FemtoLASIK After Descemet Membrane Endothelial Keratoplasty

Luis Fernández-Vega-Cueto, MD, PhD,* Carlos Lisa, MD, PhD,* Miguel Naveiras, MD, PhD,* David Madrid-Costa, PhD,† and José F. Alfonso, MD, PhD*

Purpose: To evaluate the efficacy and safety of femtosecond laser-assisted in situ keratomileusis (FemtoLASIK) to correct the residual refractive error after Descemet membrane endothelial keratoplasty (DMEK).

Methods: This case series study included 7 eyes that underwent FemtoLASIK after a DMEK surgery. The refractive error, uncorrected (UDVA) and corrected (CDVA) distance visual acuities, corneal topography (Sirius, CSO, Italy), and anterior segment optical coherence tomography (Visante, Carl Zeiss-Meditec AG, Jena, Germany) were registered at each postoperative follow-up visit.

Results: All surgeries were uneventful, with no intraoperative or postoperative complications. The follow-up time after DMEK (before FemtoLASIK surgery) ranged from 18 to 36 months. The post-FemtoLASIK follow-up period ranged from 12 to 60 months. All cases experienced a significant improvement in UDVA after FemtoLASIK, all of them reaching a postoperative UDVA value ≥20/32. None of the eyes lost lines of CDVA, and 1 case showed a gain of lines of CDVA. In all cases, the refractive error, UDVA, and CDVA values remained stable at their respective postoperative follow-up visits. Furthermore, all topographic and pachymetric parameters were stable at the different postoperative follow-up visits.

Conclusions: Our findings suggest that the residual refractive error after DMEK surgery can be safely and effectively treated with FemtoLASIK.

Key Words: FemtoLASIK, DMEK

(*Cornea* 2019;00:1–5)

Descemet membrane endothelial keratoplasty (DMEK) has been shown to provide better visual and refractive outcomes, faster recovery, and greater patient satisfaction than the previous surgical techniques for endothelial replacement.[1–9] Owing to all these findings, DMEK has gained popularity among surgeons, and every year, the number of DMEK procedures performed increases,[5] becoming currently the preferred option for endothelial keratoplasty.

DMEK can be carried out isolated or in combination with cataract surgery (sequential or simultaneous triple procedure). Despite several studies showing that DMEK does not induce significant refractive changes, it has been reported that a slightly hyperopic shift can be found after this procedure.[10–13] Furthermore, when a DMEK is carried out in combination with cataract surgery, corneal decompensation makes foreseeing the total corneal power after DMEK difficult. Consequently, intraocular lens (IOL) power calculation may be imprecise, which could lead to residual refractive error.[14–17]

Given the excellent clinical outcomes, long-term refractive stability, and outstanding patient satisfaction yielded by the DMEK technique,[1–20] a new challenge to address, as the Melles' research group proposed,[21] is whether corneal refractive surgery could be effectively and safely used to correct the residual refractive error. Recently, Arnalich et al[22] analyzed the pachymetric and topographic parameters of pseudophakic patients who underwent DMEK and concluded that "caution should be exerted in planning corneal refractive surgery for residual refractive correction."

In the current case series study, we present 7 selected patients who had undergone DMEK surgery and at least 18 months thereafter underwent femtosecond laser-assisted in situ keratomileusis (FemtoLASIK) surgery to correct the residual refractive error after an exhaustive preoperative exploration.

PATIENTS AND METHODS

This study is a case series analysis of patients who underwent FemtoLASIK after DMEK surgery at the Fernández-Vega Ophthalmological Institute in Oviedo, Spain. This study was conducted in compliance with the tenets of the Declaration of Helsinki, and full ethical approval from the institute was obtained. After receiving a full description of the nature of the study and possible consequences of surgery, all patients provided informed consent.

The indication for DMEK was Fuchs corneal dystrophy in every case. All cases underwent standard phacoemulsification cataract surgery with IOL implantation (AcrySof SN60WF IOL (Alcon Laboratories, Inc, Fort Worth, TX) 1 month before DMEK.

Received for publication July 5, 2019; revision received September 13, 2019; accepted September 17, 2019.
From the *Fernández-Vega Ophthalmological Institute, Oviedo, Spain; and †Optometry and Vision Department, Faculty of Optics and Optometry, Universidad Complutense de Madrid, Madrid, Spain.
The authors have no funding or conflicts of interest to disclose.
Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's Web site (www.corneajrnl.com).
Correspondence: José F. Alfonso, MD, PhD, Instituto Oftalmológico Fernández-Vega, Avda. Dres. Fernández-Vega 34, 33012 Oviedo, Spain (e-mail: j.alfonso@fernandez-vega.com).

DMEK grafts were prepared following the standardized protocol for the "no-touch" technique.[23] For DMEK surgery, a 9.0-mm epithelial mark was made to outline the area of the planned Descemet membrane (DM) excision, a main incision of 2.4 mm then performed. The anterior chamber was filled with air though the side port. After scoring the recipient endothelium with an inverted Sinskey hook, a circular portion of DM was stripped from the posterior stroma so that a 9.0-mm descemetorhexis was created. Iridectomy was performed in all cases. Using a Geuder crystal injector (Geuder AG, Heidelberg, Germany) filled with balanced saline solution, the DM rolls were inserted into the anterior chamber and then oriented endothelial side down using careful indirect manipulation of the tissue with air and balanced saline solution. An x-shaped 10/0 nylon suture was used to seal the main incision. An air bubble was used to extend the graft and then reinjected underneath to position the tissue onto the recipient posterior stroma. The anterior chamber was completely filled with air for 60 minutes, followed by air–liquid exchange to pressurize the eye. A final 60% air bubble was left in the eye overnight. Patients were placed on a regimen of 1% dexamethasone drops q.i.d, tapered down over a period of 6 months to fluorometholone b.i.d.

A complete ophthalmologic examination was performed on all patients after the DMEK procedure including best corrected distance visual acuity (CDVA), manifest and cycloplegic refractions, corneal topography (Sirius, CSO, Italy), anterior segment optical coherence tomography (Visante Zeiss-Meditec, Germany), endothelial cell density (ECD), ultrasonic pachymetry, slit-lamp microscopy, Goldmann applanation tonometry, and binocular indirect ophthalmoscopy.

The time between DMEK procedure and FemtoLASIK to correct the residual refractive error varied from 18 to 36 months. The option of LASIK with femtosecond laser surgery was agreed upon between the surgeon and the patient after full understanding the potential risks. Surgery was performed under topical anesthesia using the IntraLase femtosecond laser FS60 (Advanced Medical Optics, Inc, Santa Ana, CA) to create the flap and the VISX Star S4 (Advanced Medical Optics, Inc) excimer laser to perform corneal photoablation. Femtosecond laser flaps were programmed with the following settings: 90 μm thickness, 8.0 to 9.0 mm diameter, 45-degree superior hinge angle to achieve equivalent corneal stromal surface exposure, 70-degree side-cut angle, laser raster patterns spot and line separation of 9 and 9 μm, and stromal energy of 1.0 μJ with a side-cut energy of 1.8 μJ. A pocket was created with the femtosecond laser to avoid an opaque bubble layer. The excimer laser was programmed with the conventional VISX S4 algorithm to achieve emmetropia (software version 4.60). All surgeries were performed by 1 surgeon (J.F.A.). The postoperative treatment consisted of a regimen of 1% dexamethasone drops 4 times a day for 1 week and 2 times a day for the second week and then fluorometholone one time a day. The postoperative follow-up ranged between 12 and 60 months.

Manifest refraction, uncorrected distance visual acuity (UDVA), and CDVA were registered at each postoperative follow-up visit after the DMEK procedure and after the FemtoLASIK surgery. Furthermore, the following topographic and pachymetric parameters were reviewed:

Topographic parameters (Sirius; CSO, Scandicci, Italy): keratometry, symmetry index back, symmetry index front, and 4.5- and 8.0-mm-zone root mean square value per unit area for (RMS/A) the front and back.

Pachymetric parameters (optical coherence tomography [OCT], Visante Zeiss-Meditec, Germany): thinnest corneal thickness (TCT), distance from the TCT to the apex, and central corneal thickness (CCT).

Preoperative and postoperative data were compared using the Wilcoxon nonparametric test. Statistical analysis was performed using SPSS software for Windows (version 15.0, SPSS, Inc). *P* value less than 0.05 was considered statistically significant. Data are reported as the mean ± SD.

RESULTS

The study included 7 eyes of 6 patients with a mean age of 63.6 ± 10.4 (range 49–71) years. All surgeries (both DMEK procedures and FemtoLASIK surgeries) were uneventful, with no intraoperative or postoperative complications. No dislocation and/or detachment of the Descemet membrane graft was observed in any case. Table 1 shows patient demographics before FemtoLASIK surgery. The follow-up time after DMEK (before FemtoLASIK surgery) ranged from 18 to 36 months (Supplemental Table 1A shows topographic, pachymetric parameters, and manifest refraction, UDVA, and CDVA during the postoperative DMEK course for each case; Supplemental Digital Content 1, http://links.lww.com/ICO/A923). The UDVA, CDVA, and refractive error values as well as the topographic and pachymetric parameters analyzed remained stable over the postoperative DMEK follow-up period.

Table 2 shows the pre- and post-FemtoLASIK visual and refractive outcomes. The post-FemtoLASIK follow-up period ranged from 12 to 60 months. All cases experienced a significant improvement in UDVA, all of them reaching a postoperative UDVA value ≥20/32. None of the eyes lost lines of CDVA, and 1 case showed a gain of lines of CDVA.

TABLE 1. Patient Demographics Before FemtoLASIK Surgery (Means ± SD and Range)

Characteristic	Value
Eyes (n)	7
Age (yr) (range)	63.6 ± 10.4 (49 to 71)
Follow-up (mo)* (range)	22.3 ± 6.7 (18 to 36)
Spherical equivalent (range)	−0.55 ± 1.12 (+1.75 to −1.62)
Mean refractive sphere (D) (range)	+0.57 ± 1.59 (+3.75 to −1.00)
Mean refractive cylinder (D) (range)	−2.25 ± 0.93 (−1.25 to −4.00)
Mean minimum K (D) (range)	41.96 ± 1.32 (40.15 to 43.65)
Mean maximum K (D) (range)	43.83 ± 1.74 (41.25 to 45.25)
Central corneal thickness (μm)	534.6 ± 17.1 (510 to 554)
Thinnest corneal thickness (μm)	527.4 ± 19.4 (500 to 552)
ECD (cells/mm^2)	1477 ± 288 (1102 to 1802)

*The follow-up time after DMEK (before FemtoLASIK surgery).

TABLE 2. Visual and Refractive Results Before and After FemtoLASIK Surgery (Means ± Standard Deviation (SD) and Range)

Characteristic			Value
Follow-up (mo) (range)			23.1 ± 17.1 (12–60)
	Pre-FemtoLASIK	**Post-FemtoLASIK**	***P* Value**
UDVA (Snellen scale) (range)	0.34 ± 0.13 (0.1 to 0.5)	0.71 ± 0.12 (0.6 to 0.9)	<0.0001
CDVA (Snellen scale) (range)	0.74 ± 0.16 (0.4 to 0.9)	0.80 ± 0.05 (0.6 to 0.9)	0.1
Mean spherical equivalent (D) (range)	−0.55 ± 1.12 (+1.75 to −1.62)	−0.29 ± 0.29 (0 to −0.62)	0.2
Mean refractive sphere (D) (range)	+0.57 ± 1.59 (+3.75 to −1.00)	−0.04 ± 0.17 (+0.25 to −0.25)	0.09
Mean refractive cylinder (D) (range)	−2.25 ± 0.93 (−1.25 to −4.00)	−0.50 ± 0.43 (0 to −1.25)	0.0002

In all cases, the refractive error, UDVA, and CDVA values remained stable at their respective postoperative follow-up visits (Supplemental Table 2A shows visual and refractive outcomes during the postoperative FemtoLASIK course for each case; see Supplemental Digital Content 1, http://links.lww.com/ICO/A923). Furthermore, all topographic and pachymetric parameters were stable at different postoperative follow-up visits (Supplemental Table 3A shows topographic and pachymetric parameters during the postoperative FemtoLASIK course for each case; see Supplemental Digital Content 1, http://links.lww.com/ICO/A923).

DISCUSSION

DMEK is gaining popularity among surgeons for endothelial keratoplasty because it only involves transplanting an endothelium–Descemet membrane layer that allows a faster and better visual recovery with a significantly lower rate of complications compared with other techniques for endothelial keratoplasty.[1–9] DMEK has provided stable visual and refractive outcomes at long-term follow-up.[18–20] The speed and degree of visual recovery after DMEK depends on when the surgery is performed.[24,25] Recent studies, which analyzed preoperative visual acuity[24] and corneal densitometry[25] as predictors of postoperative visual acuity, found that early DMEK surgery could have a positive impact on long-term visual acuity results. Although DMEK has been considered as a "refractive neutral procedure," a slight hyperopic shift after DMEK is strongly documented. The mean refractive change after DMEK may be considered subtle (approximately 0.3 D of hyperopic shift[11]); however, a larger myopic and hyperopic shift in some cases has also been reported.[11–13] Van Dijk et al[11,13] found that DMEK induced a refractive change larger than 1D (both myopic and hyperopic) in approximately 20%[11] and 35%[13] of the eyes analyzed. When DMEK is performed in combination with cataract surgery, the IOL power calculation presents a challenge. A widely accepted approach is to select the IOL power with a refractive target of −0.50 and up to −1.00 to compensate the expected hyperopic shift induced after DMEK. However, refractive surprises in a significant number of cases after the triple-DMEK procedure have been reported (even choosing a postrefractive target of −0.50 to −1.00 D). In the study by Laaser et al,[14] 30% of the eyes were outside 1.00 D of emmetropia and 12.5% were outside 2.00 D of emmetropia after the triple-DMEK procedure. Schoenberg et al[15] reported a refractive error greater than ±1.00 D in 50% of the eyes. Cheung et al,[16] in turn, reported that the postoperative refraction was greater than +1.25 D of the target refractive goal in 31% of the eyes analyzed. All these outcomes are in line with the results more recently obtained by Fritz et al,[17] who reported that approximately 20% of the eyes were off the planned refractive target by more than 1.00 D. At the same time, Ham et al[10] found that 32% of the eyes analyzed (16/50) experienced a change in astigmatism higher than 1.00 D (ranged from 1.25 to 2.50 D) after isolated DMEK. Laaser et al[14] reported, in 61 eyes which underwent the triple-DMEK procedure, an increase in the mean refractive cylinder from preoperative to 6 months postoperative.

From all these previous studies, it could be concluded that on average, the postoperative refractive error after isolated DMEK or triple-DMEK may be relatively small. Nevertheless, wide variations in the refractive shift between patients have been reported. Therefore, there will be a greater than expected proportion of patients with a residual refractive error after surgery. Although the first and main objective of DMEK is to improve corneal clarity, some residual refractive error may not be well tolerated with spectacles, could induce anisometropia, and/or achieve an unsatisfactory postoperative UDVA. Consequently, in those cases, the DMEK outcomes may be not as successful as would be expected.

To overcome this, in the current study, we present 7 eyes that underwent FemtoLASIK surgery to correct residual refractive error after a DMEK procedure. In the current study, the interval time between surgeries (DMEK procedure and FemtoLASIK) was at least 18 months. Previous studies have shown that postoperative refraction stabilization after DMEK occurred at 3 months postoperatively.[10,11,13] However, a longer follow-up period between surgeries was established because, beyond refractive stabilization, we wanted to verify that all the topographic and pachymetric parameters remained stable before FemtoLASIK surgery. In our case series, UDVA significantly improved in all eyes, all of them reaching a postoperative UDVA value ≥20/32. None of the eyes lost lines of CDVA, and case 6 showed a gain of lines of CDVA. In all eyes, the refractive error, UDVA, CDVA values and topographic and pachymetric parameters remained stable at their respective postoperative follow-up visits (ranged from 12 to 60 months). To the best of our knowledge, this is the first reported series of FemtoLASIK surgery after a DMEK surgery. A case series studied the use of LASIK and PRK in 5 patients with previous Descemet stripping

automated endothelial keratoplasty, achieving a significant improvement in UDVA without any complications.[26]

Despite these encouraging outcomes, it is important to be cautious because corneas can be abnormally thin after DMEK,[22] which could represent a risk to develop post-LASIK ectasia. Therefore, these patients must be closely monitored before planning any laser refractive procedure. In our case series, the pachymetric parameters studied (CCT, TCT, and distance from the TCT to the CCT) were within a normal range compared with healthy corneas.[27,28] Furthermore, all these parameters remained stable over the follow-up period between surgeries. Regarding topographic parameters, in cases 1 and 6 (see Supplemental Table 1A, Supplement Digital Content 1, http://links.lww.com/ICO/A923), corneal shape indices after the DMEK procedure were high. It should be noted that corneal higher-order aberrations could be increased after DMEK[29,30]; consequently, these topographic indices could be altered in comparison with normal corneas without necessarily presenting a risk or diagnosis of an ectatic disease. In both cases, over the follow-up period between DMEK and FemtoLASIK surgeries, all these corneal shape indices remained unchanged and the pachymetric parameters were maintained within a normal range and unchanged. In any case, it would also be interesting to carry out further studies to analyze the effect of Fuchs dystrophy resolution through DMEK on the corneal biomechanical properties.

In the current study, no complications occurred during FemtoLASIK surgery or over the entire follow-up time (ranged from 12 to 60 months) (including flap-related complications, graft failure, refractive instability, and corneal ectasia). If compared with a microkeratome, the use of femtosecond laser to create the flap has the advantage of creating more predictable and uniform flap thickness and stromal bed and less intraoperative epithelial injury.[31,32] Furthermore, it has been reported that FemtoLASIK surgery does not provide significant changes in the ECD.[33] The endothelial cell count in this case series remained stable over the post-FemtoLASIK surgery follow-up. It should be noted that a rare complication secondary to LASIK is interface fluid syndrome, which is characterized by fluid collection in the flap interface. It has been reported that endothelial decompensation and steroid-induced ocular hypertension are etiological factors. Therefore, it should be considered that in case of graft failure or rejection, these patients could have a certain risk of developing interface fluid syndrome.

Although there were no complications in any case, further long-term prospective studies, including more patients, should be performed to assess possible complications and the stability of the procedure.

In conclusion, our findings suggest that the residual refractive error after DMEK can be safely and effectively treated with FemtoLASIK. Further long-term follow-up studies, including a larger number of cases, are needed to properly analyze the stability of this surgery and to confirm the safety of the procedure.

REFERENCES

1. Melles GR, Ong TS, Ververs B, et al. Descemet membrane endothelial keratoplasty (DMEK). *Cornea*. 2006;25:987–990.
2. Dapena I, Ham L, Melles GR. Endothelial keratoplasty: DSEK/DSAEK or DMEK the thinner the better? *Curr Opin Ophthalmol.* 2009;20: 299–307.
3. Tourtas T, Laaser K, Bachmann BO, et al. Descemet membrane endothelial keratoplasty versus descemet stripping automated endothelial keratoplasty. *Am J Ophthalmol.* 2012;153:1082–1090.e2.
4. Heinzelmann S, Böhringer D, Eberwein P, et al. Outcomes of Descemet membrane endothelial keratoplasty, Descemet stripping automated endothelial keratoplasty and penetrating keratoplasty from a single centre study. *Graefes Arch Clin Exp Ophthalmol.* 2016;254:515–522.
5. Park CY, Lee JK, Gore PK, et al. Keratoplasty in the United States: a 10-year review from 2005 through 2014. *Ophthalmology*. 2015;122: 2432–2442.
6. Hamzaoglu EC, Straiko MD, Mayko ZM, et al. The first 100 eyes of standardized Descemet stripping automated endothelial keratoplasty versus standardized Descemet membrane endothelial keratoplasty. *Ophthalmology*. 2015;122:2193–2199.
7. Pavlovic I, Shajari M, Herrmann E, et al. Meta-analysis of postoperative outcome parameters comparing Descemet membrane endothelial keratoplasty versus Descemet stripping automated endothelial keratoplasty. *Cornea*. 2017;36:1445–1451.
8. Anshu A, Price MO, Price FW Jr. Risk of corneal transplant rejection significantly reduced with Descemet's membrane endothelial keratoplasty. *Ophthalmology*. 2012;119:536–540.
9. Guerra FP, Anshu A, Price MO, et al. Endothelial keratoplasty: fellow eyes comparison of Descemet stripping automated endothelial keratoplasty and Descemet membrane endothelial keratoplasty. *Cornea*. 2011; 30:1382–1386.
10. Ham L, Dapena I, Moutsouris K, et al. Refractive change and stability after Descemet membrane endothelial keratoplasty. Effect of corneal dehydration-induced hyperopic shift on intraocular lens power calculation. *J Cataract Refract Surg.* 2011;37:1455–1464.
11. van Dijk K, Rodriguez-Calvo-de-Mora M, van Esch H, et al. Two-year refractive outcomes after Descemet membrane endothelial keratoplasty. *Cornea*. 2016; 35: 1548–1555.
12. Alnawaiseh M, Rosentreter A, Eter N, et al. Changes in corneal refractive power for patients with Fuchs endothelial dystrophy after DMEK. *Cornea*. 2016;35:1073–1077.
13. van Dijk K, Ham L, Tse WH, et al. Near complete visual recovery and refractive stability in modern corneal transplantation: Descemet membrane endothelial keratoplasty (DMEK). *Cont Lens Anterior Eye*. 2013; 36:13–21.
14. Laaser K, Bachmann BO, Horn FK, et al. Descemet membrane endothelial keratoplasty combined with phacoemulsification and intraocular lens implantation: advanced triple procedure. *Am J Ophthalmol.* 2012;154:47–55.e2.
15. Schoenberg ED, Price FW Jr, Miller J, et al. Refractive outcomes of Descemet membrane endothelial keratoplasty triple procedures (combined with cataract surgery). *J Cataract Refract Surg*. 2015;41: 1182–1189.
16. Cheung AY, Chachare DY, Eslani M, et al. Tomographic changes in eyes with hyperopic shift after triple Descemet membrane endothelial keratoplasty. *J Cataract Refract Surg.* 2018;44:738–744.
17. Fritz M, Grewing V, Böhringer D, et al. Avoiding hyperopic surprises after Descemet membrane endothelial keratoplasty in Fuchs dystrophy eyes by assessing corneal shape. *Am J Ophthalmol.* 2019;197:1–6.
18. Baydoun L, Müller T, Lavy I, et al. Ten-year clinical outcome of the first patient undergoing Descemet membrane endothelial keratoplasty. *Cornea*. 2017;36:379–381.
19. Schlögl A, Tourtas T, Kruse FE, et al. Long-term clinical outcome after Descemet membrane endothelial keratoplasty. *Am J Ophthalmol.* 2016; 169:218–226.
20. Ham L, Dapena I, Liarakos VS, et al. Midterm results of Descemet membrane endothelial keratoplasty: 4 to 7 years clinical outcome. *Am J Ophthalmol.* 2016;171:113–121.
21. Tong CM, Baydoun L, Melles GRJ. Descemet membrane endothelial keratoplasty and refractive surgery. *Curr Opin Ophthalmol.* 2017;28: 316–325.
22. Arnalich-Montiel F, Mingo-Botín D, Diaz-Montealegre A. Keratometric, pachymetric, and surface elevation characterization of corneas with Fuchs endothelial corneal dystrophy treated with DMEK. *Cornea*. 2019; 38:535–541.

23. Dapena I, Moutsouris K, Droutsas K, et al. Standardized "no-touch" technique for descemet membrane endothelial keratoplasty. *Arch Ophthalmol.* 2011;129:88–94.
24. Schrittenlocher S, Bachmann B, Tiurbe AM, et al. Impact of preoperative visual acuity on Descemet Membrane Endothelial Keratoplasty (DMEK) outcome. *Graefes Arch Clin Exp Ophthalmol.* 2019;257:321–329.
25. Schaub F, Gerber F, Adler W, et al. Corneal densitometry as a predictive diagnostic tool for visual acuity results after descemet membrane endothelial keratoplasty. *Am J Ophthalmol.* 2019;198:124–129.
26. Ratanasit A, Gorovoy M. Laser-assisted in situ keratomeileusis or photorefractive keratectomy after descemet stripping automated endothelial keratoplasy. *Cornea*. 2011;30:787–789.
27. Keech A, Simpson T, Jones L. Repeatability of pachymetry and thinnest point localization using a fourier-domain optical coherence tomographer. *Optom Vis Sci.* 2010;87:736–741.
28. Linke SJ, Ceyrowski T, Steinberg J, et al. Central versus thinnest pachymetry of the cornea and thinnest point vector length: impact of ocular side, refractive state, age, and sex. *Cornea*. 2013;32: e127–e135.
29. Hayashi T, Yamaguchi T, Yuda K, et al. Topographic characteristics after Descemet's membrane endothelial keratoplasty and Descemet's stripping automated endothelial keratoplasty. *PLoS One*. 2017;30:e0188832.
30. Rudolph M, Laaser K, Bachmann BO, et al. Corneal higher-order aberrations after Descemet's membrane endothelial keratoplasty. *Ophthalmology*. 2012;119:528–535.
31. Kezirian GM, Stonecipher KG. Comparison of the IntraLase femtosecond laser and mechanical keratomes for laser in situ keratomileusis. *J Cataract Refract Surg.* 2004;30:804–811.
32. Alfonso JF, Fernández-Vega L, Montés-Micó R, et al. Femtosecond laser for residual refractive error correction after refractive lens exchange with multifocal intraocular lens implantation. *Am J Ophthalmol.* 2008;146:244–250.
33. Muñoz G, Albarrán-Diego C, Sakla HF, et al. Effects of LASIK on corneal endothelium using the 15-kHz IntraLase femtosecond laser. *J Refract Surg.* 2011;27:672–677.