Three-hundred-sixty degree barrier effect of a square-edged and an enhanced-edge intraocular lens on centripetal lens epithelial cell migration

Two-year results

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PURPOSE: To study the 360-degree barrier effect of an intraocular lens (IOL) with a square edge at the optic and an enhanced square edge at the optic–haptic junctions (Rayner 570C C-flex) on centripetal migration of lens epithelial cells (LECs) over a 2-year period.

SETTING: Department of Ophthalmology, Scarborough Hospital, Scarborough, United Kingdom.

METHODS: In a prospective study of 40 consecutive eyes, a C-flex IOL was implanted in the bag after phacoemulsification surgery. Eyes with intraoperative complications, requiring additional procedures, without 360-degree overlap of the optic, or with capsule block syndrome were excluded. Follow-up was at 6, 10, 18, and 24 months. At each visit, high-magnification retroillumination digital photographs were taken using a slitlamp-attached digital camera. The barrier effect to LEC migration across the optic edge and the enhanced square edge at the optic–haptic junction was graded as complete (no epithelial pearls or sheet), partial (few epithelial pearls without sheet), and minimal/none (epithelial sheet behind the IOL optic).

RESULTS: Twenty-four patients came to the final follow-up at 24 months. Fifteen of these eyes (63%) had a complete barrier effect throughout the 360 degrees of the IOL. Three eyes (13%) had a partial barrier effect throughout the 360 degrees of the IOL. Three eyes had a complete optic barrier effect but a partial optic–haptic junction barrier effect. Three eyes had a partial optic barrier effect but a complete optic–haptic junction barrier effect. No eye had epithelial sheets extending behind the optic at any location.

CONCLUSIONS: This study showed the barrier effect of the edge design of the C-flex IOL and the efficacy of the enhanced edge in preventing LEC migration at the optic–haptic junction. The enhanced edge was as effective as a sharp square edge in restricting the LEC migration.


The centripetal migration of lens epithelial cells (LECs) leading to development of posterior capsule opacification (PCO) after phacoemulsification surgery for cataract can be reduced in several ways.1 Apple et al.2 report 6 factors related to surgical technique and intraocular lens (IOL) choice that can reduce the overall PCO rate. Of these, an IOL optic with a square edge has proved to be one of the most effective ways of reducing LEC migration.3–9 Animal studies show that the absence of a square edge at the optic–haptic junctions is the “Achilles heel” in IOL design as it allows free centripetal migration of LECs irrespective of IOL material.10 The 570C C-flex (Rayner Intraocular Lenses Ltd.) is the first IOL designed to address this issue. In addition to the square edge at the optic, it has an enhanced edge that runs as an elevated ridge at the optic–haptic junction on both sides of the IOL. This idea originated from a study of negative-power Centerflex IOLs that consistently showed reduced LEC migration from the presence of a
360-degree sharp edge of the biconcave optic.\textsuperscript{11} In a separate observation, Amon found a higher incidence of LEC migration at the optic–haptic junction than at the optic edge of Centerflex IOLs without an enhanced edge (M. Amon, MD, personal communication, September, 2001). Indeed, experimental studies of the C-flex IOL in rabbit eyes found a significant barrier effect of the enhanced edge.\textsuperscript{12}

The present study examined the barrier effect to LEC migration at the optic edge and optic–haptic junction in human eyes over a period of 2 years.

**PATIENTS AND METHODS**

In a prospective study from September 2003 to February 2004, 40 consecutive patients (40 eyes) were recruited. Preoperative exclusion criteria were diabetes, glaucoma, and uveitis. Intraoperative exclusion criteria were posterior capsule rupture, vitrectomy, pupil stretch, capsule tension ring insertion, use of trypan blue, and absence of 360-degree overlap of anterior capsule over the optic. Eyes developing capsule block syndrome were also excluded.

All cases were operated on under topical anesthesia by the same surgeon (A.V.V.). The power of the IOLs implanted ranged from 16.00 to 26.00 diopters. The surgical steps included a clear corneal temporal incision of 3.0 mm or smaller and a well-centered continuous curvilinear capsulorhexis (CCC) aimed at 5.25 mm diameter but no smaller than 4.5 mm diameter. Hydrodissection and hydrodelamination were followed by phacoemulsification using the divide-and-conquer technique. A C-flex IOL was implanted in the capsular bag using the supplied single-piece single-use injector. The ophthalmic viscosurgical device was removed by the rock-and-roll method. The anterior capsule was not polished. Good IOL centration was ensured. All patients received prednisolone 1% drops 4 times a day for 4 weeks and chloramphenicol 0.5% drops 4 times a day for 2 weeks.

**Design of 570C C-flex Intraocular Lens**

The 570C C-flex is a hydrophilic acrylic IOL with an overall size of 12.0 mm and optic size of 5.75 mm (Figure 1). The haptics have antivaulting haptic technology to resist capsule contraction forces. The IOL has a square edge at the optic and outer and inner edges of the haptics. The optic–haptic junctions have an enhanced square edge to complete the 360-degree protection from LEC migration.

**Postoperative Visits**

At each visit, the pupil was dilated with tropicamide 1% and phenylephrine 2.5% drops, each instilled twice at an interval of 10 minutes. Retroillumination photographs were taken with a Nikon Coolpix 4500 digital camera attached to 1 of the empty eyepiece slots of a slitlamp with a Haag-Streit DA 01 ocular adapter. The photographs were then transferred to Adobe Photoshop software. Image brightness and contrast were altered when necessary. Photographs taken at the 2-year follow-up were examined by 2 investigators (A.V.V., R.N.). Figure 2, A to D, shows the drawings that were used to grade the barrier effect in each photograph. The barrier effect at the optic edge (optic edge group) and the optic–haptic junction (optic–haptic junction group) were analyzed separately.

The barrier effect to the centripetal migration of LECs was described as follows:

1. **Complete.** No epithelium was seen extending on the posterior capsule behind the IOL optic (Figure 2, A).
2. **Partial.** Some epithelium was seen extending on the posterior capsule behind the optic, but only in the form of scattered epithelial pearls and not in the form of a sheet of epithelium (Figure 2, B).
3. **Minimal or none.** Both epithelial pearls and sheets were seen extending on the posterior capsule behind the optic (Figure 2, C).
4. **Unrelated.** Nonmigratory, isolated, and scattered epithelial pearls or areas of fibrosis of the posterior capsule were seen away from the edge (Figure 2, D). These were excluded from the study.

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Eyes with growth of epithelium in the central 3.0 mm diameter area of the posterior capsule were further examined using EPCO 2000 software.

RESULTS

Of the 40 consecutive eyes operated on, 2 with a history of diabetes and 1 with pupil stretch during surgery were excluded from the study. Also, 3 eyes with extension of the CCC outside the optic edge and 1 with capsule block syndrome were excluded. The remaining 33 eyes, which had 360-degree overlap of the optic with anterior capsule, were examined at 10, 18, and 24 months. Twenty-four patients came to the final follow-up at 24 months.

There was no discrepancy between the 2 investigators in the barrier effect grades for any photograph taken at the

Figure 2. A: Complete barrier effect; the LECs are outside the optic edge, with none behind the optic. The arrow on either side of the edge indicates the extent of the centripetal migration of LECs and barrier function of the edge. B: Partial barrier effect; the LECs are outside the optic edge, with a few behind the optic close to the optic edge. C: Minimal/no barrier effect; the LECs are outside the optic edge, and many more are progressing behind the optic from the optic edge centripetally. D: Unrelated to the barrier effect; the LECs are outside the optic edge; with a few scattered, nonmigratory LECs behind the optic; complete barrier effect (serial high magnification digital photographs of the IOL edge show LEC proliferation of varying degree outside the edge but no progressive epithelial pearls migration inside the edge behind the optic).
2-year follow-up. Results of the barrier effect to centripetal migration of LECs in the 24 eyes that completed the 2-year follow-up are shown in Table 1. Fifteen eyes (63%) had a complete barrier effect throughout the 360 degrees of the IOL. Three eyes (13%) had a partial barrier effect throughout the 360 degrees of the IOL. Three eyes had a complete optic edge barrier effect but a partial optic–haptic junction barrier effect. Three eyes had a moderate optic edge barrier effect but an excellent optic–haptic junction barrier effect. No eyes had epithelial sheets extending from the optic edge or the optic–haptic junction.

Scattered epithelial pearls were present outside the central 3.0 mm area of the optic in 7 of the 24 eyes. Two eyes had a few nonmigratory LECs just within the central 3.0 mm area and were placed in the unrelated category.

The capsule followed the contour of both the enhanced edge and square edge (Figures 3 and 4), suggesting an encompassing effect of the capsule on the IOL at the optic edge and at the optic–haptic junction.

**DISCUSSION**

To our knowledge, this is one of the few studies in which the function of the optic edge in human eyes was closely scrutinized over a period of 2 years. A more recent study based on similar digital photographs found a “damming” effect to migrating LECs at the square posterior edge at 1 month.13 Our study was an objective assessment of LEC migration in relation to the square edge and enhanced edge of the optic. We put forward criteria by which these changes can be graded by digital photography.

**Table 1.** Degree of efficacy of barrier effect to centripetal migration of LECs at the square optic edge (optic edge group) and at the enhanced square edge (optic–haptic junction group) at 24 months in 24 eyes.

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C = complete; NA = not available; P = partial
Lens Epithelial Cells and the C-flex Intraocular Lens

Lens epithelial cells show continuous changes in distribution and morphology starting from the early days after cataract surgery. Most of the epithelial cells reside in the equatorial area of the capsule bag, with a few remaining on the surface of the posterior capsule after surgery. The LECs from the equatorial region multiply and migrate in a centripetal direction. Modern IOL designs aim at restricting these activities peripheral to the IOL optic area. A square edge to the optic has proved to be an effective design in this context. In traditional IOL design with J-shaped or C-shaped haptics, the optic–haptic junction is a small part of the optic circumference. Increasing this arc of unprotected optic–haptic junction, even by a small degree, can allow a significant increase in the centripetal migration of LECs. Similar observations with the Centerflex IOL without an enhanced edge have been made (unpublished data). The optic–haptic junction without a square edge design is potentially the Achilles heel of such an IOL.

Indeed, our study showed the presence of LECs behind the flat haptic, signifying the need for an additional barrier (Figures 4 and 5). The enhanced edge of the 570C C-flex IOL is specifically designed to add this further barrier to the centripetal migration of LECs around the full circumference, including the optic–haptic junction.

Another important factor in reducing LEC migration is 360-degree overlap of the IOL surface with the anterior capsule. Therefore, eyes without 360-degree overlap of anterior capsule were excluded from our study.

Overall Barrier Function of the C-flex Intraocular Lens

As many as 63% of the eyes showed complete barrier function at both the optic edge and the optic–haptic
junction over the first 2 years of follow-up. A further 13% had a partial barrier effect (Figure 6) around the 360 degrees of the optic.

While assessing the barrier effect, it is important to judge the most likely origin of LECs. Photographs repeated over a period of many months show a definite pattern of progress of these cells. A spreading sheet of epithelium from the optic edge would undoubtedly indicate a failure of the barrier function of the optic edge.

Case 11 (Figure 7) highlights the possibility of category 4 (unrelated to barrier effect of the edge). At 6 months, there were 2 areas of epithelium, both near the optic–haptic junctions. These did not increase in size throughout the 2-year period, indicating a complete barrier function. It is possible that for their proliferation, LECs on the posterior capsule left behind from the surgery are dependent on mitogenic and nutritional factors brought by migrating LECs from the equatorial region. A complete barrier effect of the enhanced edge would isolate these LECs and would remain unchanged (Figure 7). Contact inhibition of LEC proliferation by a hydrophilic IOL surface is less likely to play a major role.

In all cases, the central 3.0 mm diameter of the posterior capsule remained relatively free of epithelium. An EPCO 2000 analysis of the central 3.0 mm diameter was not significant in any eye, indicating the edge’s excellent barrier function.

Barrier Function of the Optic Edge

Our study showed a 75% complete barrier effect and 25% partial barrier effect at the optic edge. Here, the barrier effect is from the effect of the sharp, square edge. Case 24 (Figure 3) had exuberant growth of LECs outside the optic at 6, 10, 18, and 24 months but none behind the optic. The epithelial pearls clung to the optic edge but were not allowed to progress beyond this (Figure 4, right arrow).

Barrier Function of the Enhanced Edge

Identical to results in the optic edge group, there was a 75% complete barrier effect and 25% partial barrier effect at the optic–haptic junction. Here, the barrier effect is from the enhanced edge. The enhanced edge was as effective as a sharp square edge in restricting the centripetal migration of LECs. A complete barrier effect at the optic edge does not necessarily mean an excellent barrier effect at the optic–haptic junction. Although there was a close correlation, 6 eyes (16%) had a complete or partial barrier effect at the optic edge or optic–haptic junction. Furthermore, the effect at 1 optic–haptic junction may not be exactly replicated at the fellow optic–haptic junction.

Figure 6. Example of a partial barrier effect in the optic edge group at 24 months (case 6).

Figure 7. Case 11 showing no progression of the epithelium behind the optic and a complete barrier effect at the optic–haptic junction over 2 years. The preexisting epithelium at 6 months did not progress, even at 2 years.
Future of Photographic Assessment of the Barrier Function

Although neodymium:YAG capsulotomy rates and EPCO scores give an assessment of the PCO rate for a given IOL, they do not evaluate and compare the barrier function of the individual features of IOL design. This study used a method by which the function of the optic edge and optic–haptic junction can be assessed objectively. We put forward a simple classification that may assist in the evaluation of future IOL designs.

CONCLUSION

Our study showed the barrier effect of the edge design of the C-flex IOL. It further demonstrated the specific efficacy of the enhanced edge in preventing LEC migration at the optic–haptic junction, even when the square edge design failed. The barrier function of the enhanced edge at the optic–haptic junction was as effective as that of a sharp square optic edge.

REFERENCES
