Although IOLs are implanted for optical correction, they are being used to fill more than one role. IOLs are used to reduce astigmatism, manage presbyopia, eliminate ametropia and cover iris defects. IOLs are also used for macular protection and prevention of PCO.

PCO

The acrylic AcrySof IOL (Alcon Inc., Fort Worth, U.S.A.) has been associated with the reduction of PCO when compared with earlier IOLs. Some works have suggested that the acrylic polymer prevents capsular opacification because of its tacky surface, fibronectin and biocompatibility.

Additionally, studies have demonstrated that the posterior convexity of the optic and the angulation of the haptic play a significant role in reducing PCO. However, square-edge design is the chief factor of IOL design that reduces PCO.

Kayo Nishi, MD, and colleagues have demonstrated that if a discontinuous capsular bend is created by an IOL with square edges, the bend may induce contact inhibition of migrating lens epithelial cells (LECs), irrespective of the IOL material. As a result, the posterior capsule can adhere to the posterior surface of the IOL and remain clear either long-term or indefinitely. This factor appears to be the reason that the square-edge design may reduce, retard or eliminate PCO. Experimental studies established that a square-edge design inducing non-continuous capsule bending is the most important IOL characteristic that retards PCO. LECs can grow and migrate in sheets but they cannot make a 90° turn in the process, and growth and migration is suppressed with the square-edge design.

However, a square-edge design will not guarantee against the incidence of PCO. Design factors, such as posterior angulation of the haptic supports, posterior convexity of the optic, size of the optic and tackiness of the surface, may enhance the opportunity for capsular bend to occur. Surgical factors are also reported to contribute to reducing rates of PCO.

Before Dr. Nishi’s study, it was presumed that prevention of PCO was limited to AcrySof IOLs based primarily on the composition of acrylic material. However, both the Clariflex Foldable IOL with OptiEdge (AMO, Santa Ana, U.S.A.) and the 911A (Pfizer, New York, U.S.A.) silicone material with squared edges have also been reported to retard PCO. The square edge that touches the posterior capsule provides a barrier that stops LECs from proliferating across the posterior lens capsule. Thus, the addition of a square posterior edge to the Sensar Acrylic IOL (AMO) with OptiEdge significantly reduces the incidence of PCO.

Reducing risk of dysphotopsia

One adverse effect associated with the square-edge design is dysphotopsia. Dysphotopsia may be considered as undesired subjective optical effects induced by lens implants. Negative dysphotopsia (dark shadows in the temporal field) is a condition that is poorly understood and tends to be short-lived. Light streaks, halos, reflections and glare, known as positive dysphotopsia, can be permanent.

I evaluated a 73-year-old woman implanted with silicone IOL with a square-edge design in one eye. Like some patients with acrylic IOLs, she experienced long-term undesirable reflections and halos. However, the posterior capsule remained clear. The fellow eye had a different style of silicone IOL with round edges that induced no visual side effects but this eye showed signs of early PCO.

Studies suggest that light of oblique incidence is reflected internally by the squared edge and strikes the opposite retina, causing light streaks. It is likely that square-edge design, index of refraction and radius of curvature play a role in causing dysphotopsia. Other factors may include corneal curvature, pupil size, capsule overlap and depth of posterior chamber. Therefore, the square-edge design is responsible for both prevention of PCO and induction of dysphotopsia.
Evaluating dysphotopsia

Dysphotopsia is a set of subjective optical phenomena without objective findings. In turn, dysphotopsia can be difficult to evaluate. At present, there are no universally accepted means for testing the severity of dysphotopsia and no physical findings that can be attributed to the condition. Because of variability of patient sensitivities, lifestyles and expectations, there is not an exact science. Most reported studies have relied on questionnaires, surveys and telephone interviews with patients postoperatively. Therefore, there are no uniform criteria for evaluation.

Dysphotopsia represents a subjective set of symptoms and must be differentiated from reflections that stem from the surface of the implanted lens. These reflections are enhanced forms of Purkinje images, which are the natural light reflexes that are generated from the corneal and limbal surfaces. Purkinje images are noted by an observer and represent a cosmetic, not a visual, problem for the patient.

Zemax (Zemax Development Corp., San Diego, U.S.A.) non-sequential ray tracing analysis has become the present standard for computerized testing of the optical pathways of light through IOLs. One group using this method demonstrated the induction of undesired light reflexes by the double square-edge Acrysof IOLs, and compared the behavior of several IOL edge types. They concluded that dysphotopic symptoms were associated with internal light reflections of oblique incidental light.

Alternative theory

Although considerable attention has been paid to square-edge design and dysphotopsia, Jay Eric, MD, and colleagues have proposed an alternative theory of causation. In their analyses, dysphotopic images are induced by the reflective characteristic of the IOL material, the radius of curvature of the anterior surface of the IOL, and the curvature of the patient’s cornea.

Their theory suggests that an IOL’s anterior radius of curvature that is flatter than 17 mm is associated with the induction of undesired optical images generated by light striking the eye nearly coincident with the line of fixation. In their ray tracing analysis, they suggest that the offending images originate from light reflected from the retina to the back surface of the anterior curvature of the IOL and then back to the retina where it is perceived by the patient.

Most likely, the original theory of edge-induced dysphotopic images and Dr. Eric’s theory are complementary and all factors contribute to some extent. In some patients, all factors may be causal, whereas in others only a single factor is the cause.

Despite having small pupils or overlapped optic edges, some patients may have complaints with silicone or acrylic IOLs since the causes of dysphotopsia are multifactorial. One published case reported on a mature woman who had positive dysphotopsia in one eye that was implanted with a double square-edge biconvex silicone IOL (911A).

Negative dysphotopsia may be associated with any IOL type and style. Although common, negative dysphotopic complaints rarely persist beyond a few weeks. One may ask if this phenomenon is related to temporally oriented cataract incisions, which usually exhibit focal temporal corneal edema for several weeks after surgery.

Preventing or retarding PCO

Can the desired effect of preventing or retarding PCO be achieved without the adverse effects of dysphotopsia? Investigators testing the new triple-edge OptiEdge lens have indicated that patients reported little to no dysphotopic complaints. Ray tracing strongly suggest that the double square-edge optic produce significantly greater internal reflection of oblique light as compared to the OptiEdge (Figure).

Also using ray tracing analysis, optical engineers analyzed a series of IOLs at varying angles of oblique light and determined the magnitude of internal reflections. Double square-edge IOLs are associated with a significantly higher degree of total internal reflection than lenses with the OptiEdge. Also, round-edge IOLs have reflection profiles that are similar to those of the OptiEdge IOLs.
Conversely, Alcon modified the AcrySof three-piece IOL design to a single-piece implant to reduce dysphotopic symptoms. The anterior curvature is now steeper than the posterior surface. Following Dr. Erie’s theory, this might tend to reduce dysphotopsia. Also, the one-piece design was made planar rather than posteriorly angulated, reducing the dimension of the posterior chamber, which is another strategy against dysphotopsia.

**Conclusion**

It would appear that IOLs can be used to retard PCO by creating a discontinuous capsule bend that inhibits migration of LECs onto the posterior capsule. However, it appears that a trade-off is unavoidable, as positive dysphotopsia is an undesired byproduct. Because it is impossible to sort out the symptomatic from the asymptomatic patient on the basis of an ocular examination, manufacturers are addressing the issue with innovations. However, it would seem a better solution to eliminate LEC activity by means other than IOL design. Implant design could focus on the best quality of vision. Presently, though, there are no well-established methods for reducing LEC migration and proliferation.

A recent development is the Perfect Capsule (Milvella Pty. Ltd., Sydney, Australia). This is a diaphragm-like device that is applied by suction to the emptied capsule bag at the time of surgery. The device is a means of irrigating the capsule bag immediately after cataract removal. This may prevent fibrosis and opacification of the capsule bag, which are important for the function of accommodative IOLs. The Perfect Capsule isolates the internal aspect of the capsular bag from the remainder of the anterior segment structures and allows for closed irrigation of the capsule sac. Agents such as distilled water could be used to destroy the LECs without damaging the other structures of the anterior segment.

Although in its early stages, this new technology may be effective against PCO and capsule bag fibrosis, both of which are essential to the long-term success of the IOL. While innovative designs like the OptiEdge offer certain clinical benefits, optimally, other methods for eliminating LEC growth will allow IOL design to focus on best quality of vision.

**References**


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