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Major review

Determinants of visual quality after endothelial keratoplasty

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ABSTRACT

Endothelial keratoplasty is now favored over full-thickness penetrating keratoplasty for corneal decompensation secondary to endothelial dysfunction. Although endothelial keratoplasty has evolved as surgeons strive to improve outcomes, fewer patients than expected achieve best corrected visual acuity of 20/20 despite healthy grafts and no ocular comorbidities. Reasons for this remain unclear, with theories including anterior stromal changes, differences in graft thickness and regularity, induced high-order aberrations, and the nature of the graft-host interface. Newer iterations of endothelial keratoplasty such as thin manual Descemet stripping endothelial keratoplasty, ultrathin automated Descemet stripping endothelial keratoplasty, and Descemet membrane endothelial keratoplasty have achieved rates of 20/20 acuity of approximately 50%, comparable to modern cataract surgery, and it may be that a ceiling exists, particularly in the older age group of patients. Establishing the relative contribution of the factors that determine visual quality following endothelial keratoplasty will help drive further innovation, optimizing visual and patient-reported outcomes while improving surgical efficacy and safety.

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1. Introduction

Endothelial disorders such as Fuchs endothelial dystrophy (FED) and pseudophakic bullous keratopathy (PBK) account for over one-third of corneal transplants.[39,60] In recent years, selective replacement of the diseased endothelium with a donor endothelial graft has superseded traditional full-thickness penetrating keratoplasty (PKP),[91] with endothelial keratoplasty (EK) constituting 40% of all corneal grafts in the USA in 2010—compared with only 4.5% in 2005.[6] Full-thickness PKP may still be required when anterior stromal scarring has occurred secondary to the underlying endothelial pathology, although significant visual improvements have still been achieved with EK in such cases.[44,104]

Benefits of EK over PKP include superior biomechanical integrity, faster visual recovery with better uncorrected visual acuity, and a more predictable refractive outcome with less induced astigmatism,[13,14,55,94,120,138] often with a spherical equivalent close to zero.[76] There is less need for general anesthesia and a lower incidence of sight-threatening complications such as endophthalmitis and suprachoroidal hemorrhage because of increased mechanical integrity both intraoperatively and postoperatively.[6]

Somewhat tempering these advantages, final best corrected visual acuity (BCVA) after EK is variable. Mean postoperative BCVA is 20/40 at 3–6 months postoperatively,[6,8] and rates of patients achieving 20/40 or better following EK range from 38% to 100%.[6] Guerra and colleagues reported that only 23% of DSAEK patients achieved VA >20/25 at 12 months follow-up, despite having otherwise healthy eyes and clear corneas with no evidence of graft failure,[45] and similar results with EK have been found by several others.[71,76,107,136] Possible explanations for this include optical degradation at the graft-recipient interface,[63] increased corneal thickness, increased high-order aberrations (HOAs), stromal scarring and fibrosis secondary to the underlying pathology, and increased light scatter.[53]

In their review Anshu and colleagues commented that a higher proportion of patients receiving PKP for endothelial dysfunction may eventually achieve BCVA of 20/20 through the use of hard contact lenses[6]; however, no primary data were provided in support of this claim. Head-to-head comparisons of PKP and EK have failed to demonstrate statistically significant differences in final BCVA outcomes.[68,85] Earlier, large series of PKP reported visual acuity of 20/40 or better in 47%–65% patients treated for FED, and 20%–40% in patients treated for PBK or aphakic bullous keratopathy, with follow-up ranging from 2 to 8 years.[6] In contrast, 38%–100% of patients undergoing manual or automated Descemet stripping EK (DSEK/DSAEK) achieve 20/40 or better across several studies.[6] Furthermore, a large study of the UK National Transplant Registry comparing patients with FED undergoing EK ($n = 678$) or PKP ($n = 1{,}087$) found better mean BCVA at 2 years postoperatively in the EK group (0.30 logMAR; Snellen equivalent 20/40) than in the PKP group (0.40 logMAR; Snellen equivalent 20/50, $P < 0.0001$).[43] These figures indicate that, while a proportion of DSEK/DSAEK patients fail to reach their full visual potential, visual outcomes are superior to those of PKP.

Descemet membrane EK (DMEK) can deliver superior visual outcomes to DSEK or DSAEK. Poor visual outcomes after DMEK are almost always due to ocular comorbidity, central corneal scarring, or graft failure,[28] although DMEK remains more technically challenging than DSEK or DSAEK.[17] Busin's technique of ultrathin DSAEK has achieved visual outcomes comparable to DMEK, with greater proportions of patients achieving 20/20 BCVA than with older iterations of EK.[18] Busin reported 48.8% patients achieved BCVA 20/20 or better at 24 months after ultrathin DSAEK, excluding eyes with vision-limiting comorbidity.[18] Similarly, half of patients undergoing DMEK achieve BCVA 20/20 or better.[44,104] As a comparison, excluding patients with ocular comorbidity, 94.6% of patients undergoing cataract surgery with phacoemulsification achieve BCVA of 20/40 or better, and 52.3% achieve 20/20 BCVA.[59] In other words, modern iterations of EK may offer comparable results to routine cataract surgery in terms of BCVA.

We review what is currently understood about the optical effects of EK. We highlight areas yet to be fully elucidated that require further study to refine techniques and improve long-term visual outcomes. We do not seek to argue the case for one form of EK over another. Instead, we strive to explore what prevents patients achieving their greatest potential visual quality after EK to direct future surgical innovation and research.

2. Determinants of corneal optical quality after EK

Visual performance in the human eye depends on both corneal transparency and surface regularity. A highly organized matrix of corneal collagen fibrils maintains corneal clarity by minimizing light scatter. Light scatter is limited by the small fibrillar cross-section, and any scattered light is further reduced by destructive interference by adjacent fibrils. Anything that disturbs this matrix or affects the corneal surface threatens the optical quality of the cornea.

2.1. *Visual acuity versus visual quality*

There are several theories regarding why some patients fail to achieve their full visual potential after EK. Visual acuity is an important component of visual quality, but quality of vision can also be degraded by several other factors. These include abnormal diffraction in the posterior graft, anterior host cornea, and the interface; HOAs related to surface and interface irregularity; and light scatter from corneal haze.[83,90,137] Patients with high-contrast visual acuity of 20/20 or better may complain of poor visual quality secondary to phenomena such as glare and poor contrast sensitivity that do not always correlate with visual acuity. A full assessment of visual quality therefore requires testing of these visual functions, not just high-contrast acuity.

2.2. *HOAs and light scatter*

Correlation has been found between HOAs and visual acuity after DSAEK,[110] femtosecond laser–assisted keratoplasty, and