Analysis of edge glare phenomena in intraocular lens edge designs

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ABSTRACT

Purpose: To determine the image and relative intensity of reflected glare images from 4 commonly used intraocular lens (IOL) edge designs to assess the potential for noticeable postoperative edge glare.

Setting: University of Texas Medical School, Houston, Texas, USA.

Methods: The interaction of light rays from 4 common IOL edge designs were examined in an eye model using the OptiCAD 3-D radiometric ray-tracing program (Opticad Corp.). Comparison of the potential of the 4 edge designs to produce visual sensations was derived from plots of the spatial location and energy distribution of rays forming the retinal image.

Results: Edge designs with no anterior and posterior dioptric powers at the lens periphery (lenticular) and rounded corners distributed the edge glare rays over a large retinal area. Edge designs with sharp edges formed by "cropping" the anterior and posterior optic zones focused edge glare rays into distinct arc-shaped images. The peak intensity of the arc-shaped image was 8 to 10 times stronger than the peak intensity of the diffuse image formed by lenses with rounded edges.

Conclusions: Rounded IOL edges distribute reflected glare image over a significantly greater area than sharp edges. Rounded edges reduce the potential for edge glare phenomena that appear to the patient as a thin crescent or partial ring. *J Cataract Refract Surg 1999; 25:748–752 © 1999 ASCRS and ESCRS*

The optical and mechanical design of an intraocular lens (IOL) to provide ideal performance includes many parameters.[1] Among those that have been evaluated are optic shape (equiconvex, asymmetric biconvex, convexplano, planoconvex, and meniscus), optic and haptic material, haptic angulation, and optic diameter. One parameter that has received no theoretical and little clinical evaluation is the edge design of the optic.

The IOL's edge design can significantly affect its optical and mechanical performance after implantation. The optical effects are usually referred to as edge glare or unwanted optical images,[2–4] and the mechanical effects may influence posterior capsule opacification (PCO) rates (D.J. Apple, MD, Q. Peng, MD, N. Visessook, MD, R.J. Schoderbek, MD, "Enhancement of the IOL Optic Barrier Effect Against Posterior Capsule Opacification Using a Truncated Optic," presented at the XVIth Congress of the European Society of Cataract & Refractive Surgeons, Nice, France, September 1998). The purpose of our study was to explain the nature of edge glare and unwanted optical images as a function of the edge design.

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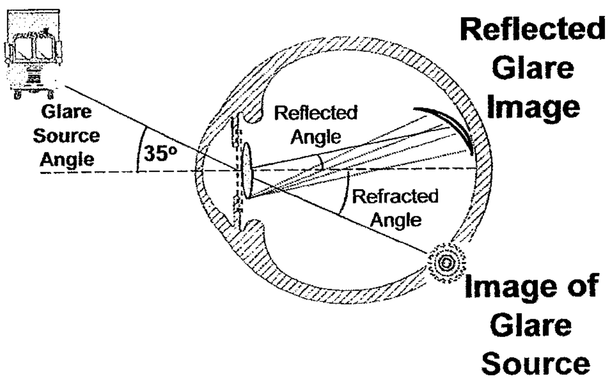


Figure 1. (Holladay) Pseudophakic edge glare: A glare source at a given angle to the visual axis at the nodal point of the pseudophakic eye will produce a refracted and a reflected image if rays are able to reflect internally from the edge of the lens. The unwanted reflected glare image will appear as a thin crescent or partial ring on the side of the retina opposite the glare source.

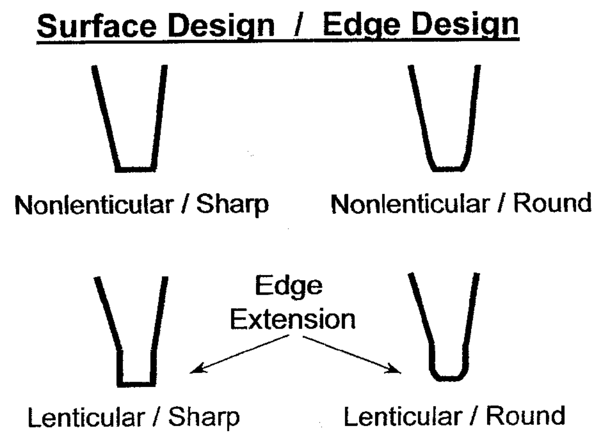


Figure 2. (Holladay) Four common edge designs: The top 2 designs are nonlenticular biconvex (power on both surfaces all the way to the edge), 1 with sharp corners (upper left) and 1 with rounded corners (upper right). The bottom 2 designs are lenticular biconvex, with plano extensions. The plano lentical can have sharp corners (lower left) or rounded corners (lower right), similar to the nonlenticular biconvex.

Materials and Methods

The interaction of light rays as a function of edge design was evaluated using an eye model and the OptiCAD 3-D radiometric ray-tracing program (Opticad Corp.). The pseudophakic eye model with a glare source (Figure 1) consisted of the following physiologic parameters: corneal power, 42 diopters (D); external anterior chamber depth, 4.5 mm (corneal vertex to anterior vertex of IOL); IOL power, 20 D; optic diameter, 6 mm; axial length, 23 mm; and pupil diameter, 5 mm. The glare source consisted of a collimated light source at a 35 degree angle to the optical axis, consistent with nighttime glare conditions. Preliminary ray-trace analysis indicated that a 35 degree angle maximized the intensity of the reflected glare image. The image of the glare source and the reflected glare image were formed on opposite sides of the peripheral retina (Figure 1).

Four IOL edge designs were evaluated: nonlenticular biconvex with sharp or rounded edges and lenticular biconvex (edge extension) with sharp or rounded edges (Figure 2). In all cases, the IOL body diameter remained 6 mm. The optic diameter was reduced by 0.74 mm in the lenticular designs. An

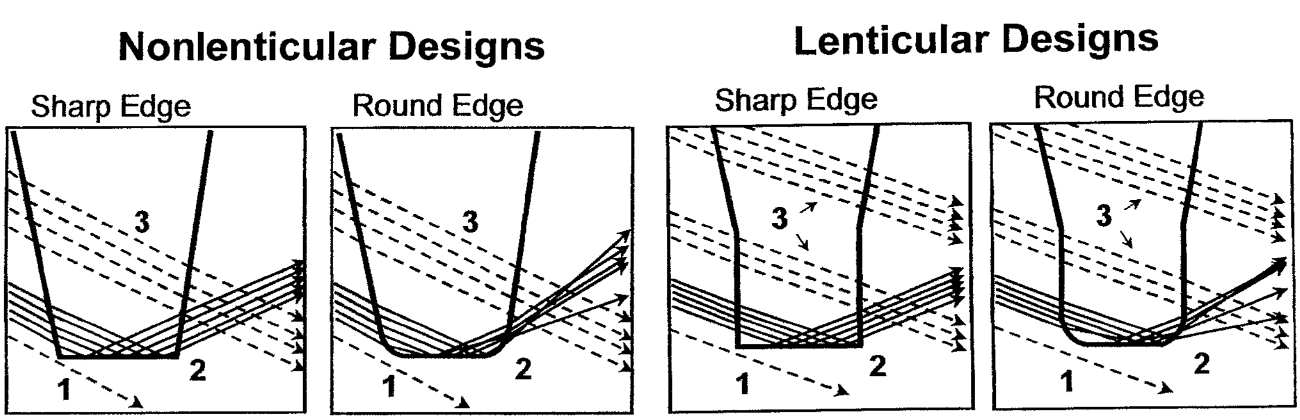


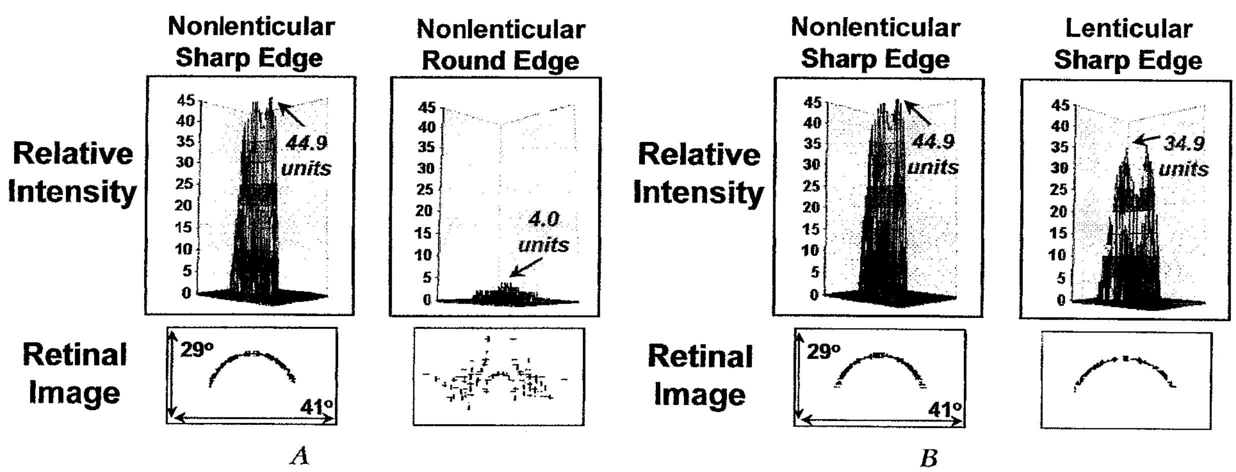
Figure 3. (Holladay) Selected ray tracing through 4 edge designs using 3 groups of rays: (1) rays that miss the lens; (2) rays that are refracted by the anterior surface, reflected internally by the edge, and then refracted by the posterior surface; and (3) rays that are refracted by both surfaces. Selected ray tracings are shown for nonlenticular lenses (*left*) and lenticular lenses (*right*). Note the dispersion of the internally reflected rays in both designs with rounded corners.

edge radius of 0.068 mm was used for the rounded-edge designs. For each design, the analysis traced 160 000 rays from the glare source through the pseudophakic eye model to the produced retinal image. The large number of rays used ensured accurate peak intensity, spatial location, and energy distribution of the reflected glare image.

Results

Analysis of the results revealed 3 classes of rays in the vicinity of the optic edge (Figure 3). The first class missed the IOL entirely, causing an aphakic crescent located near the image of the glare source. The second class was reflected internally by the optic edge. The third class avoided the optic edge and was refracted by the anterior and posterior optic surfaces to form the image of the glare source.

Figure 4, *A* shows the energy distributions and retinal images formed by the nonlenticular sharp- and rounded-edge designs. The sharp-edge design formed a distinct arc-like pattern and the rounded-edge design, a diffuse image. Rounding a nonlenticular biconvex lens reduced the peak intensity of the reflected glare image from 44.9 to 4.0 relative units, a 91% reduction. Figure 4, *B* shows the energy distributions and retinal images formed by the sharp-edge nonlenticular and lenticular designs. Both sharp-edge designs formed distinct arc-like patterns. Adding the lentical reduced the peak intensity of the reflected glare image from 44.9 to 34.9 relative units, a 22% reduction. Figure 4, *C* shows the energy distribution and retinal image formed by a sharp-edge nonlenticular design and compares them with those formed by a rounded-edge lenticular design. The sharp-edge nonlenticular design formed a distinct arc-like pattern and the rounded-edge lenticular design, a diffuse image. The combination of edge rounding and lentical reduced the peak intensity of the reflected glare image from 44.9 to 6.0 relative units, an 87% reduction.



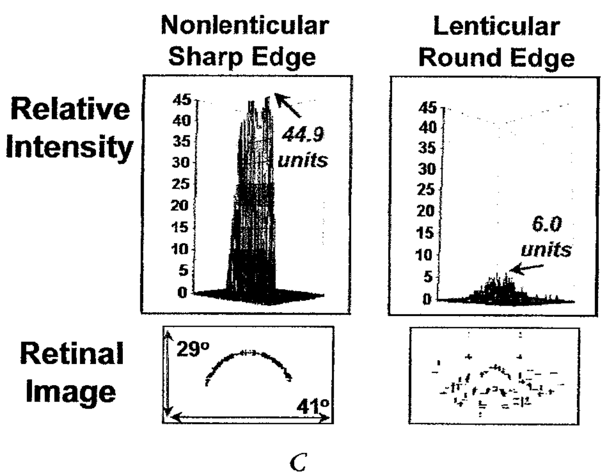


Figure 4. (Holladay) Energy distribution and retinal image formed by the 4 edge designs. *A*: Rounding the edge of a nonlenticular biconvex design. *B*: Creating an extension (lenticular biconvex) in designs with sharp edges. *C*: Combined effect of edge rounding and lentical.

edge rounding can significantly reduce the potential for unwanted optical images.

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