CJO JCO

Original Article

Phototherapeutic keratectomy versus epithelial debridement combined with anterior stromal puncture or diamond burr for recurrent corneal erosions

Yelin Yang,* Michael Mimouni,*,‡ Tanya Trinh,* Nir Sorkin,*,†,§ Eyal Cohen,* Gisella Santaella,* David S. Rootman,* Clara C. Chan,* Allan R. Slomovic*

Objective: To compare outcomes of phototherapeutic keratectomy (PTK) versus epithelial debridement combined with anterior stromal puncture (ASP) or diamond burr for the treatment of recurrent corneal erosions (RCES) in a large tertiary centre.

Methods: Patients with a diagnosis of RCES secondary to trauma or epithelial basement membrane dystrophy who underwent a surgical procedure between 2009 and 2019 were included in the study. The following data were collected: demographics, ocular history, prior medical treatment, ocular surgeries, intervention, complete epithelialization at postoperative week 1, recurrences, and complications. Recurrence was defined as either an objective finding of a corneal epithelial defect or symptoms suggestive of recurrent epithelial erosion on history. Recurrence rate and time to epithelialization were compared between groups.

Results: A total of 97 eyes (73 patients) were included in the study. Mean patient age was 51 ± 16.1 years, and mean follow-up was 474 days. RCES was secondary to epithelial basement membrane dystrophy in 80% (n = 78 of 97), trauma (15%, n = 15 of 97), or idiopathic (4%, n = 4 of 97). Epithelial debridement with ASP was performed in 34 eyes (35%), diamond burr in 33 eyes (33%), and PTK in 30 eyes (31%). Compared with epithelial debridement with ASP (recurrence 29.4%), the recurrence rate was significantly lower for both the diamond burr (9.1%, $p = 0.031$) and PTK groups (10%, $p = 0.048$). The diamond burr and PTK groups also had a significantly higher rate of complete epithelialization at 1 week ($p < 0.05$).

Conclusion: Compared with epithelial debridement with ASP, diamond burr and PTK have significantly lower rates of recurrence and time to epithelialization and may be considered first for surgical management of RCES.

Recurrent corneal erosions syndrome (RCES) is a common disorder characterized by recurring episodes of corneal epithelium breakdown.[1] The mechanism likely involves abnormal hemidesmosomes and anchoring filaments, leading to poor adhesion of the corneal epithelium to the underlying stroma.[2] Predisposing factors include trauma, corneal dystrophies such as epithelial basement membrane dystrophy (EBMD), dry eye, rosacea, and diabetes.[2]

Painful episodes often can be debilitating. In a previous study involving 117 patients, 59% of patients were still symptomatic despite treatment.[3] Several surgical options are available for those who fail medical therapy, including phototherapeutic keratectomy (PTK) and epithelial debridement with combinations of anterior stromal puncture (ASP) or abrasion of superficial Bowman membrane with a diamond-dusted rotating burr.[4] Although previous literature has described outcomes of each technique, there is a paucity of data comparing the effectiveness of these techniques, and there is no clear agreement on the best management. Therefore, the purpose of this study was to compare outcomes of PTK versus epithelial debridement combined with ASP or abrasion with a burr for the treatment of RCES in a large tertiary centre over the past decade.

Methods

This was a retrospective chart review of the tertiary cornea clinics at the Toronto Western Hospital of the University Health Network. Ethics approval was obtained from the Institutional Review Board of the University Health Network. Patients with a diagnosis of RCES of various etiologies who underwent a surgical procedure between January 1, 2009, and December 31, 2019, were included.

Outcomes

Data collected included demographics, ocular history, prior medical treatment, prior ocular surgeries, type of surgical procedure for RCES, best-corrected visual acuity (BCVA), time to epithelialization, recurrences, time to

https://doi.org/10.1016/j.jcjo.2022.01.023
ISSN 0008-4182

recurrence, and complications (Table 1). Dry eye disease was assessed via fluorescein stain for tear breakup time and superficial punctate keratitis. Recurrence was defined as either an objective finding of a corneal epithelial defect or symptoms suggestive of recurrent epithelial erosion on history (pain on awakening, blurred vision, and redness). Complications including corneal haze, hyperopic shift greater than 1.0 D, and infectious keratitis were collected. Complete epithelial healing was assessed through time of bandage contact lens (BCL) removal, and the percentage of patients with complete epithelial healing at postoperative week 1 visit was calculated.

Surgical procedure

Choice of surgical procedure depended on patient presentation and surgeon choice. If epithelial debridement was chosen, then one of 3 experienced surgeons (D.S.R., C.C. C., or A.R.S.) implemented their procedure of choice. Superficial keratectomy was performed under topical anesthesia; a full limbus-to-limbus epithelial debridement was performed with a rounded blade (64 or 57 beaver blade; Beaver-Visitec International, Waltham, Mass.) down to the Bowman layer. A full limbus-to-limbus epithelial debridement was performed rather than focally because this was thought to reduce recurrence. In cases where ASP was performed following debridement, a 25-gauge needle was used to puncture through Bowman's membrane around the affected area but not involving the central axis. Punctures were created 0.5 mm apart. In cases where a diamond burr was used, a handheld diamond burr with a large-diameter polishing head (5.0 mm; Katena, Parsippany, NJ) was used to gently polish Bowman's membrane over the entire epithelial defect for approximately 10 seconds. PTK was performed using a VISX Star S4 excimer laser (VISX Inc, Santa Clara, Calif.). After removing the epithelium with 50% alcohol diluted with Balance Salt Solution (Alcon, Fort Worth, Tex.) for 15 seconds, ablation was performed with a 7 mm optical zone and an ablation depth of 5−10 μm depending on concern for hyperopic shift. If the erosion was beyond a 7 mm area, ablation was decentred to the central area covering the entire area of erosion. The ablation rate was set according to the machine, and no transition zone was used. Following all procedures, a therapeutic BCL (Acuvue, Markham, Ont.) was placed, and topical antibiotics and topical steroids (tobramycin 0.3% and dexamethasone drops 0.1%; Alcon) were prescribed.

Following complete healing of the epithelial defect as assessed by fluorescein stain and slit-lamp examination, the BCL was removed, topical antibiotics were discontinued, and topical steroids were decreased and then stopped over a period of 4−6 weeks. Patients were routinely seen postoperatively at approximately 1 week, 1 month, and more frequently if complete epithelialization was not achieved at week 1. Patients were seen annually thereafter and were encouraged to contact the clinic if there were symptoms of recurrence. Patients from remote communities were comanaged with local ophthalmologists or optometrists and had follow-up at their local eye doctor after the procedure.

Statistical analysis

Demographics and outcomes were described using mean and standard deviation or percentages as appropriate. The BCVA was converted into logMARs and described using mean and standard deviation. The χ^2 test or Fisher's exact

Table 1—Demographics of 97 eyes (73 patients)

Characteristics	ED + ASP (n = 34)	ED + diamond burr (n = 33)	PTK (n = 30)	*p* Value
Age (years), mean ± SD	43 ± 13	57 ± 15	53 ± 16	0.001
Male:female	14:20	20:13	11:19	0.16
Etiology of RCES				
EBMD	22	26	30	<0.001
Trauma	10	5	0	0.002
Idiopathic	2	2	0	0.54
Ophthalmic history (n = 97)				
Dry eyes or MGD	0	4	5	0.03
Cataract	0	2	0	0.3
Glaucoma	1	0	1	0.76
Other (HSV, cystoid macular edema, CRVO)	0	2	2	0.46
Prior surgery				
Cataract surgery	0	5	1	0.02
Refractive surgery	2	0	0	0.33
Other	0	2	0	0.33
Prior medical treatment for RCES				
Preservative-free artificial tears (Muro 128)	23	20	26	0.09
Bandage contact lens	13	5	9	0.09
Prior surgical treatment for RCES				
ED	0	2	1	0.52
ASP	1	0	4	0.04
ED + ASP	1	0	0	0.99
PTK	0	0	2	0.09

ED = epithelial debridement; ASP = anterior stromal puncture; PTK = phototherapeutic keratectomy; RCES = recurrent corneal erosion syndrome; EBMD = epithelial basement membrane dystrophy; MGD = Meibomian gland disease; HSV = herpes simplex virus; CRVO = central retinal vein occlusion

test was used for categorical variables, whereas analysis of variance was used for continuous variables. A post hoc *t* test was used for continuous variables as indicated. Statistical significance was defined as $p < 0.05$. Statistical analysis was performed using Stata 12.0 (StataCorp, College Station, Tex.).

Results

Overall, 97 eyes (73 patients) were included in the study. Twenty-four patients underwent bilateral surgical procedures, 6 of whom had same-day procedures. Mean age was 51 ± 16.1 years, and 31 patients were male. Median follow-up was 176 days. Dry eye disease and Meibomian gland disease was the most common ocular comorbidity (n = 9, 9.3%), followed by cataract and glaucoma (n = 2 each, 2%). Ophthalmic surgical history included cataract surgery (6.2%, n = 6 of 97) and laser refractive surgery (2.1%, n = 2 of 97). One patient had prior laser-assisted in situ keratomileusis, and another patient had photorefractive keratectomy.

The RCES was secondary to EBMD in 80% (n = 78 of 97) trauma in 15% of patients (n = 15 of 97) and remaining was idiopathic (4%, n = 4 of 97). The idiopathic cases did not have evidence of dry eye or Meibomian gland disease and were not on glaucoma eye drops. Mean BCVA was 0.23 ± 0.24 logMAR preoperatively and 0.22 ± 0.26 logMAR postoperatively. A majority of eyes had undergone prior medical therapy, including artificial tears and/or Muro 128 ointment (Bausch + Lomb, Rochester, NY; 71%). In some cases, this was combined with application of a BCL (28%). Of these, 11 eyes had undergone prior surgical procedure for RCES at other centres, including ASP (n = 5), epithelial debridement (n = 3), epithelial debridement and ASP (n = 1), and PTK (n = 2).

The surgical procedures are shown in Table 2. Epithelial debridement with ASP was performed in 34 eyes, epithelial debridement with diamond burr in 33 eyes, and PTK in 30 eyes. Prior to intervention, 11 eyes had prior surgical procedures for RCES (7 for PTK, 2 each for the ASP and diamond burr groups). Following intervention, there was a significant difference in recurrence rate among the 3 groups ($p = 0.04$; Fig. 1). Specifically, there was a higher rate of recurrence following epithelial debridement combined with ASP (29.4%) compared with both PTK (10.0%, $p = 0.048$) and epithelial debridement combined with diamond burr (9.1%, $p = 0.031$). All recurrences occurred between 0.8 and 15.6 months postoperatively (Fig. 1). In the 11 eyes with prior surgical procedures, 2 eyes (18%) had recurrence, 1 after receiving epithelial debridement with ASP and 1 with diamond burr. Comparing the etiology of RCES, 2 of 16 eyes with recurrence of RCES had prior trauma, whereas 14 of 16 eyes had EBMD. Additional procedures were performed in 7 patients: 3 eyes in the epithelial debridement with ASP group (1 each for epithelial debridement, epithelial debridement with ASP, and PTK), 1 eye in the epithelial debridement with diamond burr group (repeat epithelial debridement), and 2 eyes in the PTK group (both repeat PTK).

Complications

Two eyes developed corneal haze, 1 following epithelial debridement with a diamond burr and 1 following PTK. The haze was mild in both cases and did not require additional topical steroids. Hyperopic shift of 1 D occurred after PTK in 2 eyes. No eyes developed corneal infiltrates. Using available data, complete epithelial healing, as determined through BCL removal at postoperative week 1, was achieved for 66% (13 of 25), 97% (31 of 32), 84% (21 of 25) of ASP, diamond burr, and PTK patients, respectively ($p < 0.05$ for ASP vs. diamond burr and PTK respectively). All eyes achieved epithelialization by 60 days.

Discussion

Although a variety of procedures can be performed for RCES, few studies have reported combined outcomes of surgical treatment. This study includes a large cohort of patients with long-term follow-up. The epithelial debridement with diamond burr group and PTK group had lower recurrence rates, whereas the epithelial debridement with ASP group had a significantly higher recurrence rate. The epithelial debridement with ASP group also had significantly longer time to complete epithelialization with delayed BCL removal.

Table 2—Surgical procedure and recurrences

Characteristics	Epithelial debridement + ASP (n = 34)	Epithelial debridement + diamond burr (n = 33)	Phototherapeutic keratectomy (n = 30)	*p* Value*
Median follow-up (days)	189 (36–4105)	64 (7–1097)	542 (51–3400)	—
Prior surgical treatment for RCES (%)	5.9% (n = 2)	6.1% (n = 2)	23.0% (n = 7)	0.06
Time to recurrence (months)	0.9–15.6	1.8–15	0.8– 7.0	0.51
Recurrence (%)	29.4% (n = 10)†	9.1% (n = 3)	10.0% (n = 3)	0.04

ASP = anterior stromal puncture; RCES = recurrent corneal erosion syndrome

*p Value was calculated using either one-way analysis of variance for continuous variables or a χ^2 test for categorical variables.

†Epithelial debridement + ASP group had significantly higher values than the epithelial debridement + diamond burr group and PTK group

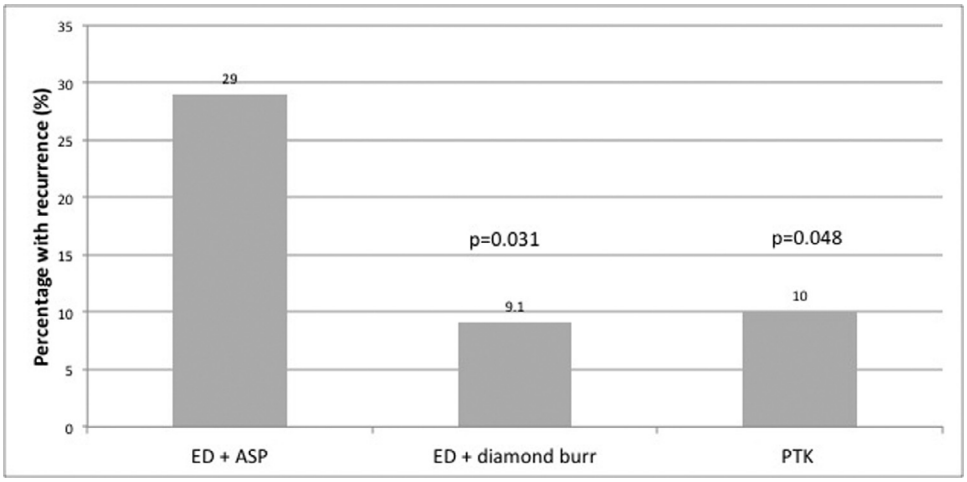

Fig. 1—Recurrence rates of various procedures: epithelial debridement + anterior stromal puncture group had statistically significant higher rate of recurrence than the epithelial debridement + diamond burr ($p = 0.031$) and phototherapeutic keratectomy groups ($p = 0.048$).

Several surgical methods for the treatment of RCES have been described, including epithelial debridement alone, epithelial debridement combined with alcohol delamination or diamond burr, anterior stromal puncture, and PTK.[5] In a study by Suri et al.,[4] involving 166 eyes with RCES, 82 required surgical treatment, including epithelial debridement, diamond burr, ASP, or PTK; the majority underwent epithelial debridement with a diamond burr (n = 68 of 82). However, few studies have compared the outcomes among various surgical techniques. Chan et al.[6] examined 33 patients with RCES and found similar recurrence rates between PTK and alcohol delamination (37.5% vs. 29.4%). Another retrospective study of 41 eyes compared epithelial debridement with diamond burr with PTK and found that diamond burr had a lower recurrence and incidence of haze.[7] In this study, a majority of patients had RCES secondary to EBMD; when these patients are compared to those with a traumatic etiology, they tend to have more severe and chronic disease requiring surgical intervention.[3,8] However, most of these patients still improved after surgery and did not have recurrences during follow-up, reinforcing the value of surgical procedures in patients with recalcitrant disease.

The highest rate of recurrence occurred after epithelial debridement combined with ASP. The superficial punctures through Bowman's layer are thought to promote the formation of firmer adhesions between epithelium and basement membrane.[5] Because it can induce scarring, ASP tends to be used for peripheral lesions not involving the central visual axis. This may have led to undertreatment of the involved part of the cornea. Although ASP can be performed alone or combined with epithelial debridement, previous studies have reported recurrence rates after ASP alone of between 17% and 40%.[9,10] To reduce the recurrence rate, we routinely combine this procedure with epithelial debridement.

Epithelial debridement combined with diamond burr had a lower recurrence than ASP. Bowman's layer is polished with the diamond burr, which creates a slightly rough surface for new epithelium to adhere to and may lead to faster re-epithelialization.[5,11] The polishing also may stimulate reactive fibrosis, which allows stronger adhesion of epithelium to stroma.[11] Previous studies have reported recurrence rates after diamond burr to be between 4% and 25%.[4,10–12] In addition to having a lower recurrence (compared with ASP), the diamond burr group also had the fastest time to re-epithelialization in our study, with an average of 8 days. This is consistent with the results of Vo et al.,[13] who showed that 81% of eyes had complete re-epithelialization within 10 days. However, vigorous polishing is not recommended because it can damage Bowman's layer and cause reactive scarring.[5] One patient in our study developed mild corneal haze that was not visually significant and did not require treatment with topical steroids. On review of the literature, corneal haze has been reported after diamond burr in up to 40% in 1 study, but this improved to 4% at 6 months.[11] Other studies have reported incidences of 22% and 26%.[4,14] Most of these cases were mild and improved with time.

With PTK, the excimer laser removes about 5–10 μm of the stroma of Bowman's layer to create a smooth surface with a microscopic roughness that may encourage epithelial attachment. The recurrence rate is comparable to that of diamond burr, reported at 11%, 13.8%, 23%, and 36% in different studies.[15–18] In our study, PTK was used for patients with more severe disease, as reflected by a greater proportion of patients who underwent a prior surgical procedure for RCES, although this was not statistically significant. All eyes that had undergone prior surgical procedures had complete resolution of RCES symptoms after PTK, suggesting the value of repeat treatment. Deeper ablations can be associated with corneal haze and refractive shift.[2] There was a hyperopic shift of 1 D in 2 patients. The use of larger

treatment zones and fewer pulses has been advocated to minimize refractive shift.[19] Alternately, a small hyperopic treatment of +0.5 D may counter this shift, as well as enlarging the treatment area to 9 mm. Compared with epithelial debridement with ASP, PTK had a significantly lower recurrence rate and should be considered as an initial surgical treatment for RCES or as an alternate to diamond burr. However, it requires a laser and thus may be less accessible and more expensive. In addition to these techniques, epithelial debridement also has been combined with alcohol delamination to reduce recurrence, with 92% of patients (11 of 12) remaining symptom free over follow-up ranging up to 40 months in 1 study.[20] However, we did not include this in our analysis because this procedure was not routinely performed at our centre. Further studies comparing a greater variety of surgical methods may be needed.

This study has several limitations, first of which is its retrospective nature. Furthermore, each surgeon had a preferred technique; as such, this may have led to a selection bias. Two surgeons had access to a laser and performed both epithelial debridement and PTK. PTK was preferred for recurrences, whereas ASP was performed for noncentral lesions. Although the choice of surgical procedure was largely surgeon dependent, the preoperative demographics were mostly similar among the 3 groups. Both eyes from the same patient were also included in the study, which may affect results. Lastly, we did not examine patients in indirect illumination by dilated pupil for the idiopathic cases. We also did not differentiate between different types of EBMD such as maps, maps and Cogan dots, fingerprint lines, and Bron's blebs. However, these subtypes all have similar mechanisms of recurrent erosions and thus should respond to treatment similarly.

Conclusions

Multiple procedures are available and effective for the treatment of RCES. The decision for intervention is multifactorial, involving consideration of risks, cost, equipment available, surgeon preferences, and nature of the pathology. Compared with epithelial debridement with ASP, epithelial debridement with diamond burr and PTK have significantly lower rates of recurrence and shorter times to epithelialization and thus may be suitable first options for surgical management of RCES.

References

1. Watson SL, Leung V. Interventions for recurrent corneal erosions. Cochrane Database Syst Rev 2018;7:CD001861.
2. Ramamurthi S, Rahman MQ, Dutton GN, Ramaesh K. Pathogenesis, clinical features and management of recurrent corneal erosions. Eye (Lond) 2006;20:635–44.
3. Heyworth P, Morlet N, Rayner S, Hykin P, Dart J. Natural history of recurrent erosion syndrome: a 4 year review of 117 patients. Br J Ophthalmol 1998;82:26–8.
4. Suri K, Kosker M, Duman F, Rapuano CJ, Nagra PK, Hammersmith KM. Demographic patterns and treatment outcomes of patients with recurrent corneal erosions related to trauma and epithelial and bowman layer disorders. Am J Ophthalmol 2013;156:1082–7 e2.
5. Miller DD, Hasan SA, Simmons NL, Stewart MW. Recurrent corneal erosion: a comprehensive review. Clin Ophthalmol 2019;13:325–35.
6. Chan E, Jhanji V, Constantinou M, Amiel H, Snibson GR, Vajpayee RB. A randomised controlled trial of alcohol delamination and phototherapeutic keratectomy for the treatment of recurrent corneal erosion syndrome. Br J Ophthalmol 2014;98:166–71.
7. Sridhar MS, Rapuano CJ, Cosar CB, Cohen EJ, Laibson PR. Phototherapeutic keratectomy versus diamond burr polishing of Bowman's membrane in the treatment of recurrent corneal erosions associated with anterior basement membrane dystrophy. Ophthalmology 2002;109:674–9.
8. Hykin PG, Foss AE, Pavesio C, Dart JK. The natural history and management of recurrent corneal erosion: a prospective randomised trial. Eye (Lond) 1994;8:35–40.
9. Avni Zauberman N, Artornsombudh P, Elbaz U, Goldich Y, Rootman DS, Chan CC. Anterior stromal puncture for the treatment of recurrent corneal erosion syndrome: patient clinical features and outcomes. Am J Ophthalmol 2014;157:273–9 e1.
10. Reidy JJ, Paulus MP, Gona S. Recurrent erosions of the cornea: epidemiology and treatment. Cornea 2000;19:767–71.
11. Wong VW, Chi SC, Lam DS. Diamond burr polishing for recurrent corneal erosions: results from a prospective randomized controlled trial. Cornea 2009;28:152–6.
12. Soong HK, Farjo Q, Meyer RF, Sugar A. Diamond burr superficial keratectomy for recurrent corneal erosions. Br J Ophthalmol 2002;86:296–8.
13. Vo RC, Chen JL, Sanchez PJ, Yu F, Aldave AJ. Long-term outcomes of epithelial debridement and diamond burr polishing for corneal epithelial irregularity and recurrent corneal erosion. Cornea 2015;34:1259–65.
14. Aldave AJ, Kamal KM, Vo RC, Yu F. Epithelial debridement and Bowman's layer polishing for visually significant epithelial irregularity and recurrent corneal erosions. Cornea 2009;28:1085–90.
15. Maini R, Loughnan MS. Phototherapeutic keratectomy retreatment for recurrent corneal erosion syndrome. Br J Ophthalmol 2002;86:270–2.
16. Cavanaugh TB, Lind DM, Cutarelli PE, et al. Phototherapeutic keratectomy for recurrent erosion syndrome in anterior basement membrane dystrophy. Ophthalmology 1999;106:971–6.
17. O'Brart D, Muir M, Marshall K. Phototherapeutic keratectomy for recurrent corneal erosions. Eye (Lond) 1994(8):378–83.
18. Baryla J, Pan YI, Hodge WG. Long-term efficacy of phototherapeutic keratectomy on recurrent corneal erosion syndrome. Cornea 2006;25:1150–2.

19. Rojas MC, Manche EE. Phototherapeutic keratectomy for anterior basement membrane dystrophy after laser in situ keratomileusis. Arch Ophthalmol 2002;120:722–7.
20. Dua HS, Lagnado R, Raj D, et al. Alcohol delamination of the corneal epithelium: an alternative in the management of recurrent corneal erosions. Ophthalmology 2006;113:404–11.

Footnotes and Disclosure

The authors have no proprietary or commercial interest in any materials discussed in this article.

YY and MM were involved in data collection, data analysis and manuscript preparation. TT, NS, EC and GS were involved in data collection. DR, CC and AS provided feedback on manuscript and were involved in manuscript revisionAU: Please check for correctness..

From the *Department of Ophthalmology and Visual Sciences, University of Toronto, Toronto, ON; †Ophthalmology Department, Assaf Harofeh Medical Centre, Sackler Faculty of Medicine, Tel Aviv University, Tel Aviv, Israel; ‡Department of Ophthalmology, Rambam Health Care Campus, Technion-Israel Institute of Technology, Haifa, Israel; §Ophthalmology Department, Tel Aviv Medical Center, Sackler Faculty of Medicine, Tel Aviv University, Tel Aviv, Israel.

Originally received May. 25, 2021. Final revision Nov. 11, 2021. Accepted Jan. 26, 2022.

Correspondence to Clara C. Chan, MD, FRCSC, FACS, Department of Ophthalmology and Vision Sciences, Toronto Western Hospital, 399 Bathurst St, 6th Floor East Wing, Reception 1, Toronto, ON M5T 2S8. clarachanmd@gmail.com