Avoiding Hyperopic Surprises After Descemet Membrane Endothelial Keratoplasty in Fuchs Dystrophy Eyes by Assessing Corneal Shape

MARIANNE FRITZ, VIVIANE GREWING, DANIEL BÖHRINGER, THABO LAPP, PHILIP MAIER, THOMAS REINHARD, AND KATRIN WACKER

• PURPOSE: It is unclear which patients unexpectedly have a hyperopic refractive outcome after combined Descemet membrane endothelial keratoplasty and cataract surgery (triple DMEK). We assessed how corneal shape predicts hyperopia after triple DMEK.
• DESIGN: Retrospective cohort study.
• METHODS: Patients with Fuchs endothelial corneal dystrophy (FECD) with Scheimpflug examinations before uncomplicated triple DMEK at a tertiary referral center were included. The arithmetic error was calculated (stable postoperative refraction minus predicted refraction). Using multinomial logistic regression, risk ratios of $>+0.5$ diopter (D) hyperopic and >0.5 D myopic arithmetic errors were calculated.
• RESULTS: In 112 eyes, the median predicted refraction was −0.43 D (interquartile range [IQR], −0.47 to −0.17) with an achieved refraction of −0.63 to 0.56 (IQR). The arithmetic error was 0.34 D (IQR, −0.22 to 0.81). A hyperopic arithmetic error was present in 46% of eyes. FECD eyes with an oblate posterior cornea (Q value >0) had a 3.0 times higher risk of hyperopic shift after triple DMEK (95% confidence interval [CI], 1.3–7.0; $P = .011$), compared to spherical or prolate corneas (Q value ≤ 0). In eyes with posterior Q $>$ 0, the mean prediction error was +0.50 D higher than in eyes with negative Q values (95% CI, 0.19–0.82; $P = .002$), independent of corneal thickness.
• CONCLUSIONS: Hyperopic surprises after triple DMEK particularly occur in corneas that are flatter centrally than the periphery because of edematous changes (oblate posterior profile). Eyes with a positive Q value on Scheimpflug imaging should be considered for additional power at the intraocular lens level. (Am J Ophthalmol 2019;197:1–6. © 2018 Elsevier Inc. All rights reserved.)

PATIENTS WITH FUCHS ENDOTHELIAL CORNEAL DYSTROPHY (FECD) gain faster and more complete visual rehabilitation after Descemet membrane endothelial keratoplasty (DMEK) compared to full-thickness penetrating keratoplasty (PK).[1–3] Beyond mere corneal clarity and graft survival, optimizing refractive outcomes is becoming more relevant for patients.[4]

After combined DMEK and cataract surgery (triple DMEK), a hyperopic shift has commonly been reported. Refractive outcomes deviate significantly from the planned refraction.[5–7] Anticipating a hyperopic shift, many surgeons target for extra myopia in FECD eyes undergoing triple DMEK than they normally would in healthy corneas undergoing cataract surgery alone.[6,8–10] It is unclear how much of a hyperopic shift needs to be anticipated and, more importantly, which subgroup of patients becomes more hyperopic than expected.

The reasons for hyperopic shifts may lie in the posterior corneal profile. Because of progressive edematous changes over the course of disease, the posterior profile becomes flatter and more spherical, and it bulges toward the anterior chamber compared to its generally very stable ellipsoid shape (Figure).[11–13] Ham and associates describe this process as a myopic shift, which is reversed by triple DMEK.[14] Because of the stable anterior corneal profile,[6,14] it has generally been suggested to base the intraocular lens (IOL) power calculation not only on the anterior corneal curvature but also on the posterior profile. However, risk factors of postoperative hyperopia are unknown.[15]

We hypothesized that preoperative assessment of the corneal profile may guide refractive planning by identifying patients at risk of hyperopia. We therefore examined preoperative Scheimpflug metrics of corneal profile and their association with refractive deviation or arithmetic error after triple DMEK.

METHODS

• **PARTICIPANTS AND STUDY DESIGN:** In this retrospective cohort study, consecutive FECD patients who underwent uncomplicated triple DMEK between January 2011 to December 2017 at a tertiary referral center were included. Four surgeons performed all triple DMEK, as described previously.[2] The study was approved by the institutional review board of the medical center (University of Freiburg, Freiburg, Germany) and adhered to the tenets of the Declaration of Helsinki.

Accepted for publication Aug 30, 2018.
From the Eye Center, University Medical Center Freiburg, Freiburg, Germany.
Inquiries to Katrin Wacker, University Medical Center Freiburg, Killianstr. 5, 79106 Freiburg im Breisgau, Germany; e-mail: katrin.wacker@uniklinik-freiburg.de

0002-9394/$36.00
https://doi.org/10.1016/j.ajo.2018.08.052

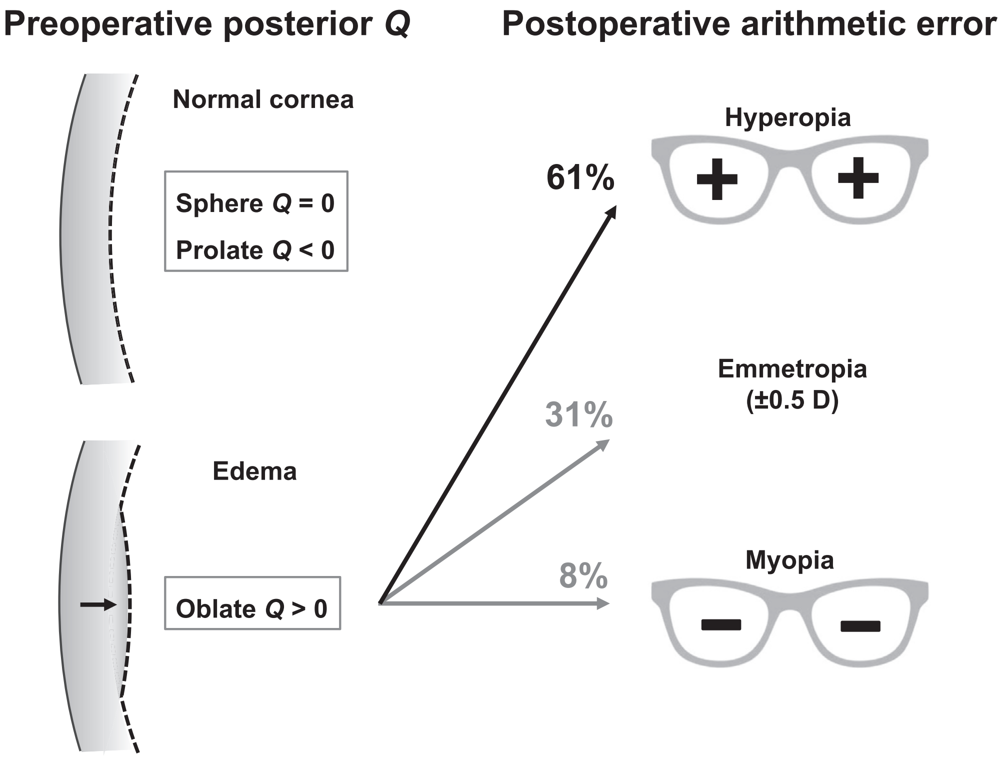

FIGURE. Avoiding hyperopic surprises after Descemet membrane endothelial keratoplasty in Fuchs dystrophy eyes by assessing preoperative posterior Q. The preoperative Q value is as a measure of the surface profile and eccentricity that may be positive (oblate cornea), negative (prolate cornea), or zero (spheric). Normally, the corneal surface is slightly steeper in the center than in the periphery (prolate, slightly negative Q value). In the presence of edema, the cornea can be flatter centrally than in the periphery (oblate, positive Q). Fuchs endothelial corneal dystrophy patients with a posterior Q $>$ 0 had a 3.0-fold higher risk to become hyperopic (95% confidence interval, 1.3–7.0) compared to eyes with negative posterior Q (P = .011).

Patients with a minimum follow-up of 3 months, stable postoperative refraction, intraocular lens calculation with optical biometry (IOL-Master 500, IOL-Master 700; Carl Zeiss Meditec AG, Jena, Germany), and Scheimpflug imaging prior to surgery were included. Patients with previous ocular surgery, intraoperative or postoperative complications, or comorbidities that may affect visual acuity, precision of biometry, refraction, or Scheimpflug imaging were not included.

• **PREOPERATIVE ASSESSMENT:** Patient demographics, comorbidities, visual acuity, and refraction were abstracted from medical electronic records. Planned refraction based on the implanted IOL was derived from recorded biometry data using the Haigis and SRK/T formulas.[16,17] The arithmetic error between the achieved and the predicted spherical equivalent was calculated. Preoperative corneal tomographic raw data were extracted from the Scheimpflug camera (Pentacam HR; Oculus, Wetzlar, Germany; software version 1.20r118). Predefined parameters were (1) Q values, (2) radius of corneal curvature, and (3) central corneal thickness. Q value is defined as a measure of surface profile and eccentricity that may be positive (oblate cornea), negative (prolate cornea), or zero (spheric cornea). Normally, the corneal surface is slightly steeper in the center than in the periphery (prolate, with a slightly negative Q value). In ectatic diseases such as keratoconus, the cornea can be more prolate. If edema is present, the cornea tends to be flatter centrally than in the periphery (oblate, positive Q) (Figure).[18]

• **STATISTICAL ANALYSIS:** We reported unadjusted summary statistics with median (interquartile range [IQR]) or count and percentages (Table 1). For hypothesis testing, the predefined Scheimpflug characteristics served as measures of preoperative FECD severity.[11,19] The outcome was the arithmetic error, categorized in 3 groups as $> +0.5$ diopter (D) hyperopia, > 0.5 D myopia, and emmetropia (± 0.5 D). To estimate the risk of postoperative hyperopic and myopic shift, compared to emmetropia, risk ratios were calculated using multinomial regression models. First, the arithmetic error in eyes with a normal prolate posterior corneal shape ($Q < 0$) was compared to eyes with an abnormal oblate cornea ($Q > 0$) as a measure of edematous changes. Second, to determine a dose-response relationship between preoperative metrics and postoperative refractive outcome, eyes were separated in quartiles based on preoperative posterior Q.

TABLE 1. Patient Characteristics After Combined Descemet Membrane Endothelial Keratoplasty and Cataract Surgery for Fuchs Endothelial Corneal Dystrophy, by Arithmetic Error (Postoperative Minus Predicted Refractive Error)

	Postoperative Arithmetic Error After Triple DMEK		
	Hyperopic >+0.5 D	Emmetropia −0.5 D to +0.5 D	Myopic >0.5 D
Demographics			
Eyes, n (%)	52 (46)	42 (38)	18 (16)
Age at surgery [years]	70 (60 to 76)	70 (63 to 76)	69 (64 to 77)
Women, n (%)	27 (54)	20 (56)	7 (47)
Optical biometry			
Axial length [mm]	23.7 (22.9 to 24.7)	23.6 (23.0 to 24.5)	23.2 (22.5 to 25.1)
Corneal cylinder [D]	1.32 (0.85 to 1.81)	1.28 (0.72 to 1.70)	1.26 (0.83 to 1.56)
Intraocular lens power [D]	21.0 (17.3 to 23.0)	21.0 (19.0 to 22.5)	21.3 (18.5 to 23.5)
Predicted refractive error [D]	−0.36 (−0.50 to −0.19) (mean ± SD, −0.54 ± 0.68)	−0.29 (−0.44 to −0.21) (mean ± SD, −0.38 ± 0.39)	−0.18 (−0.31 to −0.13) (mean ± SD, −0.20 ± 0.87)
Preoperative tomography			
Anterior corneal cylinder [D]	1.10 (0.80 to 1.90)	0.80 (0.50 to 1.40)	1.05 (0.75 to 1.45)
Anterior *Q* value	−0.30 (−0.41 to −0.23)	−0.35 (−0.42 to −0.27)	−0.35 (−0.43 to −0.27)
Posterior corneal cylinder [D]	0.30 (0.20 to 0.40)	0.30 (0.20 to 0.40)	0.30 (0.20 to 0.45)
Posterior *Q* value	0.33 (−0.22 to 0.58)	−0.13 (−0.33 to 0.21)	−0.38 (−0.52 to 0.04)
Thinnest corneal thickness [μm]	606 (582 to 627)	584 (556 to 615)	618 (590 to 653)
Postoperative stable refractive outcome			
Follow-up [months]	11 (7 to 14)	10 (6 to 13)	9 (6 to 13)
Postoperative refraction [D]	0.63 (0.25 to 1.00)	−0.38 (−0.63 to −0.13)	−1.06 (−1.50 to −0.88)
Arithmetic error, postoperative – predicted refractive error [D]	0.84 (0.62 to 1.19) (mean ± SD, 1.04 ± 0.60)	0.08 (−0.17 to 0.22) (mean ± SD, 0.03 ± 0.27)	−0.77 (−0.98 to −0.67) (mean ± SD, −0.95 ± 0.54)
Absolute error [D]	0.84 (0.62 to 1.19) (mean ± SD, 1.04 ± 0.60)	0.21 (0.12 to 0.33) (mean ± SD, 0.23 ± 0.14)	0.77 (0.67 to 0.98) (mean ± SD, 0.95 ± 0.54)
Absolute error [D], n (%)			
<0.5	–	42 (100)	–
0.5 to 1.0	33 (63)	–	14 (78)
>1.0 to 2.0	14 (27)	–	3 (17)
>2.0	5 (10)	–	1 (6)

D = Diopter; DMEK = Descemet membrane endothelial keratoplasty.
Data represent median (interquartile range) unless otherwise indicated.

The association of arithmetic error (continuous) and Scheimpflug variables (continuous) was assessed in linear regression models. Accounting for correlations between fellow eyes using mixed linear regression models or age did not significantly alter estimates. Mean differences in arithmetic error between groups with respective 95% confidence interval (CI) were calculated using linear regression. Differences were considered statistically significant if $P < .05$ in 2-sided tests. All statistical analyses were conducted using Stata 15.1 (StataCorp, College Station, Texas, USA).

RESULTS

• **PARTICIPANTS AND SURGERY:** One hundred and twelve eyes from 101 patients with FECD undergoing triple DMEK met inclusion criteria (47 male and 54 female). Age at the time of surgery ranged from 40 to 90 years. Three eyes required intraoperative corneal abrasion owing to epithelial edema. Quality of biometry and preoperative refraction in these 3 eyes was comparable. Three aspherical and 1 spherical IOL types were used: CT Asphina (n = 66, 59%; Carl Zeiss Meditec, Jena, Germany), SA60WF (n = 37, 33%), SN60WF (n = 1, 1%), and SA60AT (n = 8, 7%; all: Alcon Pharma, Fort Worth, Texas, USA). Based on the IOL power determined by optical biometry, surgeons targeted for slight myopia with a median planned refractive error of −0.43 D (IQR, −0.47 to −0.17) (Table 1). The planned refraction followed individual preferences, mostly emmetropia or mild myopia (range, −3.45 to 0.10 D). In 1 additional case, a patient preferred to be hyperopic because of mild disease in the hyperopic fellow eye (planned refraction, 2.69 D).

TABLE 2. Risks of >0.5 D Unexpected Hyperopia (Arithmetic Error) After Combined Descemet Membrane Endothelial Keratoplasty and Cataract Surgery for Fuchs Endothelial Corneal Dystrophy

Posterior *Q*	1st Quartile (Low)	2nd Quartile	3rd Quartile	4th Quartile (High)	*P* Trend[a]
Arithmetic error > +0.5 D, n (%)	6 (21)	10 (34)	16 (59)	20 (71)	
Median of *Q* (range)	−0.5 (−1.2 to −0.3)	−0.2 (−0.3 to 0.0)	0.3 (0.1 to 0.4)	0.7 (0.4 to 1.6)	
RR for hyperopia (95% CI)[b]	1.0 (Reference)	1.4 (0.4 to 5.1)	3.2 (0.9 to 11.3)	6.7 (1.7 to 25.4)	<.001
RR for hyperopia (95% CI), adjusted for corneal thickness and radius of curvature[c]	1.0 (Reference)	1.0 (0.3 to 4.1)	3.0 (0.7 to 12.3)	7.7 (1.2 to 50.6)	.001

D = diopter; RR = risk ratio.
[a]*P* trend indicates a test for a linear increase in risk of postoperative hyperopic arithmetic error with increase in posterior *Q* (higher quartiles).
[b]RR of hyperopic arithmetic error by quartile of posterior *Q*.
[c]RR adjusted for corneal thickness and posterior radius of curvature.

• **REFRACTIVE OUTCOME AND ARITHMETIC ERROR:** At a median follow-up of 10 months (IQR, 7-13 months) after triple DMEK, median stable postoperative refraction was −0.06 D (IQR, −0.63 to 0.56 D). Median arithmetic error (postoperative minus predicted refractive error) was in the hyperopic direction with 0.38 D (IQR, −0.22 to 0.81 D). Forty-two eyes (38%; 95% CI, 29%–47%) were in the emmetropic group (within ±0.5 D). More than 46% of eyes (95% CI, 37%–56%; n = 52) had a hyperopic arithmetic error of > +0.50 D with a median arithmetic error of 0.84 D (range, 0.51–3.19 D). A hyperopic arithmetic error of > +1.00 D was present in 17% of eyes (95% CI, 11%–25%; n = 19). Myopic errors of > 0.5 D were less common (16%; 95% CI, 10%–23%, n = 18). The magnitude of myopic arithmetic errors was less pronounced (range, −0.56 to −2.87 D, median −0.77 D). Among all eyes, 79% of eyes (95% CI, 71%–86%, n = 89) had an arithmetic error of < ±1.0 D. Risk factors of preoperative hyperopia, such as shorter axial length or flatter anterior corneal surface, were not different between groups (Table 1).

• **ASSOCIATION OF CORNEAL PROFILE AND HYPEROPIA:** In eyes with a positive posterior *Q* value, the arithmetic error was hyperopic in 61% of eyes (95% CI, 48%–72%; n = 36), within ±0.5 D in 31% of eyes (95% CI, 20%–43%; n = 18), and myopic in 8% (95% CI, 4%–18%; n = 5) of eyes (Figure). In comparison, of eyes with a negative posterior *Q* value (prolate cornea), 30% were hyperopic (95% CI, 20%–44%; n = 16), 45% within ±0.5 D (95% CI, 33%–59%; n = 24), and 24% myopic (95% CI, 15%–38%; n = 13). Eyes with a positive posterior *Q* (oblate cornea) had a 3.0-fold higher risk to become hyperopic (95% CI, 1.3–7.0; *P* = .011) compared to eyes with negative posterior *Q*. Eyes with a positive posterior *Q* had a 0.50 D higher arithmetic error (95% CI, 0.19–0.82; *P* = .002) after surgery compared to eyes with negative *Q* values.

The dose-response relationship between preoperative posterior *Q* and arithmetic error is shown in Table 2. FECD eyes in the highest quartile of posterior *Q* (range, 0.4–1.6), representing abnormally oblate corneas, had a 6.7-fold higher risk of hyperopia (95% CI, 1.7–25.4; *P* = .005) compared to the lowest quartile of posterior *Q* (normal, prolate cornea; range, −1.2 to −0.3) (Table 2).

We additionally analyzed how much unintended hyperopia could be avoided if eyes with an oblate cornea (positive posterior *Q* value) would have had a more myopic planned refraction. With a +0.5 D more myopic planned refraction for oblate corneas, only 17% of eyes (95% CI, 11%–25%, n = 19) would have had a hyperopic arithmetic error of > +0.50 D, and the median arithmetic error would have been −0.16 D (95% CI, −0.31 to 0.0). More importantly, only 6% of eyes (95% CI, 3%–12%, n = 7) would have had an arithmetic error of > +1 D.

We verified whether corneal shape (*Q* value) or simply posterior corneal radius of curvature or corneal thickness predicted hyperopic shift. In a univariable analysis, a 1-mm increase in preoperative posterior mean radius of curvature, indicating a flattening of the posterior surface, was associated with a 0.3 D increase in arithmetic error (95% CI, 0.0–0.6 D; *P* = .025). Adjusting for posterior *Q*, the association between radius of curvature and arithmetic error was no longer significant (difference, −0.1 D, 95% CI, −0.4–0.3 D; *P* = .60). Additionally, preoperative corneal thickness could be responsible for the arithmetic error after DMEK. In univariable models, the thicker or thinner the cornea, the higher the risk of postoperative myopic or hyperopic shift. However, adjusting for posterior *Q*, corneal thickness was no longer associated with arithmetic error. The association of posterior *Q* and arithmetic error remained significant when adjusting for thickness or radius of curvature (0.49 D higher arithmetic error in eyes with positive *Q* compared to eyes with negative *Q*, 95% CI, 0.08–0.90 D; *P* = .018) (Table 2). At the anterior corneal surface, postoperative arithmetic errors and preoperative anterior *Q* or anterior keratometry were not associated with arithmetic error (data not shown).

DISCUSSION

IN THIS STUDY, WE IDENTIFIED THE Q VALUE FROM THE POSterior cornea as a simple preoperative metric that allows identification of those FECD patients who are more likely to be hyperopic after combined DMEK and cataract surgery. With refractive surprises being common after triple DMEK, 46% of eyes experienced more than +0.5 D of an unexpected hyperopic shift in this study. The risk of postoperative hyperopic shift was increased 3.0-fold in eyes with a centrally flat, oblate posterior cornea (positive posterior Q), which is a measure of edematous changes of FECD,[11–13] compared to nonflat corneas. Assessment of the posterior profile with simple Scheimpflug tomography prior to surgery may help avoid these unnecessary refractive surprises. Subtracting 0.5 D of planned refraction in eyes with a posterior positive Q value can reduce unexpected hyperopia significantly (from 61% to 17%).

Refractive surprises after endothelial keratoplasty were common in this study, with every fifth eye being off the planned refractive target by more than 1 D (range, −2.8 to +3.2 D), which is comparable to other studies.[7,20] Range and severity of refractive deviation may vary between reports because of variation in surgical techniques (DMEK vs Descemet stripping endothelial keratoplasty) and variation in definition (predicted postoperative refraction for the implanted IOL is a better subtrahend to calculate the arithmetic error than preoperative refraction).[6] Nevertheless, our data on arithmetic error (stable postoperative refraction minus predicted refractive error) with a median of 0.38 D (IQR −0.22 to 0.81) are in line with previous reports ranging from 1.2 D to emmetropia.[5,6,9,14,21] Different strategies to counteract the directional shift toward hyperopia have been recommended. To counteract postoperative hyperopia with spectacle dependence or anisometropia, several authors recommend selecting IOLs with higher power for a predicted refractive outcome of −1.0 to −1.5 D.[6,8–10] The practice pattern in our study followed the recommendations, as surgeons targeted for slight myopia.

Ideally, risk factors of postoperative hyperopia or (myopia) should guide individualized refractive planning. In this study, FECD patients with a posterior corneal surface that was flatter and bulged toward the anterior chamber in preoperative measurements (oblate, $Q > 0$) were more likely to develop postoperative hyperopia. We also demonstrated a dose-response relationship between increase in posterior Q and increase in arithmetic error (Table 2). The increased risk of unexpected hyperopia with a flatter posterior cornea is supported by prior evidence. We and others previously identified that directional posterior surface changes owing to progressive corneal edema are characteristic features of FECD. They increase with severity and normalize after endothelial keratoplasty.[11–13]

Technically, Q values are a metric of general posterior corneal flattening that can be visualized in the posterior elevation map as posterior depression relative to the best-fit-sphere (Figure). In practice, assessing whether Q is positive or negative or assessing the actual posterior Q value may help adjusting IOL power, particularly in those patients at risk of postoperative refractive shift. For routine clinical use, no data export is needed and Q values can be visualized easily, for example at the “4-maps refractive” screen. Of note, our data show that corneal thickness or radius of curvature alone are insufficient to guide refractive planning.

We advocate for future prospective validation of the Q value as a predictor of postoperative hyperopia to guide individual refractive planning. Risks of postoperative hyperopia based on the Q value were high in this retrospective study and are physiologically plausible based on prior studies.[11] Of note, all patients in our study underwent Scheimpflug imaging. Therefore, our study population may have had a higher prevalence of preoperative astigmatism than an unselected population. We did not find evidence for higher or more irregular astigmatism compared to other cohorts when analyzing preoperative keratometry and refraction and quality indicators of the Scheimpflug images (Table 1; data in part shown).

In summary, our results may help improve refractive outcomes by accounting for preoperative posterior profile. With FECD being a bilateral condition, unexpected refractive outcomes in both eyes are difficult to address, even with costly spectacle correction for otherwise perfectly clear corneas after triple DMEK. Refractive surgical options are limited in FECD eyes because of unknown effects on transplant health and structural alternations in the residual host stroma.[4,22,23] In the future, optimizing refractive outcomes might be possible in FECD eyes by using ray tracing for IOL calculation to account for the directional, edematous surface changes in FECD.[19,24] Currently, the experience with and availability of ray tracing formulas is still limited. Assessing the posterior Q value Scheimpflug imaging prior to surgery is easy. Therefore, it might be a practical approach to estimate the individual risk of a postoperative hyperopic shift after triple DMEK.

FUNDING/SUPPORT: THE STUDY WAS SUPPORTED BY THE BERTA OTTENSTEIN PROGRAM, FACULTY OF MEDICINE, UNIVERSITY of Freiburg, Germany (Fellowship to K.W.). Funding entities had no role in the design, conduction, or presentation of this study. Financial Disclosures: The following authors have no financial disclosures: Marianne Fritz, Viviane Grewing, Daniel Böhringer, Thabo Lapp, Philip Maier, Thomas Reinhard, and Katrin Wacker. All authors attest that they meet the current ICMJE criteria for authorship.

REFERENCES

1. Maier P, Reinhard T, Cursiefen C. Descemet stripping endothelial keratoplasty–rapid recovery of visual acuity. *Dtsch Arztebl Int* 2013;110(21):365–371.
2. Heinzelmann S, Bohringer D, Eberwein P, Reinhard T, Maier P. 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(3):515–522.
3. Flockerzi E, Maier P, Bohringer D, et al. Trends in corneal transplantation from 2001 to 2016 in Germany: a report of the DOG-Section Cornea and its keratoplasty registry. *Am J Ophthalmol* 2018;18891–18898.
4. Price FW Jr, Price MO. Combined cataract/DSEK/DMEK: changing expectations. *Asia Pac J Ophthalmol (Phila)* 2017;6(4):388–392.
5. Price MO, Giebel AW, Fairchild KM, Price FW Jr. Descemet's membrane endothelial keratoplasty: prospective multicenter study of visual and refractive outcomes and endothelial survival. *Ophthalmology* 2009;116(12):2361–2368.
6. Schoenberg ED, Price FW Jr, Miller J, McKee Y, Price MO. Refractive outcomes of Descemet membrane endothelial keratoplasty triple procedures (combined with cataract surgery). *J Cataract Refract Surg* 2015;41(6):1182–1189.
7. Tong CM, Baydoun L, Melles GRJ. Descemet membrane endothelial keratoplasty and refractive surgery. *Curr Opin Ophthalmol* 2017;28(4):316–325.
8. Bonfadini G, Ladas JG, Moreira H, et al. Optimization of intraocular lens constant improves refractive outcomes in combined endothelial keratoplasty and cataract surgery. *Ophthalmology* 2013;120(2):234–239.
9. 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(12):1548–1555.
10. Laaser K, Bachmann BO, Horn FK, Cursiefen C, Kruse FE. Descemet membrane endothelial keratoplasty combined with phacoemulsification and intraocular lens implantation: advanced triple procedure. *Am J Ophthalmol* 2012;154(1):47–55 e2.
11. Wacker K, McLaren JW, Patel SV. Directional posterior corneal profile changes in Fuchs' endothelial corneal dystrophy. *Invest Ophthalmol Vis Sci* 2015;56(10):5904–5911.
12. Brunette I, Sherknies D, Terry MA, Chagnon M, Bourges JL, Meunier J. 3-D characterization of the corneal shape in Fuchs dystrophy and pseudophakic keratopathy. *Invest Ophthalmol Vis Sci* 2011;52(1):206–214.
13. Kwon RO, Price MO, Price FW Jr, Ambrosio R Jr, Belin MW. Pentacam characterization of corneas with Fuchs dystrophy treated with Descemet membrane endothelial keratoplasty. *J Refract Surg* 2010;26(12):972–979.
14. 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(8):1455–1464.
15. Alnawaiseh M, Zumhagen L, Rosentreter A, Eter N. Intraocular lens power calculation using standard formulas and ray tracing after DMEK in patients with Fuchs endothelial dystrophy. *BMC Ophthalmol* 2017;17(1):152.
16. Haigis W, Lege B, Miller N, Schneider B. Comparison of immersion ultrasound biometry and partial coherence interferometry for intraocular lens calculation according to Haigis. *Graefes Arch Clin Exp Ophthalmol* 2000;238(9):765–773.
17. Retzlaff JA, Sanders DR, Kraff MC. Development of the SRK/T intraocular lens implant power calculation formula. *J Cataract Refract Surg* 1990;16(3):333–340.
18. Sinjab MM. Corneal Topography in Clinical Practice (Pentacam System) Basics and Clinical Interpretation. New Delhi: Jaypee Brothers Medical Pub; 2012.
19. Wacker K, Cavalcante LCB, Baratz KH, Patel SV. Hyperopic trend after cataract surgery in eyes with Fuchs' endothelial corneal dystrophy. *Ophthalmology* 2018;125(8):1302–1304.
20. Deng SX, Lee WB, Hammersmith KM, et al. Descemet membrane endothelial keratoplasty: safety and outcomes: a report by the American Academy of Ophthalmology. *Ophthalmology* 2018;125(2):295–310.
21. Parker J, Dirisamer M, Naveiras M, et al. Outcomes of Descemet membrane endothelial keratoplasty in phakic eyes. *J Cataract Refract Surg* 2012;38(5):871–877.
22. Patel SV, Baratz KH, Hodge DO, Maguire LJ, McLaren JW. The effect of corneal light scatter on vision after Descemet stripping with endothelial keratoplasty. *Arch Ophthalmol* 2009;127(2):153–160.
23. Price FW Jr, Price MO, Guerra F. Is excimer laser corneal surgery appropriate after resolution of corneal edema in Fuchs dystrophy by Descemet membrane endothelial keratoplasty? *J Refract Surg* 2011;27(4):299–302.
24. Preussner PR, Wahl J, Weitzel D. Topography-based intraocular lens power selection. *J Cataract Refract Surg* 2005;31(3):525–533.