (+0.59/+1.03)	+0.81 (±0.29) [+0.31/+1.87]	+0.76 (+0.58/+0.99)	>0,05
SA-Z40	+0.07 (±0.38) [-0.82/+0.65]	+0.14 (-0.17/+0.37)	+0.18 (±0.37) [-0.79/+0.87]	+0.32 (-0.06/+0.45)	<0,05
Z(3+1)	-0.03 (±0.36) [-1.34/+0.76]	-0.02 (-0.16/+0.12)	+0.01 (±0.32) [-0.92/+0.8]	+0.04 (-0.16/+0.2)	>0,05
Z(3-1)	-0.05 (±0.53) [-1.81/+0.75]	+0.04 (-0.19/+0.23)	+0.11 (±0.36) [-1.35/+1.35]	+0.12 (-0.08/+0.33)	>0,05
/Z31/	+0.46 (±0.37) [+0.03/+2.0]	+0.36 (0.2/+0.64)	+0.41 (±0.27) [0.01/+1.48]	+0.34 (+0.23/+0.54)	>0,05
Kappa angle	+0.23 (±0.12) [+0.01/+0.6]	+0.23 (+0.14/+0.3)	+0.23 (±0.13) [0/+0.82]	+0.22 (+0.14/+0.31)	>0,05

Topographic aberrations (μm) measured at 6mm optical zone:

RMS-HOA: Total root mean square high order aberrations,

SA-Z40: Spherical aberration

WFA Coma aberrations: Z (3+1) : horizontal coma, Z(3-1): Vertical coma; /Z31/: Pentacam^{TM} Vectorized coma

* Mann-Whitney test

Figure 1

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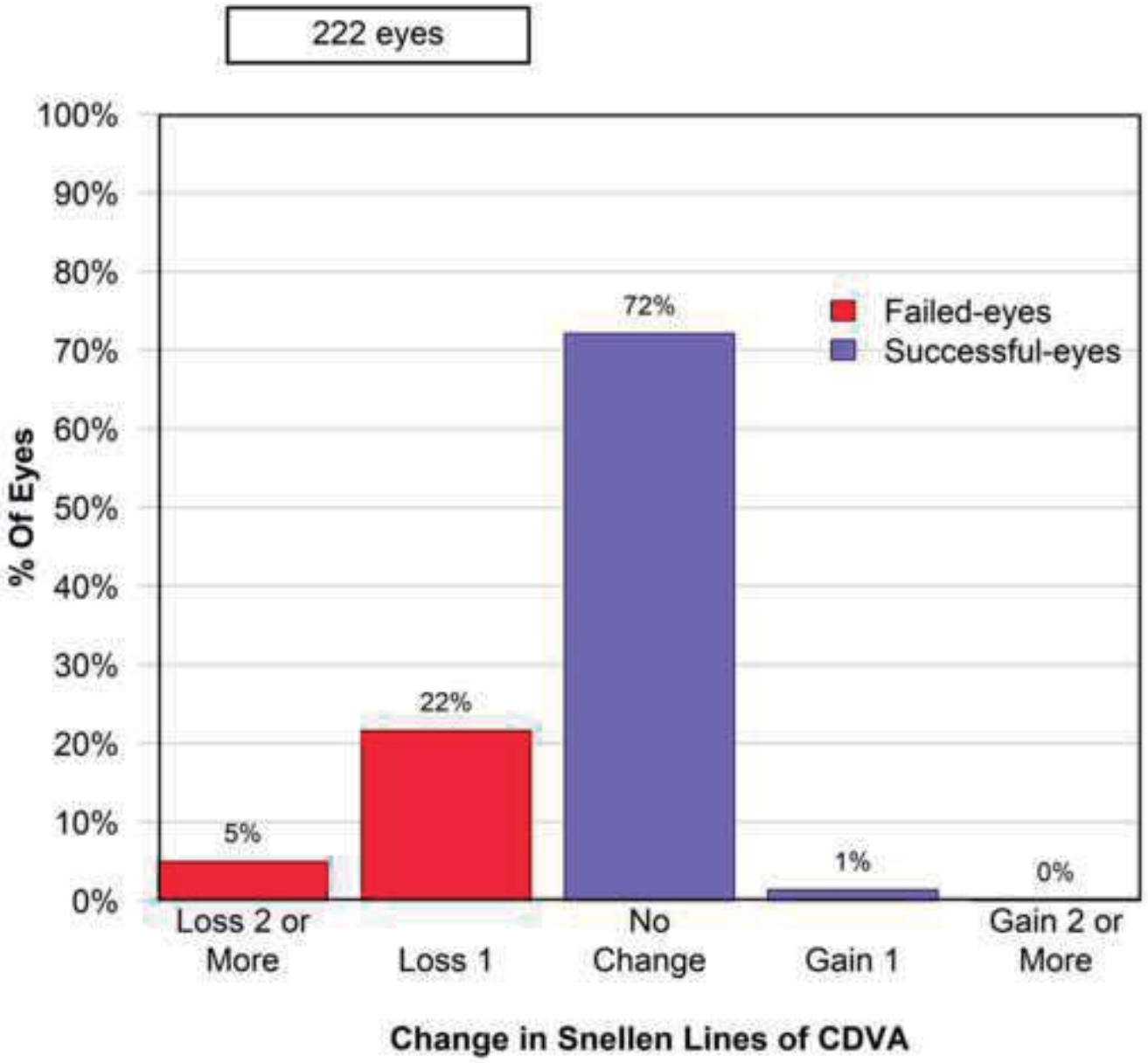

Figure 2

Click here to access/download;Figure;FIGURE 2 Aberrations -MTF POSTLASIK.jpg