


Surgical Techniques and Indications for Intraocular Lens Explantation: A Narrative Review

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Abstract: While the outcomes of cataract surgery are remarkably positive, complications do still occur, some of which require intraocular lens (IOL) explantation. These complications often include corneal endothelial loss for anterior chamber IOLs, whereas posterior chamber IOLs are usually explanted because of dislocation, opacification, or patient dissatisfaction with visual quality. Surgical management is challenging, with numerous IOL types/methods of implantation requiring different techniques for explantation. En bloc removal is the simplest of techniques, requiring large incisions with large rates of astigmatism. While folding and cutting methods allow for smaller incisions, the extensive manipulation these techniques require do lead to the potential for endothelial trauma. More novel methods such as cartridge-assisted extraction or IOL scaffolding theoretically minimize anterior chamber manipulation and risk of IOL prolapse into the vitreous but are less widely reviewed with few ophthalmologists having experience with the techniques. If the lens has become displaced into the vitreous, one can also cleave the lens prior to moving it the anterior chamber of the eye, thus even more greatly minimizing corneal endothelial damage. Ultimately, the variety of techniques paired with the rarity of explantation make it difficult to develop expertise in each of these many surgical methodologies. Therefore, it is important to review the indications, complications, general principles, and specific steps for each of the approaches to IOL explantation.

Keywords: intraocular lens, cataract, pseudophakia, intraocular lens dislocation, explantation

Introduction

Cataract surgery is one of the most commonly performed surgeries today, with upwards of 3.7 million in the United States annually.¹ Additionally, refractive lensectomy is gaining popularity and contributing to an expanded pseudophakic population.² While outcomes of cataract surgery are among the best of any surgical procedure, intraocular lens (IOL) explantation remains a serious, albeit rare, necessity. The factors that lead to lens explantation are diverse with some occurring during initial cataract surgery, within the global perioperative period, or even decades later.³ There have been major developments in surgical techniques over the last 20 years. Though there are case reports and literature on many of the methods of explantation in isolation, there is a dearth of publications that offer a comparative discussion of multiple techniques of IOL removal. Thus, this review aims to summarize the indications and techniques for IOL explantation, focusing on practical principles for surgeons.

Method of Literature Search

The review was written based on a comprehensive query of English articles published after 1980. The following terms were used to identify relevant literature: “IOL explantation”, “Intraocular lens explantation”, “IOL exchange”, “Intraocular lens exchange”, “IOL explantation techniques”, “Intraocular lens explantation techniques”, “IOL exchange techniques”, “Intraocular lens exchange techniques”, “IOL explantation indications”, “Intraocular lens explantation indications”, “IOL exchange indications”, and “Intraocular lens exchange indications”. Additionally, the references of the articles that showed up

in our literature search were also analyzed for inclusion in the review. The literature search was performed exclusively on PubMed Central, and two main types of articles were included in the review. The first were articles that provided general insight into the indications and background for intraocular lens explantation. The other category of included articles were those that described specific techniques for explantation. Preference was given to articles providing robust descriptions and videos of the techniques; however, articles with a limited description of the surgical techniques were included if the published technique was not found elsewhere in the literature.

Indications for Intraocular Lens Explantation

Many complications of cataract surgery may necessitate IOL explantation. The prevalence of these complications and rate of IOL explantation depends on the type of lens and position of initial implantation. The 1990s led to a drastic change in the indications for explantation through the standardization of phacoemulsification and use of foldable posterior chamber IOLs (PCIOLs) over polymethylmethacrylate (PMMA) lenses.^{4,5} The main reason for explantation in anterior chamber intraocular lenses (ACIOLs) tends to be the result of corneal endothelial cell loss leading to pseudophakic bullous keratopathy (PBK). Specifically, Mamalis et al reported that 39.7% of ACIOL explantations were due to PBK and 19.1% were due to uveitis-glaucoma-hyphema (UGH) while IOL instability caused only 10.3%.⁶ Despite advancements in IOL design and surgical technique, the complication profile of ACIOL has remained largely unchanged with more recent studies reporting 38.6–63.6% of ACIOL explantations due to PBK and 27.8% due to iritis.^{7,8}

Though indications for IOL explantation are wide, this remains an uncommon complication of cataract surgery. For example, reports from the Moran Eye Center show decreasing rates of IOL explantation: 1.75% (1986–1990), 0.77% (1998–2004), and 0.53% (2007–2011).^{9–11} This is likely the result of the adoption of PCIOLs, improved surgical training/technique, and enhanced lens designs. More recent data from a Saudi Arabia population reported the average annual incidence of IOL removal/exchange as 2.5 per 10,000.¹² However, the follow-up time after cataract surgery was only 8 years in this study, leading to a potential underestimation of the incidence. This conclusion is supported by another study out of Minnesota by Bothun and colleagues that tracked exchange/explantation from 1986 to 2016 and reported a 1.5% 30-year cumulative probability of exchange/explantation.¹³

Posterior chamber IOLs became the predominant lens in the 1990s, changing the indications for explantation drastically. Studies report 40–80% of PCIOL explantations result from dislocation/decentration, an especially common complication in eyes that have had prior vitrectomy.^{7,8,11–16} A Hungarian study reported 95.7% of their PCIOL explantations were due to dislocation.⁸ Incorrect lens power, IOL opacification, and neuroadaptation failure make up the remaining causes of explantation. Improved lens technology has led to a decrease in IOL opacification risk in recent years, but it was particularly common in early hydrophilic acrylic IOLs.^{17,18} In contrast, there has been a rise in explantation due to patient dissatisfaction caused by visual aberrations and undesired visual acuity, likely owing to the rise in multifocal and extended depth of field (EDOF) IOLs.^{19,20} These lenses are associated with decreased contrast sensitivity and higher rates of positive and negative dysphotopsia compared to monofocal IOLs; these patients often also have higher expectations at baseline.^{19,20} Ultimately, the changing complication profile of cataract surgery has led to a shorter duration between IOL implantation and explantation (6–10 years for ACIOLs versus 3–5 years for PCIOLs).^{3,8} It should be noted that IOLs can also become damaged during the initial implantation procedure (broken haptic, material defect, impaired unfolding, etc).²¹

As discussed above, most cases of IOL explantation typically occur years after implantation rather than due to acute emergencies. With this in mind, clinicians often need to decide when watchful waiting is appropriate versus surgical intervention. When the reason for explantation is due to corneal endothelial cell loss, which is often the case with ACIOLs, guidelines recommend moving forward with explantation when the endothelial cell density approaches ~1,500 cells/mm² or a total ECD loss \geq 25% after 3 years.^{22,23} This is a reasonable time to proceed with explantation as true decompensation often occurs when the cell density falls to 500 cells/mm²; thus, the cutoff of ~1,500 cells/mm² allows for a permissive buffer of the losses that occur due to surgical trauma.^{24,25} When explantation is performed due to functionally impaired vision quality/patient dissatisfaction (dysphotopsia, opacification, decentration, or wrong power), it is recommended to first trial nonsurgical methods such as spectacles, YAG capsulotomy, etc. However, one review from Grzybowski et al and one from Patel et al indicate that functionally impairing symptoms/visual acuity, not a specific

cutoff, are an indication for explantation as most patients undergoing exchange achieve excellent outcomes with visual acuity usually $>20/40$.^{26,27}

Explantation rates remain low, with reports of 0.2%–0.3% in 5 and 8 year studies.^{12,13} However, it is a remarkably important skill for an ophthalmologist to maintain as the pseudophakic population only continues to grow.

Techniques for IOL Explantation

Explantation technique is complex and dependent on a variety of factors. Specifically, the approach is based on the type of lens being explanted, the chamber it is being explanted from, lens adhesions/attachment site, and concurrent anatomical variants/comorbidities. Broadly, the first step of explantation involves freeing the lens from its site of implantation and moving it into the anterior chamber of the eye. Once the lens has been freed to the anterior chamber, it must next be removed from the eye while minimizing the size of the incision used to extract the lens. The main techniques by which the lens can be explanted after being freed to the anterior chamber are by folding, cutting, or en bloc. We will review each of these techniques, indications, complications, and steps in greater detail.

It should be noted that throughout this review, we will name specific tools used by the referenced publications. The specific tools are listed as recommendations, and unless specified, similar tools are reasonable to consider.

Freeing the Lens to the Anterior Chamber

Capsular Bag

The most common type of lens explanted today is a foldable, acrylic lens that is implanted in the capsular bag.¹¹ After making the necessary incisions for access and filling the anterior chamber with viscoelastic, the anterior and posterior leaflets of the capsular bag must be separated using a combination of mechanical and viscoelastic-assisted dissection. If necessary, sharp dissection with a pair of micro scissors can be used to open the capsular bag, but care must be taken here to avoid damaging the bag or causing zonular dehiscence.²¹ Following this, the haptics should be grasped, freed from the capsular bag, and the lens moved into the anterior chamber.

It should be noted that in cases where extensive fibrosis of the capsular bag precludes the mobilization of the haptics, cuts can be made at the optic-haptic junction.²⁸ Cutting the optic-haptic junction may allow for easier removal of the haptic, however occasionally a haptic may require abandonment within the capsular bag. While lost/broken haptics and lens fragments during IOL implantation have been associated with corneal decompensation, there is not a reported risk associated with leaving haptics in the capsular bag following explantation.^{29,30} Ultimately, avoiding damage to the capsular bag and zonular support takes priority over explanting a haptic. As an alternative to cutting the optic-haptic junction when the capsule is particularly phimotic/contracted, relaxing incisions in the anterior capsule may need to be made with microscissors, Nd:YAG, or femtolasers to allow mobilization of the optic.^{31,32}

Sulcus

The principles of removing an IOL from the ciliary sulcus are not much different than removing a lens from the capsular bag. Briefly, blunt dissection and viscoelastic material are used to separate the lens from the anterior capsule and posterior iris. The lens can then be migrated into the anterior chamber.

Iris-Fixated

Occasionally sulcus IOLs may need to be fixated to either the iris or sclera due to insufficient capsular support.³³ Iris-claw and iris-sutured IOLs create unique challenges. Removal may cause iris trauma, and there is potential for the IOL to become displaced into the vitreous. One technique published avoids cutting sutures by rotating the haptics out of intact sutures.³⁴ Using microforceps, the IOL optic is shifted until the proximal portion of the opposite haptic is visible. The haptic is then grabbed and a second pair of microforceps is used to brace the iris, while the haptic is rotated back until the haptic disengages from the iris suture.³⁴ This step can then be repeated on the opposite haptic, and the IOL can be moved to the anterior chamber and removed. Occasionally, iris-sutured IOLs may be so overly fibrosed that cutting the sutures and haptics are necessary.

Scleral-Fixated

To remove scleral sutured IOL, the scleral flaps from the original scleral fixation operation should be identified. Subsequently, a conjunctival peritomy should be performed to expose the scleral fixation sutures or flanges. To minimize risk of dropping the IOL into the vitreous, miotics may be used to constrict the pupil, allowing for iris capture of the lens optic prior to disinserting the scleral fixation.³⁵ While the method described above should be adequate in most cases, additional steps can be taken when the iris is fragile or insufficient pupil constriction is achieved. For example, sutures can be threaded across the pars plana behind the IOL. This provides posterior support to the IOL when the scleral sutures are cut.³⁶ These techniques have not been published in the context of scleral fixated IOL explantation, and they may require a greater comfort with vitreoretinal surgery than some anterior segment surgeons possess.

Anterior Chamber

While anterior chamber IOLs are less frequently seen today than in the past, an ophthalmologist must still have confidence in explanting them.^{4,5} Compared to IOLs in the posterior chamber, these lenses are easier to free from their site of implantation. However, as anterior chamber IOLs tend to be rigid, their removal often necessitates a larger incision.³⁷ While clear corneal incisions heal more rapidly, are self-sealing, and have a decreased risk of bleeding compared to scleral shelved incisions, they are known to induce surgically induced astigmatism (SIA), especially with larger incisions.^{38–40} Scleral incisions have been reported to result in nearly 50% less SIA when compared to clear corneal incisions.³⁹

Occasionally, peripheral anterior synechiae can envelope the haptics of ACIOLs. In these cases, intraocular scissors or YAG laser may be used for synechialysis.^{41–43} The optic can then be removed from the anterior chamber as discussed later in this review. Once the optic is removed, the haptics should be able to be freed from the iris by rotating them out of the adhesions with microforceps.⁴² However, it should be noted that removing the haptics and optic of ACIOLs separately is quite rare as most are made of PMMA which preclude cutting.

Explanting the Lens from the Anterior Chamber

En Bloc Removal – Whole Lens Removal

Whole lens removal represents the oldest method of IOL explantation ([Video S1](#)).⁴⁴ This method of lens removal naturally requires the largest incision (typically 6.50 mm), which is not ideal due to the increased intraoperative risk of anterior chamber instability, which could lead to iris prolapse, vitreous loss, and corneal damage.^{39,40} Moreover, post-operative SIA and increased intraocular pressure have also been correlated with these larger incisions.^{39,40} However, it is often the only method of removal in the case of non-foldable and rigid IOLs, such as those made of polymethylmethacrylate (PMMA).⁴⁵ These older IOLs have been largely phased out as they require a large 5.50 mm to 6.00 mm incision for implantation, but they are still used in anterior chamber implantation and are also the primary PCIOLs in resource limited settings, owing to their low production cost.⁴⁶ Ultimately, thick three-piece acrylic IOLs or PMMA IOLs may require up to a 6.50 mm incision for explantation. In the case of thinner lenses, one technique for explantation involves using a toothed forceps inserted through the main incision to grasp the center of the optic while a lens manipulator is inserted via a side port incision 180° away. A combined force of pulling on the IOL via the main incision while also pushing on the optic through the side port incision should be applied to the lens. The pushing and pulling forces will naturally cause the IOL to fold inside the incision as it exits, thus avoiding the risks that come with cutting or folding the lens in the anterior chamber.⁴⁷

En Bloc Removal – Refolding

While explantation traditionally relied upon an enlarged main incision to remove the lens whole, the ubiquitous adoption of foldable IOLs and microincision cataract surgery led to new explantation techniques. Specifically, techniques of explanting IOLs via small incisions (down to 2.20 mm) have been developed using refolding methods in the anterior chamber.^{48–52} It should be noted that this method of explantation is well suited for soft foldable lens such as those made of acrylic, collamer, and silicone; however, this method is incompatible with polymethylmethacrylate (PMMA) lenses or lenses that are too thick to be safely folded ([Table 1](#)).

Table 1 Concise Summary of the Advantages and Disadvantages of the Various Methods of IOL Explantation

| Technique | Advantages | Disadvantages | Reference | Figure |
|---|--|---|-----------|--------|
| <i>En Bloc Removal</i> | | | | |
| Whole Lens | 1. Can remove non-foldable and rigid IOLs 2. Less lens manipulation in anterior chamber | 1. Incisions as large as 6.50 mm (risk for post-operative SIA and increased intraocular pressure) | [39,41] | |
| Folding (Spatula Posterior to IOL) | 1. No cutting of lens | 1. Corneal endothelium damage 2. Challenging to rotate lens 360° with one hand | [42] | |
| Folding (Twist-and-Out) | 1. Small 2.20 mm incision 2. No cutting of lens 3. Avoids corneal endothelial damage | 1. Challenging to rotate lens 360° with one hand | [43] | |
| Folding (Cannula) | 1. Small 2.40 mm incision 2. No cutting of lens 3. Avoids corneal endothelial damage 4. Less technically challenging (can use two hands to rotate lens) | 1. Requires additional paracentesis to insert cannula | [44] | |
| Folding (Cartridge Method) | 1. Less lens manipulation in anterior chamber | 1. Requires custom made tools (cartridge and snare) 2. Larger 3.50 mm incision 3. Technically challenging to capture lens with snare | [45, 46] | |
| <i>Intraocular Lens Cutting</i> | | | | |
| Full Bisection | 1. Easy to perform | 1. Cut lens fragments may fall into vitreous 2. Risk for posterior lens capsule damage 3. Rotating lens in anterior chamber for second cut may damage corneal endothelium | [47] | IA |
| Partial Bisection | 1. Avoids rotating and full bisection of lens (limits corneal endothelium damage and risk of lens fragment displacement to vitreous) | 1. Risk for posterior lens capsule damage | [49] | IB |
| Crisscross Lensotomy | 1. Moderately sized 3.00 mm incision | 1. Great deal of fragmentation and lens manipulation (corneal endothelium damage and risk of lens fragment displacement to vitreous) | [53] | IC |
| Triangular Bisection "Pac-Man" | 1. Small 2.20 mm incision 2. Less lens manipulation | 1. Cut lens fragment may fall into vitreous | [54] | ID |
| Trisection | 1. Small 2.20 mm incision | 1. Additional cuts may cause corneal endothelium damage and IOL fragments may fall into vitreous | [55] | IE |
| Partial Trisection: One Trip Explantation | 1. Moderately sized 3.00 mm incision 2. No fragmentation of lens 3. Does not require extensive rotation of lens for cuts | 1. Additional cuts may cause corneal endothelium damage | [56] | IF |
| S-Plasty and "Cut and Conquer" | 1. Extremely small 2.00 mm incision 2. No fragmentation of lens | 1. Technically challenging 2. Great deal of lens manipulation and cuts may lead to corneal endothelium damage | [57,58] | IG, IH |

Folding (Spatula Posterior to IOL)

This method involves folding the lens around a spatula.⁴⁸ A 3.50 mm limbal tunnel incision and a side port incision 180° away are used for this technique. One of the haptics can be pulled through the limbal incision. Subsequently, a blunt spatula is inserted into the side port incision and positioned under the IOL. Folding forceps can then be inserted into limbal tunnel incision and used to pinch the lens around the spatula. The spatula should be carefully removed from under the lens, and the forceps along with the lens withdrawn. While this technique avoids needing to cut the IOL, it has been shown to lead to a reduction in corneal endothelial cell counts.⁴⁸ This is likely the result of the posterior positioning of the spatula, which provides zero protection to the corneal endothelium.

Folding (Twist-and-Out)

As a means of avoiding the corneal endothelial damage associated with the previous method, one can use a method termed “twist-and-out”. One haptic is explanted via a clear corneal incision (2.20 mm in the referenced publication) and a straight spatula or cannula is also inserted into a paracentesis 90° from the main incision. With the surgeon’s hand maximally supinated, a straight forceps is introduced through the main incision. It is key to position the forceps across the lens and grasp the optic near the haptic on the side of the paracentesis. Then, the surgeon should attempt to pronate their hand to rotate the lens approximately 360° against the cannula, this way protecting the cornea and essentially rolling the lens. The lens can then be removed via the main incision ([Video S2](#)).⁴⁹ While this method protects the cornea, achieving 360° of rotation with one hand while operating in the anterior chamber is challenging for many surgeons.

Folding (Cannula)

If the previous method is not feasible for a surgeon, there is an alternative method of folding the lens that does not require 360° of one-handed rotation. The initial steps of this method follow the twist-and-out technique, except two side port paracenteses are made 180° from each other and 90° away from the main incision. Instead of using a spatula, a 25-gauge cannula is threaded across the anterior chamber through the two paracenteses. The 25-gauge needle should be adequately secure without being held. This permits two hands to be used to insert serrated forceps into the main clear corneal incision, grasp the lens, rotate it 360° against the cannula, and withdraw it through the main incision. While this method requires an additional paracentesis, it is a more user-friendly technique of intraocular lens refolding, and cases of explantation through 2.40 mm incisions have been published using it.⁵⁰

Folding (Cartridge Method)

Other groups have turned to explanting IOLs via cartridges. This limits the amount of anterior chamber lens manipulation/folding, thus lowering the potential for complications.

Specifically, one method involves using a snare-like device threaded through an Alcon A cartridge to remove IOLs.⁵¹ The snare is made by blunting the tip of a 20-gauge needle with a pumice stone and creating two side holes in the tip of the cannula. Subsequently, the two ends of either a 3–0 prolene suture or guitar string should be threaded through the two holes in the 20-gauge needle, creating a loop that is approximately 3/4th the length of the Alcon A cartridge. The loop can then be secured by clamping the cannula with pliers at various points. Next, the Alcon A cartridge is modified by making two 2.50 mm incisions in the nozzle tip along the horizontal axis, 180° apart. Now, the created snare can be threaded through the modified cartridge and used to explant the IOL. It should be noted that it is critical to warm the modified cartridge immediately prior to the procedure as a means of increasing its flexibility/ease of taking up the IOL.⁵¹

Interestingly, the publication demonstrating this technique also made use of an intraocular lens scaffold prior to inserting the cartridge-snare device (discussed later in the review). Once the new IOL is placed (if lens exchange is indicated), the cartridge-snare must be filled with warmed viscoelastic for lubrication and to prevent iris incarceration. It can then be inserted into the anterior chamber bevel down through a (3.50 mm corneal or limbal incisions in referenced publication). Here, a secondary instrument, such as forceps or a spatula, should be inserted via a side port incision and used to hook the haptic onto the snare. Finally, the combined forces of pushing the cartridge while pulling on the snare will pull/fold the lens fully into the device. The device can then be removed from the eye. While unorthodox, this method is advantageous as the guitar string and 3–0 prolene suture are both less likely to damage the corneal endothelium or posterior capsule than rigid metal tools. Additionally, no folding or cutting needs to be performed in the anterior chamber; however, the use of custom devices, a large main incision, and only being able to explant one-piece IOLs has hampered widespread adoption of this technique.⁵¹

Fortunately, there is a method that can explant a wide variety of one- and three-piece soft IOLs using a similar system. This method uses a D1 cartridge and Fukuoka IOL extraction forceps instead of the custom snare.⁵² Specifically, the metal forceps are threaded through the D1 cartridge, and the cartridge-forceps system is inserted into the anterior chamber. Subsequently, the metal forceps can be minimally advanced through the cartridge, used to grasp the optic, and withdrawn back into the D1 cartridge.⁵² While this method still uses metal forceps to fold the lens, most manipulation occurs within the cartridge, protecting the anterior chamber. Moreover, ophthalmologists likely are more comfortable

grasping the lens with forceps than with the snare employed by the previously discussed technique. Ultimately, a few cartridge-based systems for lens explantation have been reported in the literature in recent years but refolding and cutting (discussed later in the review) remain the dominant methods of lens removal used by ophthalmologists today.

Intraocular Lens Cutting

Explantation via certain refolding techniques is widely adopted and provides a nice balance between minimizing incision size and extensive anterior chamber IOL manipulation. However, it is also standard practice to cut the lens in the anterior chamber to facilitate its removal through a potentially smaller incision^{53–55} (Table 1).

Full Bisection

The first method of intraocular lens cutting that was described in the literature is the full bisection method. An inferior main incision (3.50 mm scleral incision used in referenced publication) should be made. The lens should be positioned so the haptics are oriented temporally and nasally. The lens can then be cut along its radius with IOL cutters, partially bisecting it. The lens should then be rotated 180° with a Sinsky hook and cut again along its radius, fully bisecting the lens (Figure 1A). The surgeon can then remove the lens in two pieces by pulling on the optic with McPherson forceps.⁵³ Ultimately, this method allows for a moderately sized incision, but rotating the lens is technically challenging and could lead to corneal endothelium and posterior lens capsule damage, despite appropriate viscoelastic usage.^{56,57} Moreover, by fully bisecting the lens, there is a risk for the resulting fragments to fall into the vitreous, especially in cases where the posterior capsule is compromised.⁵⁸ A modified variant of this technique that bisects the lens in the context of an IOL scaffold (discussed later in the review) is included for reference (Video S3).

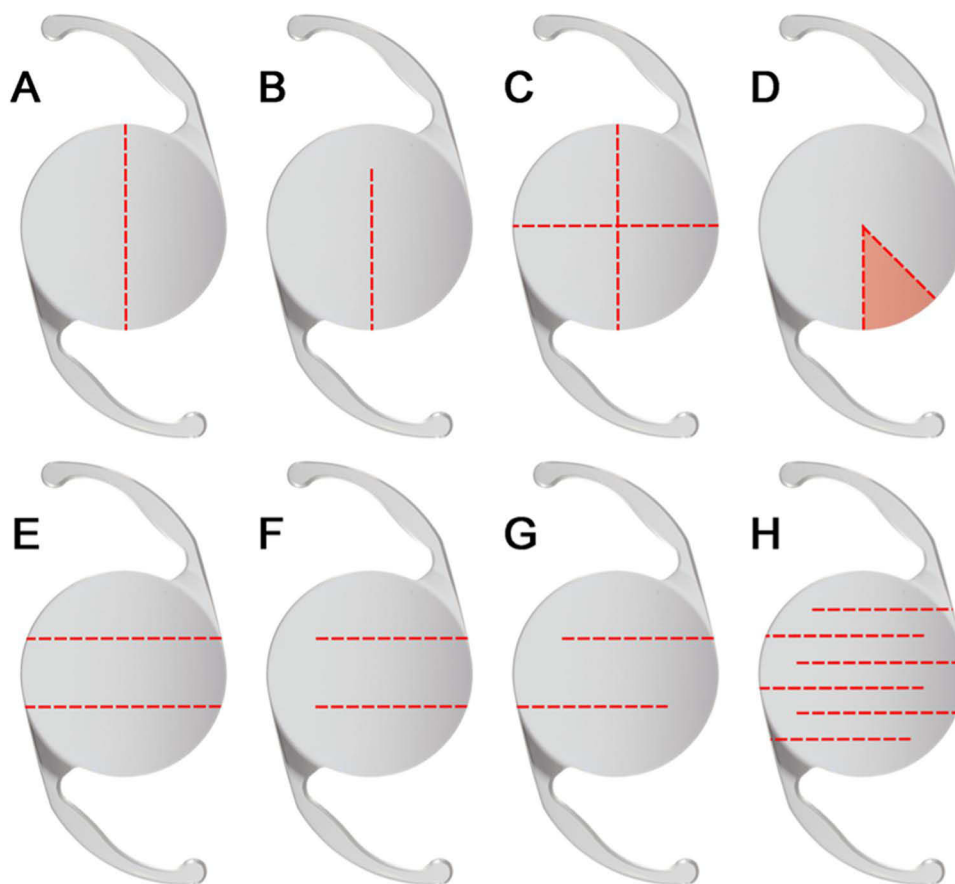


Figure 1 Schematic representation of IOL cuts for explantation via full bisection (A), partial bisection (B), crisscross lensotomy (C), triangular bisection “Pac-Man” (D), trisection (E), partial trisection (F), S-Plasty (G), and “Cut and Conquer” (H).

Partial Bisection

Given the technical difficulty and risk of complications that can arise with rotating and fully bisecting the lens, there is a simpler method of explantation that involves partial bisection. A 3.20 mm incision was used by the authors. McPherson forceps should then be used to pull and anchor the haptic outside of the main corneal incision, and a radial cut is to be made halfway through the optic. The surgeon should then be able to embed half of the lens into the main incision along the radial optic cut. Finally, McPherson forceps can be used to rotate the remainder of the IOL out of the eye (Figure 1B).⁵⁵ As demonstrated, this technique does not require complex manipulation or complete fragmentation of the IOL (Video S4). However, smaller main incisions can be used via alternative techniques that involve additional cuts in the lens.

Crisscross Lensotomy

If one would like to achieve an even smaller incision than possible via the partial bisection method, they can make use of a technique termed “crisscross lensotomy”, a technique first demonstrated with a silicone plate IOL. The group that published this method used a single, inferior 3.00 mm clear corneal incision to move the lens to the anterior chamber and then oriented it in long axis relative to the 3.00 mm incision. Here, the surgeon can then use Osher cutting scissors to make a longitudinal, long axis cut 1/3 the way across the IOL. The IOL must then be rotated 90° and an additional cut made, freeing a small rectangle segment. This segment is then removed from the eye using forceps. The above procedure should be repeated freeing an additional rectangle segment. The resulting crisscross-shaped lens can then be easily removed (Figure 1C).⁵⁹ Ultimately, this method allows for a smaller incision than the partial bisection technique, but it requires a great deal of fragmentation and lens manipulation.

Triangular Bisection “Pac-Man”

While the crisscross lensotomy technique was a great technique at the time it was developed, a more recently developed triangular bisection method of IOL explantation is superior. This involves making two radial incisions to remove a triangle segment from the lens, permitting the lens to be explanted via clear corneal incisions as small as 2.20 mm. Once in the anterior chamber, IOL cutters are used to make two radial cuts approximately 40° degrees apart on the optic. This will free a small triangular fragment of the lens that is able to be removed with McPherson forceps. The remaining IOL segment can subsequently be pulled out of the small corneal incision with a circular motion (Video S5).⁶⁰ Ultimately, this technique takes minimal IOL manipulation, and the removed triangular segment enables greater flexibility and a smaller incision than would be afforded by a single radial cut. The main downside of this technique is the risk of the triangle fragment falling into the vitreous (Figure 1D).⁵⁸

Trisection

In cases where the surgeon is particularly interested in minimizing the incision size, the IOL can also be trisected. Specifically, through a 2.20 mm temporal incision and a superior paracentesis 90° away, the IOL should be moved to the anterior chamber and positioned so the haptics are oriented superiorly and inferiorly. With IOL cutters, two full length cuts must then be made on the same side of the optic at its superior-middle junction and middle-inferior junction. The three pieces of the lens are then subsequently withdrawn from the 2.20 mm temporal corneal incision with McPherson forceps. This technique is especially useful in the context of modern day microincision cataract surgery as it requires a very small cut and does not require difficult rotation of the optic.⁶¹ However, as with all techniques, more cuts and IOL fragments increase the risk of corneal damage, posterior capsular tears, and dropping fragments into the vitreous (Figure 1E).^{56–58}

Partial Trisection: One Trip Explantation

If one wishes to avoid the risks that come with fragmentation and is comfortable with a slightly larger incision, they can use partial trisection to remove the lens. To begin the operation, a 3.00 mm scleral tunnel incision at 11 o'clock and a side paracentesis incision at 2 o'clock should be used to free the IOL to the anterior chamber. Once in the anterior chamber, a pair of vitreoretinal forceps should be inserted into the side paracentesis to stabilize the IOL with its haptics oriented

temporally and nasally. Scissors should then be used to make two partial vertical cuts (leave 1.00 mm uncut) on the same side of the IOL. This will create a middle flap in the IOL, which can then be grasped and dragged out through the 3.00 mm scleral tunnel. In doing so, the two outer segments of the cut IOL will fold in and overlap each other as they pass through the incision (Figure 1F). A variety of IOLs including 1-piece acrylic hydrophilic, 3-piece hydrophobic, and 4-haptic hydrophilic acrylic lenses have all been explanted using this technique.⁶² In addition to being demonstrated with a variety of lenses, this method is ideal as it does not require extensive rotation or fragmentation of the lens.

S-Plasty and “Cut and Conquer”

While the triangular bisection and trisection techniques enable the surgeon to remove the lens via small 2.20 mm incisions, these techniques both require fragmentation of the IOL. There is a way to explant the IOL through small 2.20 mm and even 2.00 mm incisions as a single unit.

Using the methods described throughout this paper, the surgeon should create a 2.20 mm temporal clear corneal incision. Next scissors should be introduced into the main corneal incision and a Nagahara chopper should also be inserted into the side paracentesis for countertraction. Two 4.50 mm deep slits that are 2.00 mm apart must then be created on opposite sides of the optic, producing an S pattern. It is key that the incisions are made near each optic-haptic junction to allow for optimal uncurling of the lens during removal; these two slits will effectively segment the IOL into three 2.00 mm wide pieces that are connected by uncut “hinges” (Figure 1G). This will permit the resulting lens to be pulled out haptic first while remaining in one piece.⁶³ Fechin has further developed this method through a technique termed “cut and conquer”, where up to 8 oppositely oriented partial cuts are made, enabling the resulting zig-zag/snake shaped lens to be pulled out of a 2.00 mm incision (Figure 1H).⁶⁴ While the resultant IOLs in these two techniques are remarkably small and can be removed from tiny tunnels without stressing the incision, creating the “S-shape” or “snake” is challenging and requires a great deal of IOL manipulation in the anterior chamber. If the surgeon is not proficient in their technique, it opens up a great deal of risk for complications. Nonetheless, when performed well, the small incision size minimizes SIA.^{39,40}

Bimanual Cleavage in the Vitreous Chamber

The previous techniques enable the removal of lens fragments from profoundly small incisions. However, most of these techniques rely on cutting and manipulation of the IOL after it has been moved to the anterior chamber which has the potential to cause endothelial corneal damage.^{56,57} To address this concern, a recent technique effective in ten patients with IOL subluxation/dislocation utilized the vitreous cavity as the surgical workspace.⁶⁵ The technique began by performing a standard pars plana vitrectomy to clear vitreous and create adequate working space. The authors then used a 23-G serrated forceps and a vitrectomy probe to separate and remove the capsular bag from the IOL. Following this and without moving the intact IOL into the anterior chamber, scissors are used to make a horizontal cut to the midpoint of the lens plate. Subsequently, two forceps are used to grasp the lens at both haptics, and the two forceps are pulled apart, exerting perpendicular force on the cut, cleaving the IOL. The IOL fragments can then be moved into the anterior chamber and extracted through a 2.2 mm corneal incision. While this technique requires the expertise of an ophthalmologist trained to operate in the vitreous, it allows one to handle lenses that have become displaced into the vitreous and minimizes endothelial corneal damage.

Intraocular Lens Scaffold

In cases with a damaged posterior capsule, vitreous prolapse can occur and IOL fragments can potentially be lost into the vitreous.^{56–58} Implanting the new IOL prior to removing the original IOL from the anterior chamber (Video S3) may lessen the chance of capsular damage and posterior lens dislocation.^{66–68}

Discussion

IOL explantation is a necessary skill for every cataract surgeon, especially given the increasing use of multifocal and extended depth of field (EDOF) IOLs and rising expectations that patients have. Each IOL model and method of IOL

implantation requires different explantation techniques. Reports of these techniques in the literature are scattered and may be difficult to thoroughly review as a result. This review encompasses both common and uncommon techniques in depth.

Corneal incisions are more commonly used today due to better healing and less bleeding, but they can cause SIA.^{38–40} Although the risk of SIA is minimized by the smaller incisions used in modern-day cataract surgery, scleral tunnel incisions are still best when SIA is a major concern.⁴⁰ With that said, reopening the main incision from the primary operation is usually the best choice, most commonly in the early post-operative period following cataract surgery. Once incisions are made, viscoelastic should be used to fill the anterior chamber. Cohesive viscoelastic is primarily used, but dispersive viscoelastic and a combined “sandwich” technique can also be employed based on the preferences of the surgeon.⁶⁷

Once viscoelastic has been used to fill the anterior chamber, the lens must be freed to the anterior chamber. The specific methods of doing so depend on where the IOL is implanted. However, a combination of blunt dissection and viscoelastic are ultimately used to free the haptics and IOL.²¹ In patients with extensive fibrosis, scissors and YAG lasers can be used to make cuts at the optic-haptic junction to facilitate removal.^{41–43} The haptics can be left in the capsular bag if there is concern of damaging the capsular bag and zonules during removal.^{32,33} In cases of iris-sutured IOL explantation, iris trauma can be minimized by removing the IOL without cutting the sutures.³⁴ However, removing scleral-sutured IOLs may not require sutures to be cut.³⁵

After the IOL is secure in the anterior chamber, the surgeon must decide between refolding it, cutting it, using a cartridge system, or removing the lens whole. In cases where lens exchange is indicated, IOL scaffolding may prevent posterior capsular damage or posterior dislocation of the IOL being explanted.^{66,67,69} Folding the lens against an anteriorly positioned spatula using the “twist-and-out” technique or with the assistance of a cannula allows one to remove the lens via a small incision while protecting the cornea.^{49,55} Alternatively, the “S-plasty” and “cut-and-conquer” techniques enable one to remove the lens from a remarkably small incision, although these methods do require extensive cutting and rotating of the lens.^{63,64} If this extensive manipulation is a concern for the surgeon, “trisection” or “partial bisection” of the IOL require less manipulation and cutting while still enabling removal through a small incision.^{55,61} In cases where the IOL has become dislocated into the vitreous, a pars plana vitrectomy can be performed. Following this, the lens can be cleaved within the vitreous cavity, with subsequent removal of the fragments through a small corneal incision, thereby minimizing endothelial corneal damage seen with cutting in the anterior chamber.

Ultimately, the choice of IOL explantation technique depends not only on lens type and the patient anatomy but also on the surgeon’s level of experience. As discussed throughout the review, ophthalmologists less experienced in IOL removal may be more comfortable with approaches such as partial bisection, trisection, or twist-and-out refolding. On the other hand, techniques such as S-plasty, cut-and-conquer, or IOL scaffolding are newer techniques that do demand greater dexterity, likely necessitating greater comfort/training in the anterior segment. Similarly, the bimanual cleavage in the vitreous chamber technique should only be attempted by a retina specialist who is comfortable operating in the vitreous chamber.

While we have curated a comprehensive review of all the techniques of surgical explantation present in the literature, only one study has directly compared the outcomes of different methods of explantation. In a retrospective comparative series of 175 eyes undergoing explantation or exchange of one-piece foldable acrylic IOLs between 2010 and 2022, surgically induced astigmatism was minimal in the refolding and bisection groups ($\approx 0.08 \pm 0.13$ D and 0.09 ± 0.17 D, respectively) but substantially higher ($\sim 0.83 \pm 0.29$ D) in cases managed with en bloc removal via an enlarged incision. Visual acuity outcomes were otherwise equivalent across groups. Complication rates were low overall; however, bisection was associated with the highest rates of corneal edema (15.1%) and anterior chamber reaction (6.0%), both resolving with steroid treatment without consequence (70).

Other than the abovementioned study, most articles are case reports and case series that simply describe innovative techniques. This is a gap that future investigation could fill, but it will be challenging given the rarity of explantation. Even reports simply describing the techniques are rare, with only one or two case reports comprising the entire literature on many of the techniques. While it is difficult to assess outcomes of explantation, it might be beneficial to investigate which of the techniques are best performed/most efficient for ophthalmology residents to learn. This way, residents can be trained on the techniques most easily mastered in the few cases of explantation that they will encounter throughout their training.

While comparative data remain limited, it appears that visual acuity is largely equivalent across explantation techniques. With that said, en bloc removal without folding is associated with significantly higher rates of surgically induced astigmatism and should generally be avoided unless necessary (eg, rigid anterior chamber IOLs). Cutting the IOL with scissors in the anterior chamber does also appear to carry a higher risk of transient corneal edema and irritation than methods of refolding, particularly the twist-and-out method, but these complications tend to typically resolve without lasting consequence. Since cutting and refolding approaches appear comparable in outcomes, surgeon familiarity and comfort with a given technique should guide the choice of method. In cases of IOL posterior dislocation, cutting the IOL while it is still in the vitreous cavity prior to displacing it into the anterior chamber is recommended as a means to minimize unnecessary cornea endothelial damage. In summary, an abundance of techniques for IOL explantation have been described, allowing surgeons to select a few versatile techniques to master for different clinical scenarios (Table 1).

Consent Statement

Consent was obtained from all patients for the publication of clips from their surgeries in this review. All surgical videos are devoid of identifiable patient information and anonymized.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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