Visual acuity and contrast sensitivity following Descemet stripping automated endothelial keratoplasty

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ABSTRACT

Purpose To describe improvements in visual acuity and contrast sensitivity following Descemet stripping automated endothelial keratoplasty (DSAEK).

Methods We analysed 128 consecutive patients (128 eyes) with Fuchs endothelial dystrophy (FED) and bullous keratopathy (BK) who underwent DSAEK at a single tertiary referral centre from January 2006 to September 2009. Our main outcome measures were best-corrected visual acuity (BCVA) and contrast sensitivity over 24 months follow-up.

Results Median age was 67 (60–73) years with 55% women (n=70) and majority Chinese (74%, n=94) in our Asian population. There were no significant differences between demographics between the FED (48%, 61 eyes) and BK (52%, 67 eyes) groups. Forward multivariate linear regression adjusted for age, gender, donor graft thickness and diagnosis (FED vs BK) revealed that preoperative visual acuity was the most significant factor associated with visual acuity at 1 year (β=0.032, p=0.03, R²=0.122). Visual recovery was longer in eyes with BK, with a significantly better visual acuity in the FED group at 12 months (mean logarithm of the minimum angle of resolution BCVA BK: 0.27±0.1 vs FED: 0.22±0.9; p=0.001), but not significant at 24 months (p=0.154). Contrast sensitivity significantly improved more in the first 6 months in the FED when compared with the BK group (at 3.0, 6.0 and 12.0 cycles per degree, p<0.01).

Conclusions Our study suggests that while there was significant improvement in contrast sensitivity and visual acuity after DSAEK, poor preoperative visual acuity was associated with an inferior visual outcome and the time to recovery was longer in eyes with BK.

INTRODUCTION

One of the main advantages of endothelial keratoplasty (EK) over penetrating keratoplasty is the rapid visual recovery and superior postoperative refractive outcomes.1–3 Eyes after Descemet stripping EK (DSEK) achieve best-corrected visual acuity (BCVA) 20/40 or better in 38%–100% by 20 months after surgery;1 and up to 47% could achieve BCVA 20/20 or better at 36 months.4 However, this implies that >50% of eyes with other comorbidities may not achieve 20/20 vision, largely attributed to reduced contrast sensitivity, light scatter and induced higher order aberrations from the anterior stroma, graft–host interface, unevenness or wrinkles on the posterior cornea surface.1–4

Currently, most published reports on long-term visual outcomes after DSEK were mainly in eyes with Fuchs endothelial dystrophy (FED).1 In eyes with FED vision is initially affected by a thickened Descemet’s membrane with central focal excrescences (guttata), before endothelial dysfunction and corneal oedema sets in. On the other hand, eyes with bullous keratopathy (BK) from endothelial cell loss secondary to surgical trauma usually results in diffuse, chronic progressive cornea damage, which leads to pathological changes in the corneal stroma such as subepithelial fibrosis.10 Thus, preoperative visual acuity (VA) in eyes with FED are usually better to start with, when compared with eyes with progressive BK, which may affect the perception of visual outcomes after DSEK.11

Therefore, we hypothesised that visual recovery and improvements in contrast sensitivity after DSEK differ between eyes with FED and BK. In this direct comparative study, we analysed the trends in VA with contrast sensitivity after DSEK over a 2-year period for these two diagnoses, from the same tertiary centre. Aside to the underlying corneal pathology, previous studies have also suggested that graft thickness, graft–host interface, anterior and posterior corneal aberrations contribute to visual outcomes after DSEK.12–14 Hence, we also evaluated the potential factors that could affect the final visual outcome, to determine why more than half of eyes do not achieve 20/20 vision after DSEK.

METHODS

We reviewed consecutive patients who underwent Descemet stripping automated EK (DSEK) for BK or FED from January 2006 to September 2009 from our Singapore Corneal Transplant Study (SCTS)—an audited, prospective cohort study which tracks all clinical data and outcomes of patients who undergo corneal transplants in Singapore. For the purpose of this nested study, we excluded eyes with other ocular comorbidities that would limit visual outcome assessment, including (but not limited to) age-related macular degeneration, pre-existing advanced glaucoma (on optic disc assessment or as defined by the glaucoma severity staging system),15 amblyopia, advanced corneal stromal scarring, iris abnormalities and retinal abnormalities. The Singapore Eye Bank (SEB) provided all precut donor tissue with full information, including donor graft thickness as part of the SCTS study. Preoperative donor graft thickness was remeasured using ultrasound pachymetry (DGH 530 Pachette 2 Ultrasonic Pachymeter, DGH Technologies, Exton, Pennsylvania, USA) by a certified eye bank technician at the SEB. The study was...
carried out with ethics approval from the Singhealth Centralized Institutional Review Board (CIRB Reference number 2004/602/A), conforming to the tenets of Declaration of Helsinki with informed consent obtained in all study subjects.

All DSAEK surgeries were performed as previously described by corneal surgeons at our centre (including cases performed by corneal fellows under direct supervision)—using non-folding techniques,18 standard postoperative medical therapy was used as previously described:17 prednisolone acetate ophthalmic suspension 1% every 3 h for 1 week, four times a day for 3 months, three times a day for 3 months, twice daily for 3 months then once a day for up to 1 year with antibiotic cover. VA was measured using the Snellen VA chart and we analysed results using logarithm of the minimum angle of resolution (logMAR) equivalent units. Refraction results, contrast sensitivity, clinical characteristics and demographics of our patients were also collected prospectively at the preoperative visit and after surgery at 6 months, 12 months and yearly thereafter. Contrast sensitivity was assessed using the Functional Acuity Contrast Test (Vision Sciences Research Corporation, Walnut Creek, California, USA). In our study, we used five rows of nine grating patches to assess contrast sensitivity at spatial frequencies of three cycles per degree (cpd), 6.0 cpd and 12.0 cpd conducted at background illumination of 85 cd/m² (photopic).

Statistical analysis
Statistical analysis was performed using SPSS software V19 (IBM, Chicago, Illinois, USA). Median values were calculated with upper and lower quartile range for data not normally distributed. The Wilcoxon signed-rank test was used to compare the difference in BCVA and contrast sensitivity over time, while the Mann–Whitney U test was used to compare the difference in BCVA and contrast sensitivity between eyes with FED and BK. Correlations between thickness, VA and contrast sensitivity were assessed using the Spearman rho correlation coefficient. A correlation coefficient (r) of at least 0.8 was considered to be very strong, 0.6–0.8 strong, 0.3–0.5 fair and <0.3 poor. p Value of <0.05 was considered statistically significant.

RESULTS
The median age of our study population (n=128) was 67 (60–73) years with 55% (70/128) of the patients were women and 73% (94/128) Chinese in our predominantly Asian (88%, 112/128) cohort. The primary indication was BK in 67 eyes (52%) and FED in 61 eyes (48%). Preoperative BCVA was poorer in eyes with BK when compared with FED (logMAR BCVA 1.3±0.7 vs 0.66±0.6, p<0.001). The overall median graft thickness was 156 (110–180) μm and 54 eyes (42%) with donor thickness ≤130 μm. We did not find any significant correlation between the mean donor graft thickness with VA (r=0.15, p=0.192) and contrast sensitivity (correlation coefficient: 0.04–0.19, p=0.231) over 24 months. There was a fair correlation between VA and contrast sensitivity (3.0, 6.0, 12.0 cpd) at 6–12 months after surgery (correlation coefficient: 0.32–0.43, p<0.001). We studied various factors associated with visual outcome at 6 months, 1 year and 2 years and found that better preoperative VA (B=0.038, p=0.001, R²=0.098) and Fuchs dystrophy (B=-0.044, p=0.02, R²=0.087) were significantly associated with VA 1 year after DSAEK surgery in our study population (table 1). As all patients with BK were pseudo-phakic while (46, 75%) patients with FED had cataract surgery at the same time, we performed forward multivariate linear regression adjusted for age, gender, donor graft thickness, cataract surgery and diagnosis (FED vs BK) and revealed that preoperative VA was the most significant factor associated with final VA at 1 year (B=0.032, p=0.03, R²=0.122).

VA after DSAEK improved in the BK group significantly when compared with FED within the first 6 months (mean logMAR BCVA gain BK: 1.0±0.7 vs FED: 0.4±0.7; p<0.001). The observed improvement in BCVA stabilised by 12 months for both groups, that is, change in BCVA for both groups (p=0.635; figure 1). Although VA was significantly better in the FED than in BK group at 12 months (mean logMAR BCVA BK: 0.27±0.1 vs FED: 0.22±0.9; p=0.001) but not significant at 24 months (p=0.154; figure 1).

Contrast sensitivity improved most significantly after DSAEK surgery in eyes with FED within 6 months after surgery at spatial frequency of 3, 6 and 12 cpd (all p<0.01) and did not significantly improve from 6 to 24 months (figure 2). In comparison, contrast sensitivity gradually improved in eyes with BK after DSAEK over 1 year (preoperative to 6 months: 3.0, 6.0 and 12.0 cpd, all p<0.01; 6–12 months: 3.0 cpd, p=0.015; 6.0 cpd, p=0.02; 12.0 cpd, p=0.03). However, there was no significant improvement after postoperative 1 year (p=0.08; figure 2).

DISCUSSION
The main observations from our clinical study, directly comparing postoperative visual recovery in DSAEK in eyes with FED and BK, help to support insights from previous studies on these diagnoses.18 19 First, in our study population, eyes with BK had a longer visual recovery (6–12 months) period when compared with eyes with FED (3–6 months) after DSAEK. Second, while postoperative contrast sensitivity had a fair correlation with VA, eyes with FED achieved a better postoperative improvement in contrast when compared with BK. Third, eyes with poorer preoperative VA were significantly associated with a poorer postoperative visual outcome, independent of factors such as the surgical indication and donor graft thickness. Ideally, an objective assessment of preoperative cornea stromal damage could have been included in the multivariate analysis; however, this is often difficult to accurately assess in patients with severe corneal decompensation, while poor preoperative VA may be a functional indicator of the state of the cornea before surgery.20 It is also important to note that although VA was significantly better in eyes with FED (20/32) than in BK (20/40) at 1 year in our study population, the clinical significance of this small difference needs to be taken into account. Nonetheless, these observations from our study may be useful when counselling our patients after DSAEK surgery, with respect to the duration of visual recovery, improvements in contrast and the possible effect of severity and duration of stromal oedema on the final VA.18

The visual outcomes for DSAEK in our study were similar to previous reports at 1 year21 and support longer term studies on visual recovery: 97% of our FED eyes achieving ≥20/40, similar to a previous long-term study (98% ≥20/40),14 while our eyes with BK (mean logMAR BCVA 0.26±0.1) achieved a similar postoperative visual outcome to a smaller study in BK (logMAR BCVA 0.22–0.27 at 2 years).11 Gains in contrast sensitivity after DSAEK in our study also show similar trends to previous publications, improving most significantly over the first 6–12 months.21 15 20 This early improvement of visual quality after DSAEK is attributable to both the removal of diseased endothelium and the dramatic decrease in stromal oedema in the early postoperative period.5 11 Similarly, we observed a greater initial improvement in VA in eyes with BK when compared with FED in the first 6 months, which may suggest that the initial stromal oedema was greater in the eyes with BK. Thereafter, the
Table 1  Multivariate linear regression (adjusting for age and gender) for associated factors with best-corrected visual acuity at 6 months, 1 year and 2 years after surgery

<table>
<thead>
<tr>
<th>Best-corrected visual acuity</th>
<th>B (95% CI)</th>
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<tbody>
<tr>
<td></td>
<td>6 months</td>
</tr>
<tr>
<td>Age (years)</td>
<td>0.001 (−0.001 to 0.003)</td>
</tr>
<tr>
<td>p=0.60</td>
<td>p=0.35</td>
</tr>
<tr>
<td>R²=0.016</td>
<td>R²=0.023</td>
</tr>
<tr>
<td>Gender (male)</td>
<td>0.041 (−0.025 to 0.053)</td>
</tr>
<tr>
<td>p=1.00</td>
<td>p=1.00</td>
</tr>
<tr>
<td>R²=0.016</td>
<td>R²=0.023</td>
</tr>
<tr>
<td>Preoperative best-corrected visual acuity</td>
<td>0.04 (0.015 to 0.065)</td>
</tr>
<tr>
<td>p=0.006**</td>
<td>p=0.003**</td>
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<tr>
<td>R²=0.087</td>
<td>R²=0.098</td>
</tr>
<tr>
<td>Diagnosis (Fuchs dystrophy)</td>
<td>−0.059 (−0.099 to −0.019)</td>
</tr>
<tr>
<td>p=0.012**</td>
<td>p=0.06*</td>
</tr>
<tr>
<td>R²=0.087</td>
<td>R²=0.087</td>
</tr>
<tr>
<td>Donor diameter (mm)</td>
<td>−0.048 (−0.101 to 0.005)</td>
</tr>
<tr>
<td>p=0.23</td>
<td>p=0.73</td>
</tr>
<tr>
<td>R²=0.044</td>
<td>R²=0.036</td>
</tr>
<tr>
<td>Donor graft thickness (microns)</td>
<td>1.29E-4 (−2.7E-4 to 0.001)</td>
</tr>
<tr>
<td>p=1.00</td>
<td>p=1.00</td>
</tr>
<tr>
<td>R²=0.018</td>
<td>R²=0.022</td>
</tr>
</tbody>
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*p Value <0.05; **p value <0.01, with Bonferroni correction for multiple comparisons.

limitation in longer term visual recovery may be dependent on further changes in the subepithelial and host stroma affecting light scatter.22 The persistent anterior stromal changes after DSEK in eyes with BK23 may also explain the longer visual recovery we observed in eyes with BK when compared with FED, which may be related to the pathological changes in the corneal stroma and disorganisation of collagen lamellae.20 Nonetheless, our multivariate analysis suggests that despite the diagnosis (FED or BK), a poorer preoperative VA to start with was associated with a poorer visual outcome. Although not a direct surrogate to the measurements of corneal stroma damage, this supports studies which suggest that longer duration and more severe changes to the corneal stroma adversely affect the visual outcomes after DSAEK, supporting early intervention in eyes with BK.18

The results of our study may also explain why it is difficult to adequately determine the effect of donor graft thickness on visual outcomes.12 While reports of ultrathin DSEK13 and Descemet membrane EK suggest that a thinner donor could lead to better visual outcomes,24 it is important to note that these reports were performed in early cases of corneal decompensation from Fuchs dystrophy, with mild to moderate preoperative visual loss (median preoperative VA 20/40–20/50).21 These eyes could have had less anterior stromal scarring with reversible stromal changes when compared with chronic cases of BK with poor preoperative VA, highlighting the effect of the anterior host cornea stroma on the final visual recovery after any form of EK.14 In our study, although univariate analysis suggested a fair correlation between donor graft thickness and visual outcome at 24 months (r=0.35, p=0.037), this was not a significant factor on multivariate analysis. Instead, a poorer preoperative VA significantly accounted for 12% of the variance in our population after accounting for other factors such as age, gender, donor graft thickness and surgical indication. This is supported by studies which describe how straylight from corneal oedema and disorganised collagen fibrils may predict visual outcomes after DSEK.6 26

We recognise the limitations of our study, as a single-centre observational study involving a predominantly Asian cohort. The nature of our clinical study did not allow for randomisation or stratification among the FED or BK groups; and ideally, we would have performed complete preoperative assessment of corneal stroma damage and duration of corneal oedema. However, our results may suggest that initial stromal oedema...
was greater in the eyes with BK, as the early improvement of VA after DSAEK is attributable to the initial significant decrease in stromal oedema, which requires further studies directly comparing eyes with FED and BK to confirm. Nonetheless, this study potentially provides useful insights into trends in VA and contrast sensitivity results after DSAEK, comparing eyes with FED and BK from the same study cohort. The timelines and factors associated with visual recovery also provide constructive counselling data for corneal surgeons to discuss with their patients before offering DSAEK surgery.

In summary, our study suggests that eyes experience significant improvement in contrast sensitivity and VA in both BK and FED patients after DSAEK. Time to recovery was longer in eyes with BK, suggesting that changes in the cornea stroma may be more resistant to recovery as corneal oedema resolves. A poor preoperative VA was associated with a poorer visual outcome after DSAEK independent of factors such as clinical diagnosis, which may suggest that surgery before irreversible cornea damage sets in may improve visual outcomes; however, this requires further study.

**Contributors** All authors met the ICMJE criteria: (1) substantial contributions to conception and design, acquisition of data or analysis and interpretation of data; (2) drafting the article or revising it critically for important intellectual content and (3) final approval of the version to be published.

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**Data sharing statement** Additional unpublished data from the study is available on request from the corresponding author.

**REFERENCES**


