

# DIAGNOSTIC AND SURGICAL TECHNIQUES

MARCO ZARBIN AND DAVID CHU, EDITORS

## Techniques of Intraocular Lens Suspension in the Absence of Capsular/Zonular Support

Y.M. Por, FRCS (Glasg), MRCOphth, MRCSEd, MMed (Ophth),<sup>1</sup> and  
M.J. Lavin, MBBCh, FRCS, FRCOphth<sup>2</sup>

<sup>1</sup>Singapore National Eye Centre, Singapore; and <sup>2</sup>Manchester Royal Eye Hospital, United Kingdom

**Abstract:** Implantation of intraocular lenses has become the standard of care in the aphakic state. Ideally, the lens is placed in the capsular bag, which affords stable fixation at a position closest to the nodal point of the eye. However, there will always be instances where this will not be possible. Congenital weakness of the lens zonules in various conditions, trauma, and surgical complications of cataract surgery are just some examples. In this article, we review the methods that have been devised to allow intraocular lens implantation in the absence of capsular or zonular support. These include anterior chamber angle and iris-fixated lenses, as well as posterior chamber iris- and scleral-sutured lenses. The various lenses are described, and the techniques involved, advantages and disadvantages, complications, and results of each method are discussed. It is hoped that this article will provide a comprehensive overview of ways to deal with a problem that can still result in a very good visual outcome for the patient. This is particularly relevant given the many recent developments and refinements of methods in implanting intraocular lenses. (*Surv Ophthalmol* 50:429–462, 2005. © 2005 Elsevier Inc. All rights reserved.)

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Cataract surgery has become the most commonly performed intraocular procedure, with constantly improving outcomes. The intracapsular technique had been popular until the early 1980s. Planned extracapsular cataract extraction gradually became more widespread;<sup>4</sup> it was then further refined by phacoemulsification. With the intracapsular method, there was no provision for support of an intraocular lens by the lens capsule. This also happened if

extracapsular methods were complicated by marked zonular dehiscence or a large posterior break without an intact capsulorrhexis. Less commonly, traumatized eyes, ectopic lenses, or pediatric lensectomies resulted in an absence of capsular support.

The purpose of this review is to describe the methods devised to allow intraocular lens (IOL) implantation in the absence of capsular or zonular support. These include anterior chamber angle and

iris fixated lenses, as well as posterior chamber iris and scleral-sutured lenses. The techniques involved, advantages and disadvantages, complications, and results of each method are discussed.

### Definition

The lens capsule is the basement membrane of the lens epithelial cells. It is supported by the zonules which arise as multiple fine fibrils from the pars plana and also have attachment to the ciliary processes.<sup>19</sup>

With limited zonular dehiscence, intraocular lens (IOL) placement in the capsular bag with a stabilizing capsular tension ring (CTR) may be possible. In general, up to 6 clock hours of zonular dialysis may be present for a CTR to prevent postoperative IOL decentration.<sup>52</sup> It would also be possible for placement of an IOL in the bag if there has only been a small posterior capsular tear, a longstanding post-traumatic tear with fibrosed edges,<sup>141</sup> or a continuous posterior capsulorrhexis. Alternatively, a posterior chamber IOL (PCIOL) can be placed in the ciliary sulcus<sup>35,66</sup> without any additional support in the presence of less than 3-mm lens subluxation if the anterior capsular rim is intact.<sup>17</sup> If there is less capsular support present than described, an alternative method of IOL implantation needs to be considered.

### Causes of Loss of Capsular and Zonular Support

#### TRAUMA

Although the lens may be traumatized by a variety of forces including physical, electrical, thermal, or chemical factors, the main causes of compromised capsular and zonular support stem from contusive or direct forces from a penetrating object. Traumatic damage to the lens poses a multifaceted problem. Compromised capsular integrity may result in not only cataract but also phacoanaphylactic uveitis and glaucoma.

Blunt trauma has been reported as a cause of posterior capsule rupture.<sup>114,141</sup> Shockwaves passing through the eye may rupture the lens capsule. Alternatively, deformation of the eye with equatorial expansion can cause a breach in the lens capsule.<sup>148</sup> Typically, tears in such injuries have an oval or circular configuration in the central posterior capsule. Similarly, deforming forces may stretch and ultimately cause zonular dehiscence. Penetrating injuries to the eye may directly cause a capsular rupture.<sup>147</sup> Whatever the cause, the edges of a capsular tear become more fibrotic with time.<sup>141</sup>

Fresh tears are less fibrosed, more likely to extend during surgery and are associated with an increased risk of vitreous loss.<sup>148</sup> In such instances, implanting a PCIOL may pose a problem as there may not be enough capsule to support it either in the capsular bag or the ciliary sulcus.

#### COMPLICATED CATARACT SURGERY

Intracapsular cataract extraction results in total absence of capsular support. In complicated extracapsular cataract extraction, there may also be compromise of such support. This may be due directly to surgical trauma or to pre-existing anomalies such as a posterior polar cataract.

In planned extracapsular cataract extraction (ECCE), posterior capsule ruptures may be caused by excessive pressure during manual nucleus expression through an overly small incision. An anterior capsule tear present after can-opener capsulotomy may extend posteriorly if a capsular tag is caught during irrigation-aspiration and pulled. The posterior capsule may also be directly caught in the irrigation aspiration probe. Direct trauma may occur during IOL insertion. In large-incision ECCE, manual nucleus expression is performed by pressing the globe and increasing intravitreal pressure. The whole lens is pushed forward with the zonules.<sup>19</sup> If a capsular opening is too small or the nucleus too big, this force may exceed the tension tolerated by the zonules leading to zonular dehiscence.

Posterior capsule breaks can occur at any stage of a phacoemulsification procedure. During hydrodissection, excessive build up of intracapsular fluid without adequate decompression may result in capsular rupture. The posterior capsule may also be directly torn by accidental aspiration into the phacoemulsification probe or during aspiration of soft lens matter. As for planned ECCE, trauma during IOL insertion may tear the posterior capsule. Zonular damage during phacoemulsification may occur during various nuclear maneuvers. Inadequate hydrodissection and excessive force in attempting to rotate the nucleus are known to cause zonular ruptures. Insufficient power during sculpting results in excessive lens rocking and zonular dehiscence. Excessive separation of nuclear fragments during cracking causes traction on the zonules perpendicular to the direction of the cracking forces.

#### CONGENITAL AND SECONDARY WEAKNESS OF ZONULES/CAPSULE

The most common causes of congenital weakness of zonules lead to ectopia lentis and include Marfan syndrome, familial or idiopathic ectopia lentis, and homocystinuria.<sup>102</sup> Fortunately these conditions have

a low prevalence, with Marfan syndrome occurring in 4–6 per 100,000 births. This condition involves mutations in the fibrillin gene on chromosome 15, resulting in ocular and systemic abnormalities. In the eye, the combination of a higher risk of cataracts together with elongated zonules present a challenging management problem. In homocystinuria, the zonules are more abnormal with broken and fragmented areas. Other causes of congenital ectopia lentis are detailed in Table 1 and are much more rare.

Among later onset causes of zonular weakness, pseudoexfoliation (PEX) syndrome is perhaps the most common. The exact prevalence is unknown because many early cases escape detection.<sup>100</sup> Although the exact biochemical composition of the PEX material is not known, PEX aggregates have been demonstrated to arise from the lens epithelium in the pre-equatorial region, erupting through the capsular surface and invading the zonular lamellae. This interrupts the zonular insertion to the anterior lens capsule.<sup>100</sup> A similar process occurs at the zonular origin from the ciliary epithelium. Proteolytic mechanisms may also play a role as lysosomal enzymes have been found within PEX material. Weakening of the zonules predisposes to phacodonesis through to spontaneous lens subluxation. Apart from weak zonules, these eyes also tend to have small pupils, a compromised corneal endothelium and blood aqueous barrier, thus increasing the risk of complicated cataract surgery. Postoperatively, late IOL decentration and capsular contraction syndrome are more common in eyes with PEX syndrome.<sup>117</sup>

Other causes of weakened lens zonules include chronic uveitis, mature cataract, infantile glaucoma with buphthalmos and high myopia.<sup>17</sup> Prolonged silicone oil tamponade is also a known cause of zonular atrophy (Table 1).<sup>92</sup>

### Lens Implantation in the Presence of Incomplete Zonular/Capsular Support

When zonular attachments to the lens or posterior capsule are compromised, early recognition is

crucial. Preoperative examination may reveal phacodonesis, lens subluxation, or vitreous herniation at the pupil margin. Intraoperatively, excessive movement of the lens during capsulorrhexis or nuclear rotation and unusual capsular movement would increase suspicion of zonular dialysis.<sup>53</sup> Depending on the stage where this problem is identified, the following techniques may allow phacoemulsification of remaining nuclear fragments and limit further damage to the capsular diaphragm.

In complicated situations, the use of dispersive viscoelastic agents that maintain viscosity under medium shear, such as Viscoat (Alcon, Fort Worth, Texas), would be more important as they can maintain intraocular spaces better in the face of ongoing manipulations within the eye.<sup>72</sup> The dispersive and better coating qualities of Viscoat also increase endothelial protection. Some studies have also noted a less severe rise of intraocular pressure when Viscoat remains in the eye; this could be related to the presence of shorter hyaluronate chains.<sup>26,74</sup> As such, incomplete removal at the end of a complicated procedure is less of an issue with regard to postoperative intraocular pressure spikes, than may be the case for agents with mixed dispersive and cohesive (e.g., Healon 5 [AMO, Santa Ana, California]) or predominantly cohesive properties.

Although capsulorrhexis may be straightforward in routine cataract extraction, it may be difficult even to start the initial tear or exert traction vectors as intended when the lens is unstable. A bimanual method stabilizing the central anterior capsule with forceps through the main incision and tearing with a second instrument such as a cystotome or bifurcated spatula through the side port may be useful.<sup>103</sup> Besides this, cortical cleaving hydrodissection as described by Fine is very important to minimize zonular stress during cortical aspiration.<sup>46,47</sup> In the presence of a zonular or capsular defect, the pulling forces should always be directed toward the defect. With zonular dialyses, a tangential stripping motion in the region of the defect may further reduce extension of the defect.<sup>47</sup> This maneuver has also been labeled the *toilet tissue maneuver* (see video clips at [www.phacopearls.com](http://www.phacopearls.com)).

Osher’s slow-motion technique allows phacoemulsification with the minimum of intraocular pressure fluctuations.<sup>151</sup> In this technique, the bottle height is continuously adjusted between 35 cm and 50 cm. Low aspiration rates of 12–15 ml/min and vacuum settings of 12–15 mm Hg are used. This uninterrupted free flow infusion acts like a buffer against possible shallowing of the anterior chamber. Low power also has to be used to avoid chatter and

TABLE 1

*Causes of Loss of Capsular Support*

<b>Surgical</b>
Planned ICCE
Planned ECCE + can opener capsulotomy + PC break
Lensectomy
Zonular dehiscence (± trauma)
<b>Congenital ectopia lentis</b>
Primary
Secondary (Marfan’s syndrome, Weill-Marchesani syndrome, Homocystinuria, Sulphite oxidase deficiency, Hyperlysaemia, etc.)

repulsion of nuclear particles as low flow settings result in a lower drawing power. Alternatively, chopping techniques are useful for harder nuclei while minimizing capsular stress. This is in contrast to divide or cracking methods, which result in more displacement of the nuclear fragments.

Whatever method of phacoemulsification is used, capsular bag stability can be increased by the use of microhooks. These can either be normal iris retractors hooked over the capsulorrhexis edge<sup>79</sup> or specially designed long metallic retractors that extend to the capsular fornix (Cataract Support System, Duckworth and Kent, Baldock, United Kingdom). The latter were designed by Mackool, and they are less prone to slippage, much less likely to traumatize the capsulorrhexis, and require less manipulation intraoperatively.

Zonular damage can be minimized during IOL insertion if careful attention is given to the details of the maneuver. First, if a foldable lens is used, a slowly unfolding acrylic lens would be preferable to a silicone lens. Folding the IOL in an axis perpendicular to the axis of the haptics allows simultaneous insertion of both haptics in the capsular bag, eliminating the need for dialing or a second maneuver with forceps to insert the proximal haptic. However, the incision may have to be enlarged to a greater extent. Mackool described using a polypropylene suture to tie the haptics together and so reduce the overall diameter of the IOL to be inserted.<sup>87</sup> Once the PCIOL is in the bag, the suture is cut and the haptics can extend within the capsular bag. Plate haptic IOLs must be avoided due to the risk of postoperative decentration and capsular contraction.<sup>31</sup>

In the presence of limited zonulolysis, the dilemma of where to place the IOL haptics can arise. Haptic placement in the axis of the zonulolysis reduces ovalization of the capsular bag but also reduces support for one haptic. Haptic placement perpendicular to this provides more support for the haptics but will increase capsular ovalization and the risk of decentration. This problem is eliminated if a CTR is used.<sup>31</sup>

A CTR stabilizes the capsular bag and distributes deforming forces more evenly throughout the capsular bag. If lens subluxation is noted prior to surgery, it should be inserted before phacoemulsification. If zonular compromise is noted during surgery, immediate placement of a CTR in the capsular bag has been recommended.<sup>53</sup> By placing this anterior to the cortex after hydrodissection, cortex entrapment between the CTR and capsular bag can be avoided. The addition of a small viscodissection, after hydrodissection, may further reduce the possibility of cortical entrapment by the CTR.

Capsular tension rings can be inserted either with forceps or injectors (Ophtec [Groningen, The Netherlands], Geuder [Heidelberg, Germany]). The latter are suitable for use with Ophtec and Morcher (Stuttgart, Germany) CTRs. When inserting CTRs, Menapace recommends insertion of the leading end at an acute angle into the capsular bag.<sup>93</sup> The crossover point between the CTR and capsulorrhexis should be kept as proximal as possible during insertion and can be done by using a Y-spatula through a side port. Together with a large capsulorrhexis, the risk of catching the posterior capsule or capsular fornix with the leading end of the CTR can be minimized. Sometimes the lack of zonular support and consequent lens mobility prevent safe insertion of a CTR: as the CTR advances the lens is displaced. In this situation, the CTR ends can be bent and crossed over, converting the usual CTR 'C' shape (open circle) into a shape like the letter alpha. A 10-0 suture is tied around the crossing point of the haptics to maintain the alpha shape during insertion of the body of the CTR into the capsular bag. The trailing ends of the CTR are then dropped into the capsular bag, and the suture is cut, releasing the CTR ends into the bag. This "alpha" technique is similar in concept to pre-tying the haptics of a PCIOL, then cutting the suture to allow haptic extension once the PCIOL is in place within the capsular bag.<sup>87</sup>

Recently, Ahmed designed a segment capsular bag implant (see the section Capsule Tension Segment, type 6E [Morcher, Stuttgart, Germany]), with suture eyelets on each end, and which extends for 90°. It has a curved loop extending anteriorly over the capsulorrhexis with a suture eyelet. The device can be placed into the bag (no countertraction needed, no zonular stress), and an iris retractor can be hooked through the anterior eyelet to provide support for the lax capsular bag during phacoemulsification. Following phacoemulsification, permanent fixation is achieved with transscleral fixation or the segment is removed and replaced with either a standard CTR or the Cionni CTR.

After IOL and CTR placement, Cionni and Osher describe testing IOL stability by performing a bounce-back test.<sup>33</sup> This involves deliberate gentle decentration and release of the IOL. If this fails to result in spontaneous recenteration, the haptics can be reoriented and reevaluated. If this is again unsuccessful, they suggest suturing at least one haptic of the IOL.<sup>33</sup>

Alternatively, recenteration can be achieved by passing the needle of a scleral suture through the equator of the capsular bag, just central to the CTR.<sup>48,71</sup> (R. Osher, MD, 'New Approach: Synthetic Zonules,' Video Journal of Cataract and Refractive

Surgery, 1997, Volume 13, issue 1). This method uses straight needles on a double armed 10-0 polypropylene suture. The needles are passed from the corneal wound into the capsular bag, one above and one below the CTR. The needles then exit the globe through the ciliary sulcus. The suture ends, 1.5 mm posterior to the limbus, are tied and the knot rotated and buried. The disadvantage of this technique is that the sutures affect capsular integrity and haptic manipulation within the capsular bag can cause equatorial capsular tears with vitreous loss.<sup>71</sup> The introduction of modified capsule tension rings has superseded this technique. The use of the Cionni ring allows suture fixation of the CTR via an eyelet on the fixation hook. The capsular bag is also supported without its integrity being affected by sutures. To secure the Cionni ring, a double-armed suture is passed through the eyelet. The needles are placed through the incision, behind the pupil and through the scleral wall at the area of greatest zonular weakness prior to implanting the ring. After implantation, the hook can be used to dial the ring so that the eyelet is closest to the site of suture anchorage. The Cionni ring can also be used without initial suturing, with the extra suturing steps only being undertaken if there is unsatisfactory centration of the IOL/capsular bag after ring implantation.

In many cases, the above steps can help to salvage the situation while minimizing intraocular manipulation. However, in instances where there is total or almost total absence of capsular support, an intracapsular cataract extraction or pars plana lensectomy followed by alternative methods of IOL implantation need to be considered.

In the calculation of IOL power prior to implantation, many different formulas have been devised. They can be divided in general into theoretical and regression formulas. The earliest were theoretical, but in the 1980s regression formulas (exemplified by the SRK I and II) gained favor. Currently, the more popular formulas are theoretical and include the SRK-T, Hoffer-Q, and Holladay 1 or 2 formulas.<sup>123</sup> These provide greater accuracy for extremely short or long eyes. They also incorporate a constant that takes into account the post-operative anterior chamber depth (ACD). For the SRK-T, this is the A constant (also used in the SRK-II). The Hoffer formula uses an estimation of the post-operative ACD and the Holladay formula uses an S factor, which is the distance between the anterior iris plane and the optical plane of the IOL. Table 2 gives an indication of some of the commonly used values with different formulas and IOL implantation sites.<sup>123</sup>

The A constant used in the SRK formulas incorporates multiple variables, including implant location within the eye, surgical technique, and IOL

design. Because of the configuration of the SRK regression formulas ( $P = A - 2.5L - 0.9K$ ), knowing the A constant allows the surgeon to easily calculate for and select an alternate IOL to implant even if the calculations have previously been done for a different IOL. For example, if an ACIOL ( $A = 115.3$ ) was required after complicated cataract surgery and preoperatively the biometry calculated for a PCIOL ( $A = 118.9$ ) of +23.0 D to achieve emmetropia, the required ACIOL to achieve an equal postoperative refraction would have a power of +19.5 ( $23 - [118.9 - 115.3] = 19.4$ ). In other words, the difference in the A constants is subtracted from the power of the PCIOL that was originally selected. When a PCIOL is placed in the ciliary sulcus instead of the capsular bag, a reduction of IOL power of 0.5 D has been suggested to compensate for the more anterior IOL location.<sup>60</sup>

## Designs and Methods of Fixation

### ANTERIOR CHAMBER INTRAOCULAR LENSES

#### Angle-supported Lenses

Since the first implantation of an anterior chamber intraocular lens (ACIOL) in 1952 by Baron, many modifications have been made. Currently the most commonly used designs are flexible open loop ACIOLs, which have a lower rate of complications than the earlier closed loop or open 'C' loop lenses.<sup>118</sup>

These have footplates incorporated into each haptic and provide minimal and stable areas of contact with the anterior chamber angle.<sup>37</sup> They affect the anterior chamber angle structures less and because the risk of goniosynechia formation is reduced, these lenses tend to be easier to explant without undue damage to surrounding structures.

Most ACIOLs now also have an anterior vault, minimizing the risk of IOL-iris touch and iris chafe. This anterior vault is less than in some earlier designs, and with appropriate flexibility reduces the incidence of intermittent or persistent corneal touch.<sup>3</sup>

The technique of insertion of angle-supported anterior lenses is relatively simple, although they may be difficult to insert correctly;<sup>65</sup> the ten steps are listed below. The aim is to place the ACIOL in the anterior chamber with the footplates resting against the scleral spur, without capturing any iris tissue or interfering with any existing iridectomies. With these factors in mind, it has been recommended that ACIOLs be placed horizontally through a temporal corneal or sclerocorneal incision.

1. A horizontal white-to-white measurement is made of the corneal width to avoid a large discrepancy between the angle size and the

TABLE 2

*Comparison of the SRK, Hoffer Q, and Holladay Formulas with Respect to Type of IOL and the Respective Constants*

	A Constant (SRK Formulas)	ACD (Hoffer-Q)	S Factor (Holladay Formula)
ACIOL	115.0–115.3	2.8–3.1 mm	–0.75 to –0.40
PCIOL in sulcus	115.9–117.2	3.7–4.1 mm	0.10–0.70
PCIOL in bag	117.5–118.8	4.3–5.1 mm	0.90–1.60

(Adapted from Shammas.<sup>122</sup>).

- IOL size. (IOL diameter should be 1 mm greater than the above measurement)
- A grooved incision is made at the temporal region
- A stab incision is made and anterior vitrectomy is performed if vitreous is present
- Acetylcholine is injected followed by viscoelastic
- The incision is enlarged
- A lens glide is inserted into the anterior chamber through to the opposite anterior chamber angle
- The ACIOL is then inserted over this glide, taking care to avoid catching iris tissue, which would manifest itself as ovalization of the pupil
- The glide is removed, and the proximal haptic is passed behind the edge of the incision to lie in the proximal angle
- A peripheral iridectomy is performed
- Viscoelastic is removed, and the wound is sutured closed

### Iris-fixated IOL

Several anterior chamber iris-fixated lens designs have been developed over the years. Earlier designs included iris clip lenses and iridocapsular lenses. Iris clip lenses were fixated to the pupillary border usually via four clips, while the haptics in iridocapsular lenses were fixated by adhesions between the anterior lens capsule and the iris.<sup>7</sup>

The design still in current usage, including in the phakic correction of the myopic state, is the iris claw lens. Originally designed by Worst in 1978, there have been significant modifications to their design.<sup>152</sup> They are commonly placed just anterior to the iris and secured by pulling small sections of mid peripheral iris through the claws.<sup>7</sup> Alternatively, they have also been fixated to the posterior iris surface where the anterior chamber is very shallow or in the presence of extensive peripheral synechiae.<sup>116</sup> The steps for insertion are listed below:

- 3 and 9 o'clock paracenteses are made
- A superior sclerocorneal incision is made, and anterior vitrectomy performed, if necessary

- Acetylcholine is injected followed by viscoelastic
- The lens is inserted and positioned
- The midperipheral iris is grasped with forceps and pulled through the claws at the 3 and 9 o'clock positions
- A peripheral iridectomy is performed
- Viscoelastic is removed, and the wound is sutured

### Posterior Chamber Intraocular Lenses

Being located in a position closest to the original lens, PCIOLs possess the inherent advantages of having a position close to the nodal point of the eye and also of being close to the eye's rotational axis.<sup>6,17,64</sup> Apart from the optical benefit of minimal aniseikonia when compared with the phakic eye, this places the IOL in a position furthest from the corneal endothelium and avoids the trabecular meshwork. They may provide a mechanical barrier against vitreous movement or diffusion of vasoactive substances that could lead to retinal detachment or cystoid macular edema.<sup>128</sup>

### IRIS-SUTURED PCIOL

#### Haptic Suture Fixation to Iris (Fig. 1)

McCannel in 1976 described his method of iris suturing which has been used for securing a PCIOL to the iris<sup>90</sup> (see video clips of iris suture fixation at [www.phacopearls.com](http://www.phacopearls.com)):

- Paracenteses are made at 3 and 9 o'clock
- Removal of any vitreous in anterior chamber
- PCIOL inserted through main incision at 12 o'clock. Haptics inserted into ciliary sulcus and optic capture by pupil is induced. This can be facilitated by the injection of intracameral acetylcholine. The haptics will be outlined against the posterior surface of the iris
- A single armed 10-0 polypropylene suture on a CIF or CTC needle (Ethicon, Somerville, New Jersey) is passed through peripheral cornea, iris, under the haptic and back through iris and peripheral cornea

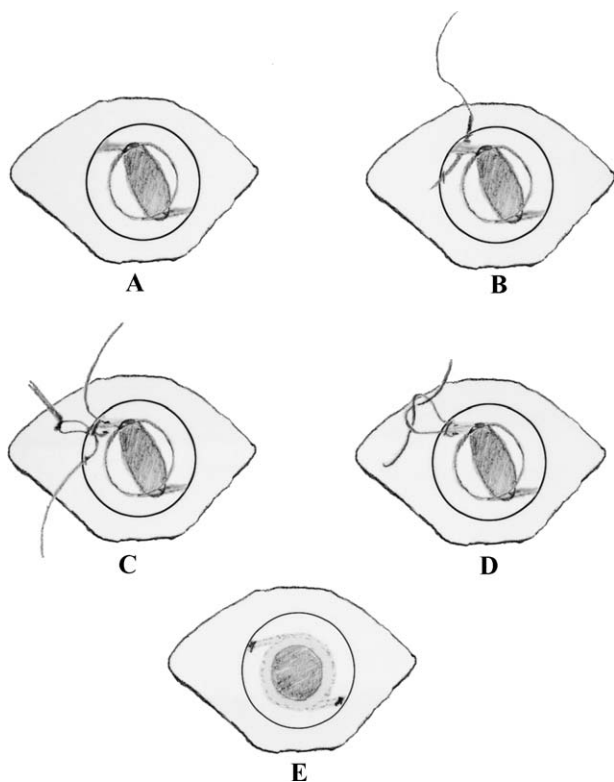


Fig. 1. A: Pupil capture is induced with the optic anterior to the iris. B: A curved needle is inserted through clear cornea, iris, underneath the haptic, and comes out again through iris and cornea. C: The suture is externalized via a paracentesis overlying the PCIOL haptic. D: The suture is tied. E: The optic is pushed back behind the iris. (Modified from Ashraf and Stark<sup>7</sup> with permission of Elsevier.)

5. After cutting off the needle, both suture ends are retrieved through a paracentesis with a Sinskey or Lester hook
6. The suture ends are tied and cut at the paracentesis and the iris pushed back into place
7. After this is repeated at the other haptic, the optic is repositioned behind the iris
8. The main incision is closed after viscoelastic removal

More recently, Chang has described suturing the haptics to the iris using Siepser's sliding knot technique.<sup>29</sup> This technique avoids excessive traction on the iris and an extra, central paracentesis but requires a wound large enough to admit Vannas scissors or the use of microincision scissors for intraocular cutting of the knots.

**Optic Fixation to Iris**

Optic fixation to the iris is another method of iris fixation of the PCIOL.<sup>101</sup> However, it involves fixing the optic rather than the haptic to the iris. The steps are as follows:

1. A Flieringa ring is sutured to the eye
2. A superior limbal incision is made to insert the IOL
3. A double-armed 10-0 polypropylene suture with straight needles on either end (Ethicon 1713G STC-6[Ethicon, Somerville, New Jersey]) is threaded through two adjacent holes of an optic with four holes
4. A second 10-0 polypropylene suture with double armed, short curved needles (Ethicon 2790G BV75-3[Ethicon, Somerville, NJ]) is passed in a mattress fashion through the two remaining holes
5. Removal of any vitreous in the anterior chamber
6. The two straight needles are passed through the incision, through the pupil, behind the inferior iris, anteriorly through inferior iris stroma, and out through peripheral inferior clear cornea
7. The sutures are hooked and tied through a paracentesis adjacent to the needle exit sites after the needles are cut off
8. The two curved needles are passed through superior iris adjacent to the incision and tied to the anterior iris surface
9. A peripheral iridectomy is made
10. Viscoelastic is removed and the incision sutured

**TRANSSCLERALLY SUTURED PCIOL**

Malbran et al first reported transscleral sulcus fixation of PCIOLs in aphakes post ICCE in 1986.<sup>88</sup> PCIOLs can also be sutured at the pars plana.<sup>54,138</sup> Even though most PCIOLs can be sutured via their haptics to the sclera with square knots or slipknots, there are several specialized haptic designs, which facilitate this maneuver. These include haptics with an enlarged end to avoid suture slippage. If this is not present, the enlargement can be created by heating the haptic end gently with a cautery device. However, this voids the warranty and creates a rough surface.<sup>6</sup>

Various holes or eyelets that allow passage of a suture through the haptic have also been developed to reduce potential suture movement or instability. In addition, eyelets allow particular types of suture fixation as described below. Commonly used PCIOLs include the Alcon CZ70BD (Alcon, Fort Worth, Texas), Bausch and Lomb 6190B (Bausch and Lomb, San Dimas, California) and the Pharmacia U152S (AMO, Santa Ana, California), which have one eyelet on each haptic. The Opsia (Chauvin Opsia, Labege Cedex, France) Grenat IOL has two eyelets on each haptic and has

been used in a variation of Lewis' flap free technique<sup>80</sup> by Cordoves et al.<sup>34</sup> Teichmann designed an IOL with haptics which had two holes drilled 2 mm apart.<sup>139</sup> This allows a continuous-loop, four-point fixation technique without inducing torque.

For pars plana fixation, a PCIOL must have an increased diameter of about 17 mm with an optic diameter of about 7 mm. Backward angulation of the haptics allows the optic position to be closer to the original lens position. The A constant would then be similar for in-the-bag placement.<sup>138</sup>

Several needles are available for suturing PCIOLs. The Ethicon TG-160-2, Ethicon CIF-4, and Ethicon STC-6 (Ethicon, Somerville, New Jersey) can be used for ab interno methods. The STC-6 straight needle is also often used in ab externo methods. Pannu designed a long curved needle with a hole at the sharp end.<sup>108</sup> This allowed suturing the PCIOL by an ab interno method without requiring passage of the whole needle through the eye. In general, 10-0 polypropylene has been the suture material of choice. Owing to recent concerns about the durability of this suture, however, there has been increasing use of 9-0 polypropylene and other suture material such as Gore-Tex for the transscleral fixation of PCIOLs.

Although there are several common steps, many methods and variations on technique have been described to suture the IOL in place.

## Technique

The aim in the most commonly used techniques is to place these lenses into the ciliary sulcus, although the final position is not entirely predictable because it is often undertaken as a blind procedure. PCIOLs implanted with transscleral fixation can be rigid or foldable. With respect to technique, there are several stages in the procedure where significant variations have been described:

1. The method of introducing suturing needles—ab externo or ab interno
2. The method of securing the haptic with the fixating suture
3. The number of points of PCIOL fixation
4. The method of avoiding suture/knot erosion

Originally, suturing techniques involved passing the needle from inside to outside the eye. Although this method may be quicker and is easier when penetrating keratoplasty is performed concomitantly, it is a blind procedure.<sup>5</sup> More recently the lenses have been sutured via an ab externo technique as described by Lewis.<sup>81</sup> This is also undertaken blindly

in that the intraocular exit point of the needle is unseen, but by knowing the entry point, sulcus positioning of the suture may be more predictable.<sup>6,39</sup> With the ab externo technique, the AC can and should remain closed during needle passes. This avoids collapse of the ciliary sulcus in the hypotonous eye, thus facilitating accurate suture placement.<sup>2</sup> It also avoids the risk of catching vitreous with the needle and incarcerating it at the fixation points.<sup>77</sup> In eyes with an increased tendency toward globe collapse (e.g., low scleral rigidity, small palpebral fissures, Oriental eyes) performing anterior vitrectomy via the pars plana and utilizing a scleral tunnel instead of corneal incision are other measures that help preserve globe integrity during suture placement.<sup>153</sup>

PCIOL haptics can be secured by looping a suture over the haptic and tying several square knots,<sup>126</sup> by using a slipknot,<sup>78</sup> or by using a girth hitch.<sup>44,64</sup> If a haptic eyelet is present, it could also be secured by a suture loop with the knot initially tied outside the eye, then rotated and buried in a second maneuver.<sup>80</sup> Asymmetrical suture placement in this method may produce a net torque on the haptics and tilting of the IOL optic.<sup>140</sup> Teichmann and Teichmann demonstrated in a model four perfect ways of threading a suture through the haptic eyelet for tying in this manner. To avoid suture-induced tilt, the surgeon needs to thread corresponding sutures 180° apart in a symmetrical fashion through the two eyelets, either from above down or from below up (Figs. 2 and 3).<sup>140</sup>

Alternatively, the suture could be passed through two separate holes in the haptic before fixation as described by Teichmann.<sup>139</sup> In general, this method or the use of a girth hitch may provide better stability against rotation via two-point fixation of each haptic.

Malbran et al's original technique employed two-point scleral fixation. Subsequently, one-, three-, and four-point fixation techniques have been described.<sup>9,15,16,80,107,113</sup> Although more points of fixation allow greater stability with less risk of decentration and tilt, this must be balanced against the greater risk of complications from multiple suture passes through sclera, uvea and the vitreous cavity. Wherever possible, capsule remnants should be used for IOL support and this may even be sufficient to allow one-point scleral fixation.<sup>9,107</sup> Knowing the patient's history, especially of the mechanism of trauma or type of surgery previously undertaken is helpful in anticipating the amount and location of capsular remnants. On the other hand, if the zonules are known to be weak from preexisting ocular disease, it would be prudent to rely more on sutures rather than capsular remnants.



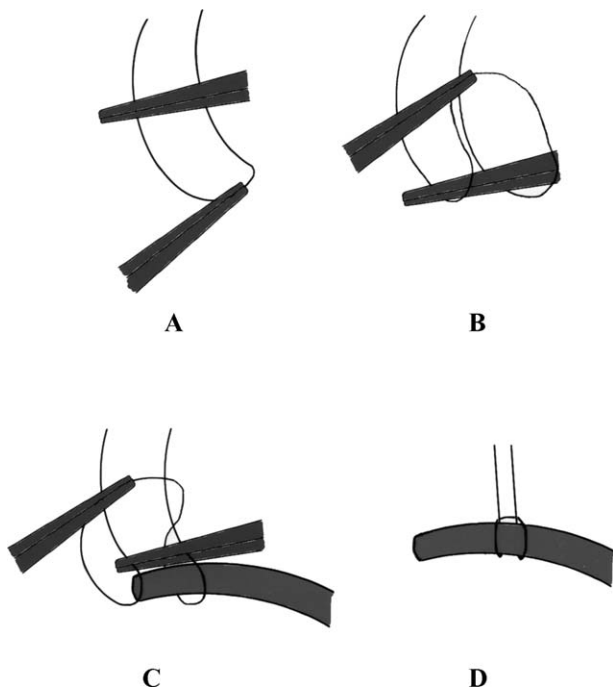


Fig. 2. Tying the girth hitch. *A and B:* A suture loop is bent over closed forceps. *C:* While holding the tip of the loop with one pair of forceps, the other forceps pulls the two proximal suture strands through the loop. This creates two other laterally disposed loops through which the PCIOL haptic is placed. *D:* A girth hitch securing an IOL haptic.

Prior to IOL implantation, an attempt should be made to determine the amount of useable capsule. Viscoelastic can be injected both above and below the iris, the latter helping to free up iris-capsular adhesions. A Kuglen hook is used to push the iris more peripherally to expose capsular remnants. In

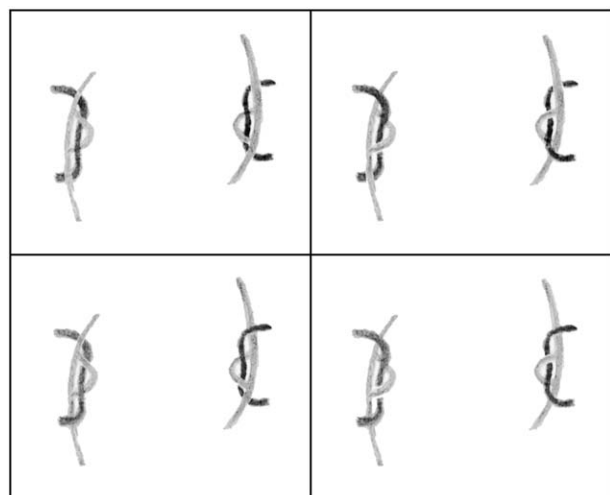


Fig. 3. Four perfect ways of threading a suture through the haptic eyelet for suture fixating a PCIOL according to Lewis' flapless technique. (Reproduced from Teichmann et al<sup>140</sup> with permission from the ASCRS & ESCRS.)

the presence of tenacious adhesions, blunt and sharp dissection can be used in addition to viscoelastic to separate capsular remnants from the iris and create a space for the IOL haptic. In general, 3 clock hours of anterior capsule should provide adequate support for one haptic.

To avoid erosion of the knots through conjunctiva, scleral flaps can be used to cover knots<sup>81,110,113,114</sup> or they can be rotated into scleral tissue without flaps.<sup>80</sup> Besides this, the suture loops are sometimes left long and Tenon's and conjunctiva sutured over them.<sup>96,126</sup> Mittelviefhaus and Wiek described posteriorising the knot after closure of the corneoscleral wound. At the exit point of the needle, a partial thickness radial slit is cut and the needle then inserted at its peripheral end. The needle is brought intrasclerally to a point 4–5 mm posterior to the limbus where another scleral bite is taken and the suture tied to itself.<sup>97</sup> The knots were thus covered with thicker posterior Tenon's capsule and conjunctiva.

Prior to introducing and suturing the PCIOL, a generous anterior vitrectomy should be performed to avoid vitreous traction.<sup>57</sup> This should clear vitreous especially around the areas of suture insertion, also termed the *anterior vitreous skirt*. The vitrectomy can be performed either via the corneoscleral wound (for IOL introduction) or pars plana. In general, the use of a non-peristaltic pump is preferred. Traditionally, vitrectomy in such situations was performed via the incision for the phacoemulsification probe. A vitreous cutter with coaxial infusion was employed. However, the infusion jet exited very near the cutting end of the probe, tending to hydrate and disturb vitreous in the anterior chamber and potentially causing more vitreous to prolapse. Separating the infusion and cutting functions using a two-port (anterior approach) or three-port (pars plana approach) technique minimizes this. The identification of residual vitreous strands can be achieved by the use of a fiberoptic light pipe, the introduction of an air bubble and sweeping inward around the pupil looking for any simultaneous movement of the pupil margin. Recently, the use of a triamcinolone suspension (Kenalog) to visualize prolapsed vitreous was described.<sup>24</sup> The following section describes the major methods which have been used to suture PCIOLs.

**AB EXTERNO TWO-POINT FIXATION + SCLERAL FLAPS**

This method leaves a knot at the surface and requires a scleral flap to prevent suture erosion (Fig. 4).<sup>80</sup> The steps involved are listed below:

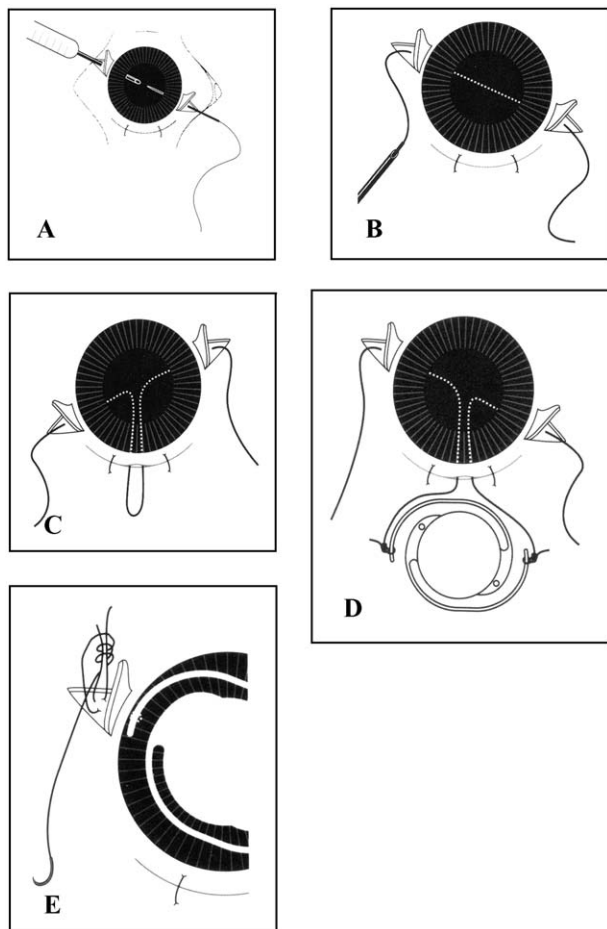


Fig. 4. A: A straight needle is inserted ab externo and retrieved at the opposite scleral bed with a hollow needle. B and C: A loop of suture is hooked out of the eye. D: The suture is cut and the ends tied to the haptics. The PCIOL is inserted into the eye. E: A second suture is used to take a bite anterior to the original suture's exit point. The long end of the second suture is tied to both its short end and the lens-fixing suture. (Modified with permission from Lewis.<sup>81</sup>)

1. A superior conjunctival peritomy is fashioned from 4 to 10 o'clock
2. Triangular scleral flaps 3 mm high by 2 mm wide are fashioned at 4 and 10 o'clock
3. A 7-mm corneoscleral wound is made followed by anterior vitrectomy
4. A straight needle attached to a 10-0 polypropylene suture is passed through the bed of a scleral flap 1.5 mm posterior to the limbus in a direction parallel to the iris, until its tip is visualized through the pupil
5. A 28-G hollow needle passed through the opposite scleral bed is used to retrieve the straight needle, via its barrel
6. The hollow needle is withdrawn from the eye, leaving the 10-0 polypropylene suture traversing the eye from one scleral bed to the other

7. A Sinsky hook is used to pull out a loop of this suture out through the superior corneoscleral wound
8. This loop is cut, with one end tied to the superior haptic and the other to the inferior haptic of the IOL
9. The IOL is inserted into the ciliary sulcus and the sutures gently pulled to secure the position of the lens
10. A second 10-0 polypropylene suture is used to take a bite just anterior to the original suture's exit point within a prepared scleral bed. The long end of the second polypropylene suture is tied to both its short end and the lens-fixing suture
11. This is repeated at the other scleral bed
12. The scleral flaps and conjunctival peritomy are closed

## VARIATIONS

### Direct Ab Externo Insertion of Sutures

This method is similar to the above except that separate sutures on two straight needles are passed into the eye, one each through the scleral beds at 4 and 10 o'clock 0.5–0.75 mm posterior to the limbus.<sup>123</sup> The needles are passed directly out of the eye through the superior corneoscleral wound. This avoids the need to pass a hollow needle to retrieve the suture that had been passed through the opposite scleral bed, as well as the next step of retrieving the suture with a Sinsky hook. However, passage of the needles from the wound may damage intraocular structures and distort the globe.<sup>10</sup>

Basti et al modified the direct introduction of sutures by utilizing 26-gauge hollow needles through which the free end of polypropylene sutures on curved needles were passed.<sup>10</sup> The hollow needle and loop of suture were passed ab externo through the sclera and ciliary sulcus, 0.50–0.75 mm from the posterior surgical limbus. The suture was withdrawn from the main incision with McPherson forceps. One advantage of this method is that it only requires routinely available materials. There is also relatively little manipulation of the globe (Fig. 5).

### Small-incision Technique

This method is very similar to one originally described by Hu et al in 1988,<sup>63</sup> except for the use of a small incision and foldable PCIOLs.<sup>112</sup> The steps are as follow:

1. Two 5-mm peritomies and two 3 × 3-mm triangular half-thickness scleral flaps are made 180° apart

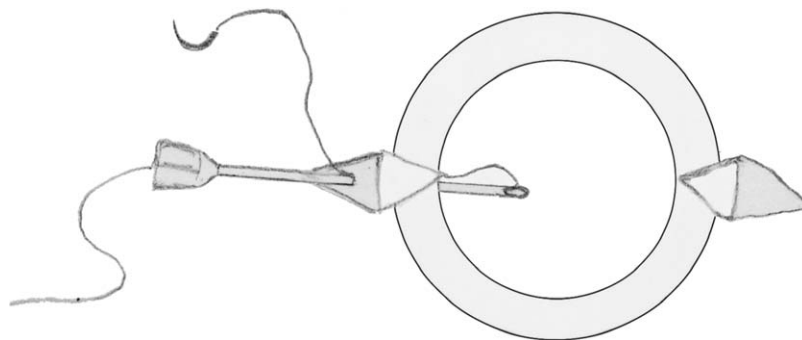


Fig. 5. The direct introduction of a suture by a 26-gauge hollow needle through which the free end of a polypropylene suture on a curved needle was passed. (Modified from Basti<sup>10</sup> with permission of the ASCRS & ESCRS.)

2. A 25-G hypodermic needle is passed in an ab externo fashion through one scleral bed and out through the opposite bed in an ab interno fashion (distance from limbus not specified, although Duffey at al's<sup>39</sup> measurements may be used as a guide)
3. The cut end of a 10-0 polypropylene suture is threaded through the full length of the needle, which is then withdrawn
4. The anterior chamber is entered through the superior scleral bed with a keratome, making a 3.5-mm self-sealing incision
5. The prolene suture is retrieved with a Kuglen hook and pulled out through the superior incision
6. This is cut in half. One end is tied to the superior haptic, and the other end tied to the inferior haptic of the IOL
7. The IOL (Acrysof MA60BM [Alcon, Fort Worth, Texas]) is folded and then inserted through the superior incision
8. The rest of the procedure is the same as the steps above (10–12) (Fig. 6)

- reverse position together with the attached 10-0 prolene suture
3. A lens dialer is used to pull the suture out through the corneoscleral wound
4. This is repeated at the opposite scleral bed

Small-incision techniques were also described by Regillo and Tidwell<sup>115</sup> and Tsai and Tseng,<sup>143</sup> modifying Lewis's original method with the use of a small incision and foldable silicone lenses.<sup>81</sup>

**Haptic Looping Method<sup>44</sup>**

This method is similar to another originally described by Hu et al in 1988,<sup>64</sup> and the steps are listed below (Fig. 7):

1. Peritomies and scleral flaps are made as above in the 2 and 8 o'clock positions. A superior corneoscleral wound is fashioned
2. A straight needle is inserted into the globe to make a port 1 mm posterior to the limbus. It is then withdrawn, and inserted again in the

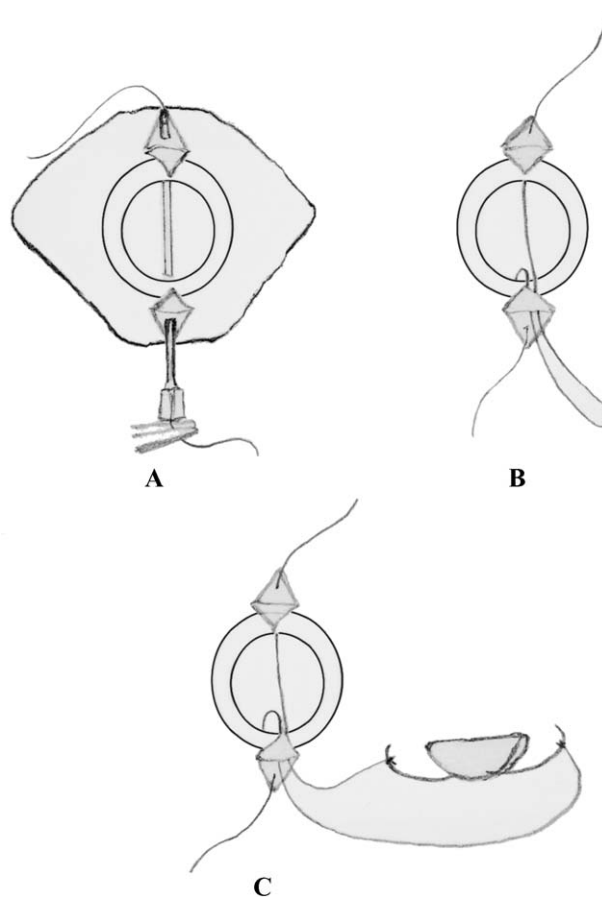


Fig. 6. A: A 25-gauge needle is passed ab externo through one scleral bed and out through the opposite bed ab interno. B: A suture loop is hooked out. C: The loop is cut, the ends tied onto the haptics, the PCIOL folded and then inserted into the eye. (Modified from Ramocki<sup>112</sup> with permission of Elsevier.)

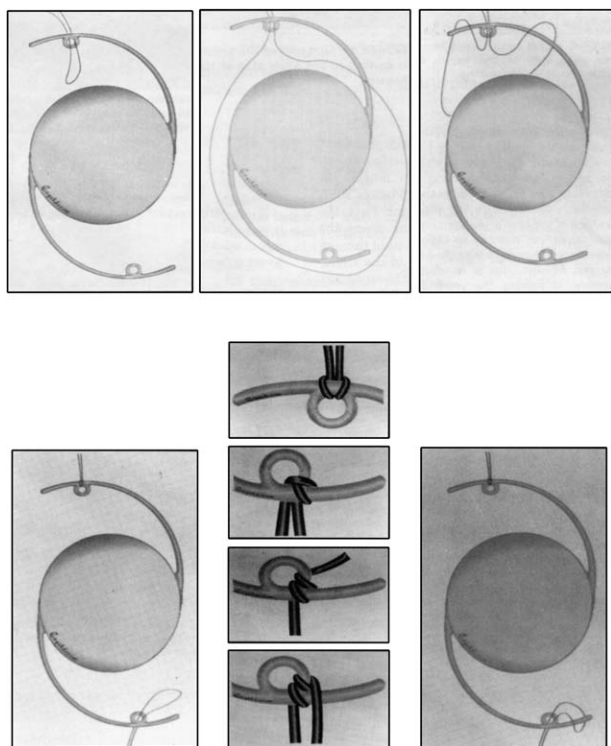


Fig. 7. Two ways of securing PCIOL haptics without knots (Modified with permission from Eryildirim.<sup>44</sup>)

5. Each suture loop is inserted through the haptic eyelet of a rigid PMMA lens. At one end, the loop is passed over the IOL. At the other end, the loop is passed over the haptic to lock the suture over the eyelet
6. The IOL is implanted in the posterior chamber
7. A needle holder is used to curve the straight needles and another bite is taken through the respective scleral bed. The suture is then tied on to itself, and cut long to avoid eroding the scleral flaps and conjunctiva

#### Ab Externo Continuous-loop Fixation

This technique (Fig. 8) allows burying the knot and does not require a scleral flap, but it may cause torque and tilt.<sup>81</sup> The steps associated with this technique are listed below:

1. A peritomy is made from 4–10 o'clock and a superior corneoscleral wound is constructed
2. A straight needle is passed from one scleral bed to the opposite bed, 0.8–1.0 mm from the limbus
3. The needle is then turned around and passed back into the eye and it emerges at the original scleral bed
4. Both transscleral sutures are withdrawn and cut

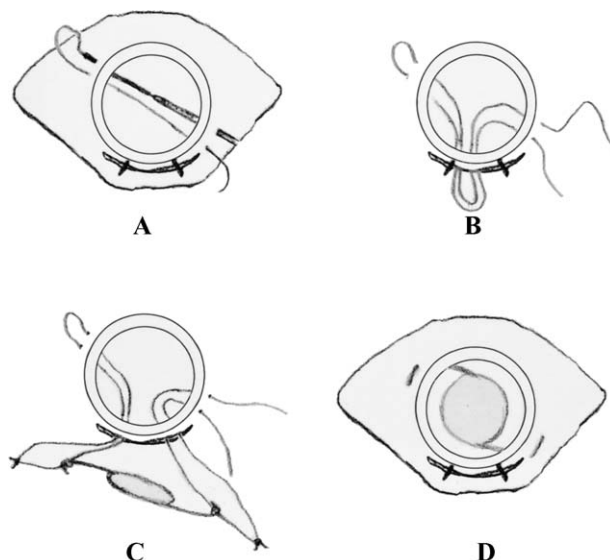


Fig. 8. A: After passing a needle ab externo and retrieving it via another hollow needle, it is turned around and the process repeated. B: The double suture loop is externalized. C: The loop is cut and the ends threaded through each haptic eyelet and tied. The knots are rotated out of the eye, and the PCIOL inserted. D: After tying the externalized suture, the knot is rotated into the eye (Modified from Lewis<sup>80</sup> with permission of the American Academy of Ophthalmology.)

5. One cut end at each side is passed through the corresponding eyelet and the sutures are tied to themselves
6. The initial knot is rotated out and the lens is placed in the sulcus
7. The long loops are cut, shortened, and tied
8. The final knot is rotated into the eye

#### VARIATIONS

##### Ab Externo Continuous-loop Fixation With Scleral Flaps<sup>113</sup> (Fig. 9)

The steps associated with this technique are listed below:

1. Conjunctival flaps are created at 3 and 9 o'clock limbus
2. Superior 7-mm clear corneal incision is made
3. L shaped scleral incisions are made at 3 and 9 o'clock positions, and the limbus based flaps are created
4. A needle with a 10-0 prolene suture is passed through one scleral bed 1 mm below the horizontal meridian, 1 mm posterior to the surgical limbus. It is guided out of the superior corneal incision with a 27-G needle
5. This suture is threaded through an eyelet from below upwards, and it is passed back into the

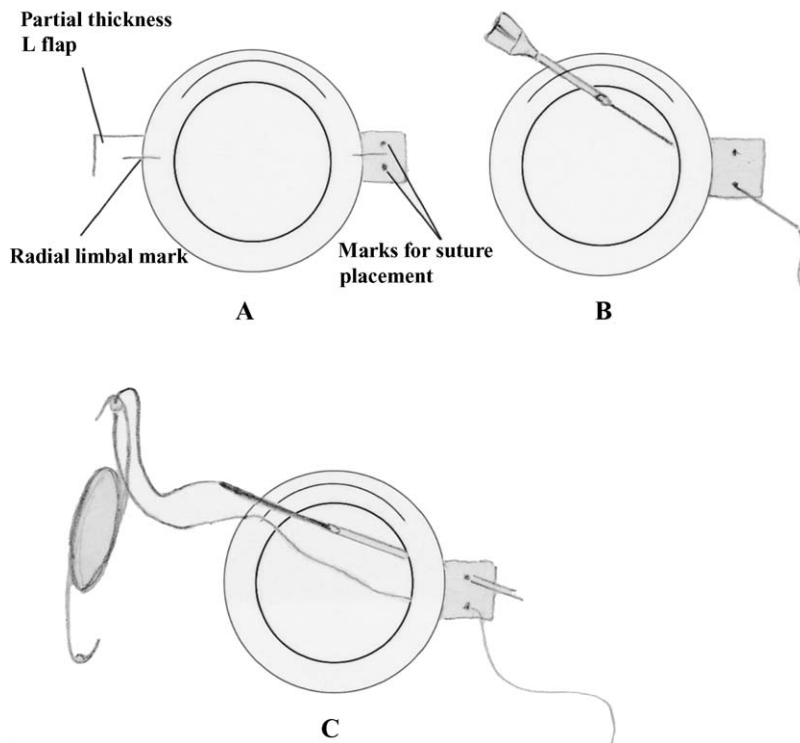


Fig. 9. A: Initial marking for procedure. B: A straight needle is inserted through one scleral bed and retrieved through the corneal incision with a hollow needle. C: After threading it through a haptic eyelet, it is passed back through the corneal incision and retrieved via a hollow needle from an adjacent point on the same scleral bed (Modified from Rao<sup>113</sup> with permission of the ASCRS & ESCRS.)

eye through the corneal incision and guided out of the eye by another 27-G needle inserted through the same scleral bed in an ab externo fashion 1 mm above the horizontal meridian, 1 mm posterior to the surgical limbus

6. Steps 4 and 5 are repeated for the other haptic
7. The corneal wound is fully opened and the IOL is inserted into the posterior chamber
8. The sutures are gently pulled, tightened and tied. The knot is rotated into the eye
9. The scleral and conjunctival flaps are closed

**Limbal-groove Incision and Double-suture Fixation to Haptic<sup>16</sup> (Fig. 10)**

The steps associated with this technique are listed below:

1. A peritomy is made from 4–8 o'clock, and 3-mm scleral grooves (parallel to the limbus) are placed 0.5–0.75 mm from the limbus at the 3 and 9 o'clock positions
2. A superior limbal incision is made
3. A double-armed 10-0 polypropylene suture on a straight needle is passed through one end of the scleral-groove incision. It is directed anteriorly through the pupil and out through clear cornea near the opposite limbus. The other arm

of the suture is passed in a similar fashion through the other end of the scleral groove incision

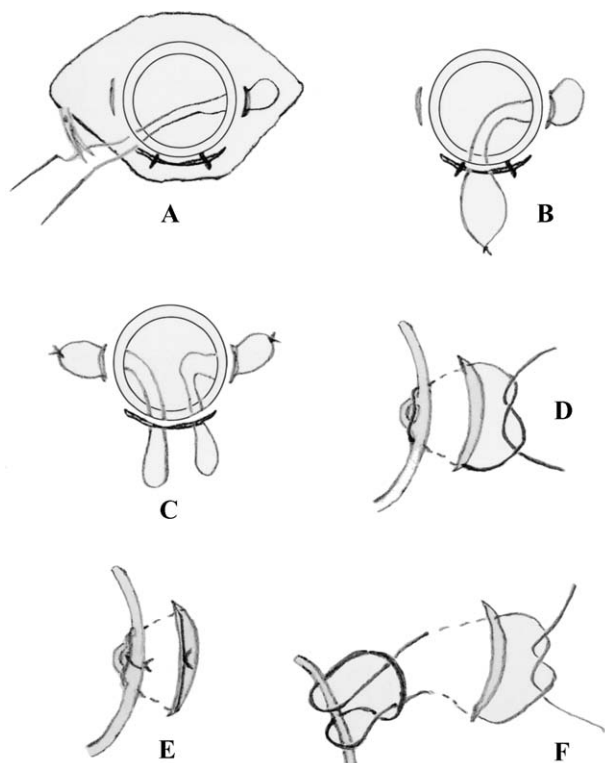
4. The needles are cut, and the sutures are pulled out through the superior limbal incision with a small hook
5. The ends are tied, and the knot is rotated until it exits the scleral groove
6. The procedure is repeated at the opposite scleral groove

**Variation**

A similar method was described by Friedberg and Berler to suture fixated PCIOLs after vitrectomy.<sup>51</sup> After pars plana vitrectomy, limbal grooves were created at 1:30 and 7:30 positions 0.75 mm posterior to the surgical limbus. Instead of passing the needles out through the opposite clear cornea, they utilized the method employed by Lewis of using hollow needles to withdraw the inserted suture needles through the opposite limbal groove. This resulted in four-point fixation with the knots buried in the grooves.

**AB INTERNO TWO-POINT FIXATION<sup>126</sup>**

This relatively straightforward method provides good visual results but as originally described it



*Fig 10.* A: Two straight needles are inserted ab externo and out through clear cornea. B: After cutting the needles, the suture is retrieved via the superior incision and tied. C: The knots are rotated out of the eye. D and E: A loop over the eyelet with an additional suture secures the haptic. F: The presence of loops allows fixation with a girth hitch (Modified from Bergren<sup>16</sup> with permission of the American Medical Association.)

involved suturing at the 3 and 9 o'clock meridians with the attendant risk of hemorrhage from the ciliary vessels. The steps are listed below:

1. A double-armed polypropylene suture is bisected and the ends tied to the haptics of a 7-mm optic lens with square knots
2. Following an 8-mm peritomy and haemostasis using cautery, a superior 7.5-mm two-plane incision is made at the limbus
3. After anterior vitrectomy, the incision is completed
4. One needle is passed through the incision, behind the iris and through the sclera 1 mm behind the limbus at 3 o'clock
5. This procedure is repeated at 9 o'clock
6. The IOL is inserted with forceps while an assistant adjusts suture tension externally
7. Each needle is passed through partial-thickness sclera 1 mm posterior to the exit from the sclera, and then tied to itself. The suture ends are left long (2 mm) and are laid flat under conjunctiva, which is sutured with 8-0 chromic catgut
8. The limbal incision is closed

#### AB INTERNO FOUR-POINT FIXATION WITH HAPTIC LOOPING<sup>55</sup> (FIG. 11)

This method provides a quick way of creating an intraocular loop with four-point fixation and also introduces the use of iris hooks to facilitate visualization of the ciliary sulcus region. The steps are listed below:

1. 50% thickness limbal based triangular scleral flaps are raised or 60% depth scleral incisions made at the 3 and 9 o'clock positions
2. Flexible iris retractors are placed at the 2,4,8, and 10 o'clock positions
3. After vitrectomy, a long 27-G bent needle is inserted ab externo at the 3 o'clock position 1 mm posterior to the limbus. It is pushed forward until it exits the 9:15 o'clock position via the ciliary sulcus [ab interno fashion] (position seen or estimated with widely dilated, retracted iris)
4. A straight 16-mm long needle with 10-0 polypropylene suture is swaged blunt end first into the barrel of the 27-G needle and maximally advanced
5. This assembly is withdrawn into the vitreous cavity then turned slightly to direct it toward the 8:45 o'clock position. It is passed out of the eye at that location
6. The straight needle (with suture) is pulled out of the 27-G hollow needle, which is then withdrawn from the eye
7. A beveled limbal incision is made at 12 o'clock and the anterior chamber entered with a blade
8. The intraocular loop of suture is withdrawn from the eye with a hook
9. The above steps are repeated from the opposite direction
10. Each loop is passed through the haptic eyelet; this is then looped over the haptic end (similar to the method described by Eryildirim<sup>43</sup>)
11. The PCIOL is inserted, the sutures tied (leaving the ends long enough to lie flat against the sclera) and the scleral flaps sutured closed

#### PARS PLANA FIXATION

Originally described by Girard,<sup>54</sup> this method of fixation has never been popular. Girard's original method used a lens with closed loops that was inserted via the pars plana and fixated within the scleral wall. Teichmann's method is significantly different and utilizes a lens with posteriorly angulated haptics.<sup>138</sup> Three-point fixation is used, with one haptic carrying one eyelet and the other having two eyelets. Compared with sulcus-fixated lenses, the

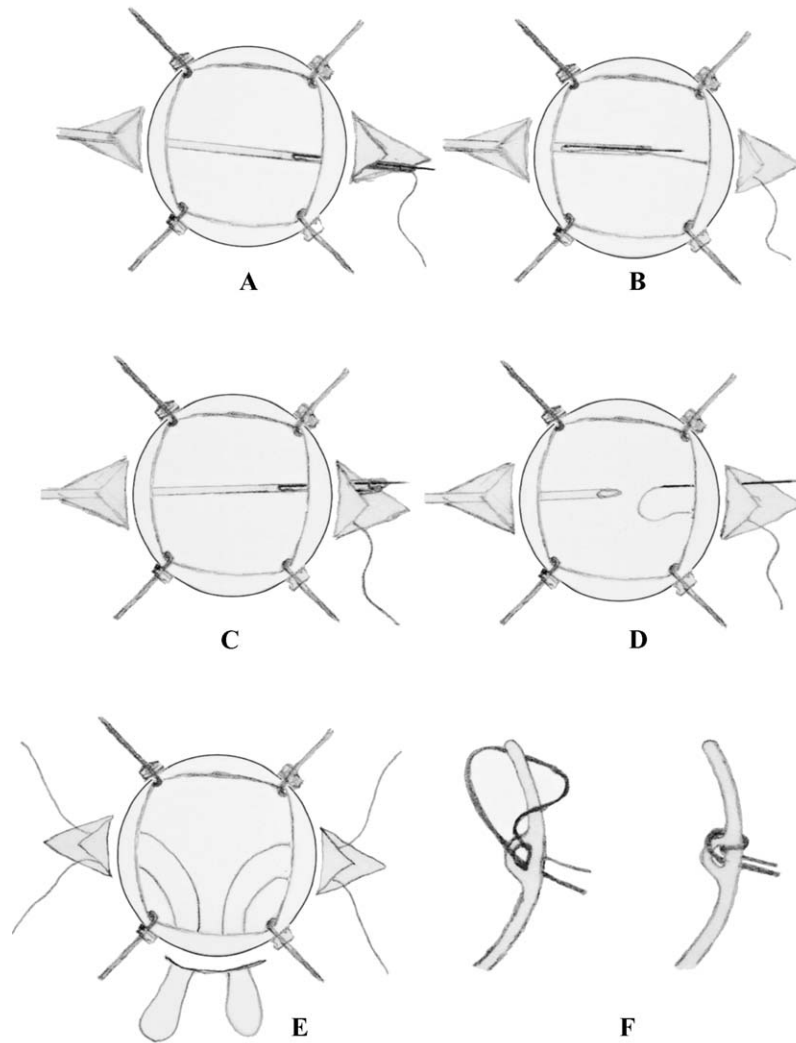


Fig. 11. A: A hollow needle is inserted ab externo then exits ab interno through the opposite scleral bed. B: A straight needle is inserted into the hollow needle, which is withdrawn into the vitreous cavity. C: The entire complex is passed out of the eye at a point adjacent to the original exit point. D: The hollow needle is withdrawn. E: This is repeated for the opposite side, and two suture loops are hooked out of the eye. F: Securing the haptics. (Modified from Grigorian<sup>55</sup> with permission of the American Academy of Ophthalmology.)

overall diameter of the lens is increased to 17 mm and the diameter of the optic to 7 mm.

Teichmann did not describe a unique method for implanting his modified lens at the pars plana. He supported the view that ab interno methods require a trial and error approach or an endoscope and suggested the ab externo continuous loop method described by Lewis.<sup>80</sup>

Because of the different location of the IOL, the position of suture placement would have to be altered. Keeping the needle parallel to the iris plane, the points of scleral entrance would therefore be 3.0–3.5 mm posterior to the surgical limbus instead of 1.5 mm. There would be two points of scleral entrance on each side that have to be diametrically opposite each other with respect to the corneal centre to avoid

lens tilt. Teichmann suggests one fixation site inferotemporally, with the scleral entrance points 2 mm apart and parallel to the limbus. The two strands of this suture would be carried symmetrically through each eyelet (on the haptic with two eyelets), either both from above or both from below.

The other haptic with one eyelet would be attached by means of a meridional (radial) suture, the scleral entrance points on this side being 3.0 and 3.5 mm from the limbus (Table 3).

### Achievement of Ciliary Sulcus Fixation

The ciliary sulcus is the area on the internal surface of the eye between the posterior iris and the pars plicata. It is a commonly used location if

TABLE 3  
*Comparison of Different Techniques of Transscleral Fixation of PCIOLs*

Method	Size of Incision for IOL Insertion	Scleral Flaps	No. of Suture Passes Through Eye	Points of Fixation	Type of Suture Fixation	Haptic Eyelets	Fixation Location
Lewis <sup>81</sup> Ab externo 2-point fixation	Large	Yes	2:Both AE (1 with SN, 1 with HN)	2	Square knots	Not necessary	Ciliary sulcus
Ramocki <sup>112</sup>	Small	Yes	2:1 AE, 1 AI (HN both passes)	2	Square knots	Not necessary	Ciliary sulcus
Eryildirim <sup>44</sup>	Large	Yes	4:All AE, 2 with needle point first, 2 with reverse end of needle through original entry sites	2	1 girth hitch, 1 suture loop over haptic	Necessary	Ciliary sulcus
Lewis <sup>80</sup> Ab Externo continuous loop fixation	Large	No	4:All AE (2 with SN, 2 with HN)	4	Suture pass through eyelet	Necessary	Ciliary sulcus
Rao et al <sup>113</sup>	Large	Yes-L' shaped flaps	8:All AE (2 with SN, 2 with HN through scleral bed, same number and passes through corneal incision)	4	Suture pass through eyelet	Necessary	Ciliary sulcus
Bergren <sup>16</sup>	Large	Scleral grooves	8:4 AE through scleral groove, 4 AI through clear cornea	4	Suture pass through eyelet	Necessary	Ciliary sulcus
Teichmann <sup>138</sup>	Large	No	4:All AE (2 with SN, 2 with HN)	4	Suture pass through eyelet	Necessary	Pars plana

AE = ab externo; AI = ab interno; HN = hollow needle; SN = solid needle.

capsular complications develop in the presence of an intact anterior capsular rim. A lens fixated in this area will be in a slightly more anterior position compared with one located in the bag.

The ciliary sulcus is a relatively avascular area and placement of the IOL here results in relatively stable fixation because of the surrounding structures. Duffey et al found in an anatomic study on cadaver eyes that the average location of the ciliary sulcus from the posterior surgical limbus was 0.94 mm in the vertical meridian and 0.5 mm in the horizontal meridian.<sup>39</sup> Ab externo methods where the sutures were inserted at such locations from the posterior surgical limbus were thought more likely to enter the ciliary sulcus, if the sutures were inserted perpendicularly through the sclera. However, clinical studies found that the ciliary sulcus was still often missed using ab externo methods.<sup>5,80,137</sup>

Belluci et al performed ultrasound biomicroscopy on 16 eyes of 12 patients after scleral fixation of PCIOLs. Of 18 haptics with a suture to limbus distance of 2–3 mm, 16 were posterior to the ciliary sulcus.<sup>14</sup> When this distance was reduced to 1.5–2 mm, six haptics were in the sulcus, six in the pars plana, and two at the iris root. This illustrates the difficulty in precisely positioning the fixation

sutures. Besides the limbus to suture distance, other variables contribute, including the angle at which the needle penetrates the eye and anatomical variations that may occur after cataract extraction. Following ICCE, ciliary processes that are retracted and rotated anteriorly may limit sulcus access. They suggest mandatory UBM examination of the anterior segment prior to scleral IOL fixation.

Horiguchi et al described locating the ciliary sulcus using transillumination.<sup>63</sup> A light-guide fiber was placed in the eye, either through a pars plana scleral port or through the main corneoscleral incision. After switching off all other lights in the theater, they found the ciliary sulcus to be visible as a bright area near the limbus in front of a darker area representing the ciliary body. Endoscopic<sup>2,67</sup> control or methods involving mirror visualization<sup>69</sup> of the ciliary sulcus may allow more accurate suture placement but require more instrumentation. These techniques are also difficult because both hands must be used to hold the endoscope and manipulate the needle.<sup>68</sup>

Operative factors found to be important in attaining sulcus fixation include entering the eye while it is closed and using an appropriately sized IOL.<sup>2</sup> When the eye has been opened and is hypotensive, the ciliary sulcus is collapsed with the



ciliary processes lying in contact with the posterior surface of the iris. Even if the needle entered the sclera at the prescribed location behind the limbus, it would easily pass through the ciliary processes or even the pars plana.<sup>2</sup> Althaus and Sundmacher also found that an IOL with a diameter of 12 mm was more likely to be fixated in the ciliary sulcus compared with one of 13.5 mm diameter. A large rigid lens cannot be pulled back into the sulcus once it has been displaced posteriorly initially.<sup>2</sup>

## Special Cases

### PENETRATING KERATOPLASTY

Many cases where penetrating keratoplasty (PK) is required involve aphakic or pseudophakic bullous keratopathy. In such cases, there are advantages to leaving the eye pseudophakic postoperatively. Monocular aphakia and contact lenses are often poorly tolerated by the elderly.<sup>131</sup>

During PK, any of the above methods including ACIOLs, or iris-fixated or scleral-fixated PCIOLs can be used to rehabilitate the aphakic eye. These lenses are implanted in an open sky method. In general, a large Flieringa ring is required to stabilize the globe as much manipulation occurs while the globe is open after removal of the recipient button. Using a large ring of at least 18 mm allows space for peritomies at sites of scleral fixation.<sup>89</sup>

There are several other possible techniques of iris and scleral fixation of PCIOLs in an open sky situation. Soong et al describe a method of PCIOL iris fixation involving an optic with four holes through which a suture can be passed:<sup>130</sup>

1. A McNeill-Goldman ring speculum is used to stabilize the globe
2. After removal of the diseased corneal button and explantation of any problematic IOLs, a double-armed 10-0 polypropylene suture is passed in mattress fashion through each pair of adjacent holes on the optic
3. The sutures are passed from the posterior chamber, through full-thickness mid peripheral (2 mm peripheral to pupillary border) iris and into the anterior chamber
4. The PCIOL is passed through the undilated pupil into the posterior chamber
5. The sutures are tied and trimmed on the anterior iris surface
6. A peripheral iridectomy was made if not already present, and the donor corneal button was sutured to the recipient

A similar method was described by Zeh and Price, in which a silicone optic without holes was used.<sup>154</sup>

A 9-0 polypropylene suture is passed through iris from posterior to anterior at 9:30, and then back from anterior to posterior at 8:30. The needle is then passed from anterior to posterior directly through the optic of a foldable silicone lens at 8 o'clock, and then from posterior to anterior through the optic at 10 o'clock. This allows the knot to be tied and left between the iris and anterior surface of the optic.

### PEDIATRIC CASES

Pediatric cataracts pose a problem in intraocular lens implantation in two main situations. In children under 18 months of age, a pars plana or limbal lensectomy has previously been advocated as the method of choice.<sup>84</sup> In such young children, it has also been the practice of many ophthalmologists to leave the eye aphakic<sup>125,156</sup> and rehabilitate the eye with contact lenses. During lensectomy and vitrectomy, the whole lens was removed and a shallow anterior vitrectomy performed. This provided a clear visual axis during the sensitive period for amblyopia and avoided the almost invariable posterior capsule opacification in such young children. However, this procedure did not leave enough capsular support for secondary bag or sulcus fixation. More recently, lens aspiration with primary posterior capsulorhexis and anterior vitrectomy has allowed capsular fixation of a PCIOL while reducing the risk of posterior capsular opacification.

Alternatively, in pediatric cases there may be associated problems such as a subluxated lens from traumatic or congenital causes, which prevent in-the-bag or sulcus fixation of the lens without sutures.

If contact lenses are used, compliance and hygiene factors become important as the child grows older, as well as the potential for complications like infective keratitis. In unioocular cases, failure to consistently wear the lenses leads to deprivation amblyopia. Many ophthalmologists are reluctant to implant ACIOLs because of the previously reported increased incidence of complications and the need in children for very long-term implantation.

Various methods have been described for implanting scleral fixated lenses in children. In these cases, large-diameter IOL optics are required not only to minimize the effects of tilt and decentration, but also to avoid pupil capture as the pediatric pupil can reach a diameter of 7.0 mm or more in darkness.<sup>37</sup> Technically, the procedure is more difficult in small eyes with narrower palpebral apertures.<sup>96</sup> Another important consideration is the different anatomical dimensions of the pediatric eye, and to use a method that minimizes the risk of long-term suture erosion through conjunctiva.

Kumar used a method essentially similar to that described by Smiddy in his series of 11 eyes.<sup>70</sup> Sharpe also used an ab interno method of passing the securing sutures, except that he used a double-armed suture for each haptic thus requiring four passes through the sclera.<sup>124</sup> Both methods used scleral flaps to cover the knots.

Buckley on the other hand used the method described by Lewis where the knot is rotated into the eye, thus leaving only the suture on the ocular surface.<sup>23</sup> Mittelviefhaus used 10-0 polypropylene sling sutures hitched to haptic eyelets without knots.<sup>96</sup> The needles were passed ab interno out to the surface, and a radial scleral slit cut with the needle in place. After closing the corneoscleral wound, the needle was passed again through half-thickness sclera, from the peripheral depth of the slit to the scleral surface more peripherally near an extraocular muscle insertion. The resulting knot was covered by thick Tenon's capsule and conjunctiva.

To date, there have been relatively few cases of transsclerally fixated PCIOLs in children. Apart from the difficulty working with small eyes, there has been no anatomical study looking at the position of the ciliary sulcus with respect to the limbus in young children. This perhaps explains the popularity of using ab interno methods and the variability of suture exit points with respect to the limbus.

Looking at the limited experience so far, it would appear that the ideal method buries the knot, as scleral flaps do not provide reliable protection against suture erosion through the conjunctiva. Perhaps using a girth hitch to secure the haptics may provide more stable fixation of the IOL. The study by Mittelviefhaus using girth hitches was the only one without significant IOL displacement, although it had the fewest eyes.<sup>96</sup> Most studies recommend caution in transsclerally fixating PCIOLs in children, because the long-term effects and potential complications are still unknown. In particular, the effect of long-term degradation of polypropylene sutures and IOL stability is of concern. Other issues include the possibility of late endophthalmitis, glaucoma, retinal detachment, and haptic erosion into the ciliary body (Table 4).<sup>102</sup>

## Adjuncts

### CAPSULE TENSION RINGS

In many cases where there is a lack of capsule support, the zonular apparatus is either weak, deficient, or absent. This includes cases of trauma, congenital conditions, such as Marfan syndrome, and late-onset conditions, including pseudoexfoliation syndrome.

TABLE 4  
*Comparison of Techniques and Results of Transscleral Fixation in Children*

Author	Patients	Suture Method	Scleral Exit Point	Complications
Kumar <sup>70</sup>	11 eyes (Age 4–9 years)	Ab interno	0.75–1.0 mm posterior to limbus	IOL decentration (1)
Follow-up: 4–18 months		Knots covered by scleral flaps		SE [through conjunctiva] (2) Glaucoma (1) CME (1) Marked AC reaction (2)
Mittelvieffhaus <sup>96</sup>	4 eyes (Age 26–35 months)	Ab interno	Slightly less than 1 mm	No significant complications
Follow-up: 25–70 months		Girth hitch to secure haptics Knots posteriorised and covered with Tenons and conjunctiva		No IOL displacement No suture erosion
Zetterstrom <sup>155</sup>	21 eyes (Age 1–11 years)	Ab externo (Lewis <sup>80</sup> ) Knots rotated into eye	1.5–2.0 mm behind limbus	Optic subluxation to AC (2)
Follow-up: 9–33 months				IOL rotation (1)
Sharpe <sup>124</sup>	7 eyes (Age 1–19 years)	Ab interno	0.5 mm posterior to limbus	No suture erosion IOL decentration (1)
Follow-up: 3–38 months		Knots covered by scleral flaps		IOL tilting (1) SE [through conjunctiva] (1)

Hara et al first described the use of a ring inserted into the capsular bag to support the zonular apparatus.<sup>58</sup> There was a closed silicone ring. Nagamoto and Bissen-Miyajima subsequently described the use of an open PMMA ring that would allow the ring to adapt to different capsular bag sizes.<sup>99</sup> Currently, these rings are made by various manufacturers, including Morcher (Stuttgart, Germany), Ophtec (Groningen, The Netherlands), Physiol (Liège, Belgium) and Ioltech (La Rochelle, France).

In the presence of an intact capsule, capsular tension rings help to maintain capsular contour and stability in the face of zonular weakness or deficiency. This was demonstrated *in vitro* by Sun and Gimbel.<sup>134</sup> Using porcine and cadaver eyes, implantation of the CTR together with a PCIOL eliminated decentration when one quadrant of zonular fibers was cut. Cionni and Osher describe a case where a CTR was implanted into a capsular bag with 240° of complete loss of zonules. Postoperatively, the IOL was slightly decentered but stable.<sup>33</sup> In a prospective randomized study of 78 eyes with cataract and pseudoexfoliation, 12.8% of control eyes had intraoperative zonular separation while this did not occur in the eyes having a CTR implanted before nucleus emulsification. Posterior capsule rupture occurred in 7.7% of the control group and 5.2% in the CTR group.<sup>11</sup> It has also been successfully implanted in a patient with Weill-Marchesani syndrome.<sup>56</sup>

Insertion of a capsule tension ring is easiest in a capsular bag well filled with viscoelastic. It can be inserted at any stage of a cataract extraction depending on when the zonular defect presents. If a zonular defect has been noted prior to surgery, it can be inserted before phacoemulsification is started.<sup>53</sup> Occasionally, zonular dehiscence can occur during the procedure itself, such as when there is excessive rocking of the nucleus during sculpting combined with insufficient phaco power use. In this event, the procedure should be temporarily halted, viscoelastic instilled into the capsular bag and the CTR inserted. By maintaining the contour of the bag and distributing the surgical forces more evenly, further zonular dehiscence can be minimized.

There have been several modifications to the original CTR concept. Cionni developed a CTR with a hook that curves centrally and anteriorly from the loop.<sup>32</sup> This incorporates an eyelet at the tip, which facilitates additional suture fixation to the scleral wall without distorting the margin of the capsulorrhexis. However, with a small capsulorrhexis, the hook may still catch the capsulorrhexis margin and there is the possibility of iris chafing by the hook as it runs in a plane anterior to the anterior capsule leaf.<sup>93</sup>

A variant to this theme is the Ahmed Capsular Tension Segment (Morcher, Stuttgart, Germany)

where a Cionni CTR type eyelet and hook is attached to a curved PMMA segment subtending 90°. The segment can be directly inserted into the area of zonular weakness without needing to slide an entire ring into the capsular bag. This appears suitable for localized zonular defects with normal remaining zonules, although up to three such implants may be placed into a single capsular bag where less support is available. The capsular tension segment (CTS) is particularly suited in cases where lens stabilization is required before phacoemulsification and where insertion of a standard CTR may be difficult because of a very large nucleus or where there is concern that such a procedure may cause further loss of zonules. Iris retractors are an option in such cases but there is the possibility of anterior capsule tears when they are used to support the anterior capsular rim directly. Inserting a CTS first, then placing an iris retractor through the CTS eyelet provides capsular support while avoiding this risk. Following phacoemulsification, the CTS may be left *in situ* and suture fixated to the sclera or it can be removed and a standard CTR inserted.

In a bid to reduce posterior capsular opacification, Menapace has developed a broader band shaped ring termed a capsular bending ring.<sup>93,104</sup> The aim is to reduce the interspace between lens optic and posterior capsule by a drumhead effect, provide a discontinuous capsular bend to inhibit lens epithelial cell migration, and to keep the anterior capsular leaf away from the anterior optic surface and posterior capsule.

## IRIS PROSTHETIC DEVICES

The normal iris serves to prevent off axis rays of light from entering the eye and to reduce the amount of light entering the eye in bright conditions. This serves to increase the depth of focus, visual acuity and on the other hand to reduce glare and prevent photophobia.<sup>25</sup> The absence of the iris also poses cosmetic concerns in some cases. Previous measures to address this problem included colored contact lenses and coloring/tattooing of the cornea. However, preexisting corneal problems are common in both congenital aniridia, such as stem cell deficiency, and traumatic aniridia, such as corneal scarring, vascularization, and decompensation. Tattooing may lead to pigment toxicity, uncontrolled dispersion of pigment, and poor color match with the fellow eye.<sup>137</sup>

There are two main types of iris prosthetic devices. The first is an all-PMMA IOL with an iris diaphragm 10.0 mm in diameter and a central 5-mm clear optic aperture (Morcher Aniridie 67F, 67G [Morcher, Stuttgart, Germany]).<sup>25</sup> This IOL consists of two parts: the black diaphragm and the optical zone.

These two parts are produced separately and clipped together in a two-step procedure.<sup>136</sup> The 67F has an overall diameter of 13.5 mm while the diameter of the 67G is 12.5 mm. Both have haptics with eyelets.

The alternative is an endocapsular ring with iris diaphragm (Morcher Type 50C [Morcher, Stuttgart, Germany]). This consists of a CTR with seven segments extending centrally. Because the segments are non-contiguous, two separate devices need to be inserted and then rotated such that the segments on one implant cover the spaces between the segments on the other implant. This device does not have an attached optic, so a separate IOL needs to be implanted as well. Variants include the Type 96F which has a single segment attached to the CTR for use in cases where there is a limited iris defect (Fig. 12).

Besides these two designs, a 10-mm disk with a 4-mm central optic surrounded by frosted PMMA has been described.<sup>146</sup> This device has four holes in the periphery for transscleral suture fixation. This has not been used as extensively as the above two

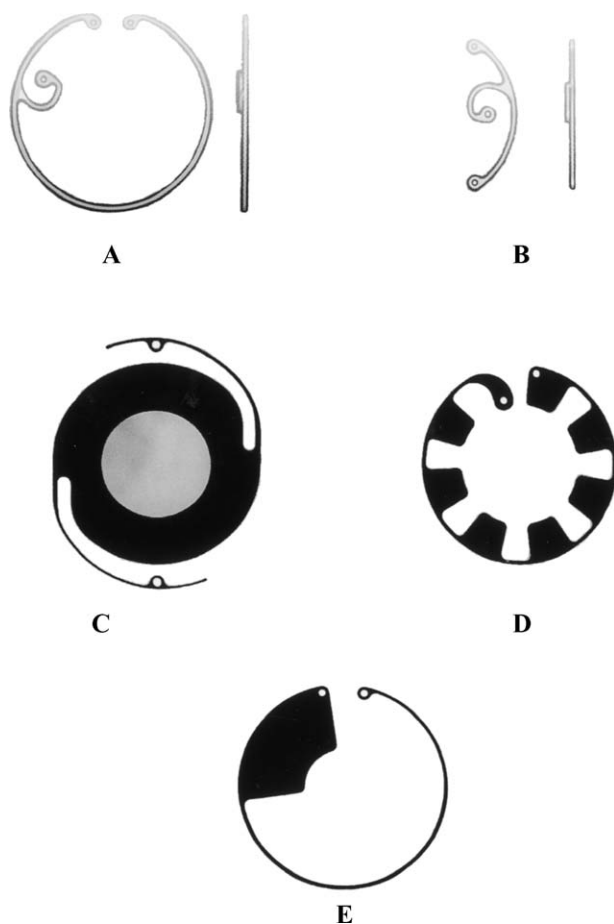


Fig. 12. Modified capsular tension rings: A: Type 2C Cionni capsular tension ring; B: Ahmed capsular tension segment. Iris prostheses: C: Type 67G, D: Type 50C, E: Type 96F (Morcher GmBH).

designs. In a series of six patients implanted with this device during penetrating keratoplasty, the iris prosthesis/IOL appeared more stable with less tilting compared with the Morcher 67F or G. However, there were two cases of subluxation/dislocation and three cases of secondary glaucoma with follow-up of up to 4 years.

If the capsular bag is absent or damaged, a single piece iris diaphragm IOL is required. Both the 67F and G can be used although Burk et al found the 67G more readily available and suited for suture fixation. They preferred the 67F for ciliary sulcus fixation because of the overall greater diameter.<sup>25</sup> However, implantation of these lenses require an incision at least 10.0 mm in length.<sup>25,142</sup> They can also be inserted through a corneal trephine opening of 7.5 mm, although this can be difficult.<sup>135,141</sup> When this is performed, there is extreme deformation of the trephination opening which makes it difficult to guide the implant into the ciliary sulcus.<sup>136</sup>

The benefit of the Type 50C endocapsular ring is that it allows implantation through a small incision. This is the same as that through which a foldable IOL is implanted.<sup>106</sup> The iris diaphragm produces a pupil size of approximately 6.0 mm, which still allows an excellent view of the fundus. However, the device is brittle and fairly susceptible to fracturing. The capsular bag also becomes rather full with three devices in it. Although cases have been described where the bag was stable using this device even with a posterior capsular tear, it is advisable to opt for implantation of a single piece device (such as the Type 67F) when the capsular bag is not intact.

Following iris prosthesis implantation, 83–96% of patients report subjective improvement in glare symptoms.<sup>25,106</sup> Although an early study on the single-piece iris diaphragm IOL described persistent postoperative inflammation in most cases,<sup>136</sup> more recent series have shown mild prolonged inflammation in about 14% of cases using this device.<sup>25,142</sup> One difference between these studies is the use of the 67B by Sundmacher et al which is slightly larger than the 67F and G used in the more recent studies. This might cause more uveal contact and possible chafing. Thompson et al also encountered secondary glaucoma in two of seven cases and one case of endophthalmitis.<sup>142</sup> Besides these, transient hypotony has also been described following iris diaphragm implantation.<sup>25</sup>

## Complications

### ANTERIOR CHAMBER INTRAOCULAR LENSES

#### Corneal Decompensation

Although some degree of endothelial cell loss occurs with each intraocular procedure, most are of

a limited extent and do not progress to corneal decompensation. In the past, the most common causes of pseudophakic bullous keratopathy were related to ACIOLs that were incorrectly sized, vaulted too steeply anteriorly or had an inappropriate degree of flexibility.<sup>3</sup> However, increased endothelial cell loss can occur even after apparently perfectly implanted ACIOLs. Apple postulates that subclinical uveitis caused by lens tissue contact liberates products of inflammation, which can be directly toxic to the endothelium.<sup>3</sup>

Newer ACIOL models having flexible loops and a highly polished surface are much less likely to cause problems. In an analysis of 1,464 explanted ACIOLs, Solomon et al found that the complication rate associated with closed-loop ACIOLs varied from 13% to 25%.<sup>127</sup> This compared with a rate of 5–6% for the flexible designs such as the Kelman Multiflex. In particular, the percentage incidence of corneal complications among explanted lenses was 57% in closed-loop designs versus 29% in open-loop designs. Bourne et al found no difference in the rate of endothelial loss over a 10-year period in patients who were left aphakic or who were implanted with medallion iris sutured implants, transiridectomy clip implants or posterior chamber implants.<sup>20</sup> However, corneal edema is still one of the most common causes of a poor result in modern secondary ACIOL implantation,<sup>150</sup> and these implants are relatively contraindicated in patients with preexisting corneal endothelial problems.

### **Glaucoma**

The placement of ACIOL haptics in the anterior chamber angle poses the possibility of trabecular meshwork damage, angle fibrosis and even PAS formation. With diminished aqueous outflow, IOP would increase together with the incidence of secondary glaucoma. Brunette et al found a mean increase in IOP of 2.5 mm Hg one year postoperatively in cases implanted with ACIOLs during penetrating keratoplasty. This retrospective study included both open-loop as well as a flexible closed-loop type IOLs.<sup>21</sup> Two of 40 cases in a study comparing ACIOLs with iris-sutured PCIOLs during PKP developed significant PAS involving greater than 90° of the angle and associated glaucoma.<sup>59</sup>

However, in a study by Schein et al using flexible, open-loop four-point fixation ACIOLs, synechial progression was found to be least compared with either iris or scleral sutured lenses during 18 months of follow-up.<sup>120</sup> In this study, it was suggested that placing the newer ACIOL in cases of IOL exchange in the same meridian as the preexisting IOL may prevent damage to healthy angle and avoid synechial progression.

Postoperative glaucoma may also be directly related to disruption of the anterior hyaloid face and vitreous spilling into the anterior chamber. If this results in pupillary occlusion and obstruction of a peripheral iridectomy, pupil block glaucoma will result. A large amount of anterior chamber vitreous may also obstruct the trabecular meshwork. Persistent vitreous traction or chafing against uveal tissues causes chronic uveitis, which may lead to secondary glaucoma. Thus, the importance of meticulous vitrectomy in this situation cannot be over-emphasized.

### **Iris Tuck/Iris Chafe**

Iris tuck is defined as posterior bowing of the iris caused by pressure from an ACIOL haptic.<sup>4</sup> This would cause secondary ovalization of the pupil. Two reasons why this might occur include oversized lenses or incorrect IOL insertion at surgery. As each haptic is inserted, there is the possibility that a small part of the underlying iris may be caught and pulled peripherally as the ACIOL is inserted. This results in excessive uveal-IOL contact, causing possible pain and uveitis. In some cases, gently lifting the ACIOL optic and stroking the iris centrally at the time of surgery may correct pupil ovalization and the accompanying iris tuck. Intraoperative gonioscopy is not commonly performed but will allow visualization of the problem and aid its correction.

In the past, uniplanar ACIOLs, particularly those with rough or poorly finished surfaces, were also associated with a high incidence of the uveitis glaucoma hyphema (UGH) syndrome.<sup>3</sup> Many cases were thought to be due to chafing of the IOL against uveal tissue, such as the anterior surface of the iris. Even with anterior vaulting, excessive flexibility may result in chafing if posterior movement of the IOL occurs, such as during eye rubbing. Excessive movement of the IOL would also occur if it were too small for the eye. The incidence of chafing and UGH has fallen markedly with newer designs incorporating tumble polishing to give rounded smooth lens surfaces. In ACIOLs, vaulting, sizing, appropriate flexibility and smoothness of surface are especially critical and much more so than for PCIOLs because of the proximity of corneal, angle and uveal tissue.

### **Lens Dislocation**

Erosion of the haptic into the ciliary body or angle recession may occur if the ACIOL is oversized.<sup>4</sup> In severe cases, the cheese-cutter effect could cause loop haptics to penetrate quite deeply into the angle recess or ciliary muscle. This issue was much more critical when rigid ACIOLs were in use but may still occur with flexible designs.

Rarely, a haptic may sublux and protrude through an iridectomy, although this may be prevented by meticulous attention to surgical technique and placement of the iridectomy with respect to the IOL.<sup>40</sup>

### Endophthalmitis

This potentially sight-threatening complication can occur after any intraocular procedure. While the mechanism is not fully understood, it is probably related to the bacterial load and the pathogenicity of the organism introduced into the eye. A previous study did not show a higher rate of endophthalmitis after IOL implantation compared with simple cataract extraction.<sup>133</sup>

In several recent small series reporting on results of ACIOL implantation, no cases of endophthalmitis occurred.<sup>12,13,36,41,86,150</sup> In an analysis of 101 explanted ACIOLs and PCIOLs, there were four cases of endophthalmitis among cases with PCIOLs and two among cases with ACIOLs.<sup>38</sup> The overall number of PCIOLs versus ACIOLs implanted was not stated, and it is probable that this reflects the greater number of PCIOLs implanted.

### Cystoid Macular Edema

Cystoid macular edema (CME) has been associated with complicated cataract extractions, situations where ACIOLs are often used. Causes of CME following cataract surgery include mechanical (vitreous strands or iris in the wound), iatrogenic (instillation of adrenaline or derivatives), inflammatory, or physical (ultraviolet photic damage) factors.<sup>75</sup>

The incidence of CME following flexible open-loop ACIOL implantation has been reported to range from 1.2% to 10%.<sup>12,36,41</sup> Several factors influence the frequency with which CME occurs with ACIOL implantation, although the reported incidence may also be affected by how intensively reduced vision is investigated. A common factor is whether the original surgery was complicated by posterior capsule rupture and vitreous loss.<sup>36</sup> In their series of 143 cases, David et al inserted ACIOLs either as secondary implants after ECCE complicated by vitrectomy, or after primary ICCE. They found CME to occur exclusively in eyes where ECCE was complicated by posterior capsule rupture and anterior vitrectomy. Weene reported four cases of CME out of 18 eyes where primary implantation was performed in the presence of vitreous loss. In the group of eyes where secondary implantation with previous vitreous loss was performed, there were no cases of CME in 14 eyes.<sup>150</sup> Weene postulates that this may be related to vitreous liquefaction and posterior detachment. Another possibility may be

that any CME was mainly related to the vitreous trauma and that this had resolved by the time of secondary ACIOL implantation.

## Posterior Chamber Intraocular Lenses

### IRIS-SUTURED LENSES

#### Iris chafe

Placing sutures within iris tissue together with an IOL close to its posterior surface might be expected to cause chronic inflammation because of the mobility of iris tissue. Indeed, histopathologic examination of some iris-sutured PCIOLs has revealed mild to moderate local inflammation.<sup>27</sup> Another study showed no suture related inflammatory infiltrates but one of four cases had a mild mononuclear ciliary stromal infiltrate.<sup>5</sup> However, these have not consistently been shown to be clinically significant. Several studies have shown no increase in the incidence of CME or corneal edema when comparing this method of fixation with ACIOLs or scleral-fixated lenses.<sup>76,120</sup> Although Hassan et al found a higher rate of endothelial cell loss with iris-fixated lenses compared with ACIOLs, the latter suffered from a higher graft rejection rate of 12.5% within 19 months of surgery compared with 3.8% in 24 months.<sup>59</sup>

Two important factors affecting the likelihood of iris chafe from the sutures are the location of suture placement and tightness of the sutures. The central iris is most mobile—not only will central suture placement result in excessive inflammation, but the fixing of central iris at sites of suture fixation will result in an irregular pupil with peaking at those sites. Excessively tight sutures or excessively large bites of iris may also cause peaking of the pupil or bunching of the iris.

#### Iridodialysis

Iridodialysis was reported in two patients in a series of 233 cases who underwent iris fixation of PCIOLs during penetrating keratoplasty.<sup>112</sup> The occurrence of this complication is related to manipulation of the iris near the iris root, because peripheral iris suturing leads to least distortion of the pupil and limitation of pupil dilation. Although intraoperative hemorrhage can occur, this is minor and controlled easily. Minimizing iris manipulation and attention to needle placement during suturing will reduce its occurrence.

### SCLERAL-SUTURED LENSES

Erosion of suture knots through the conjunctiva creates a communication between the intra- and

extraocular environments with the attendant risk of toxic and microbial contamination. Initially, when fixating sutures were tied under conjunctiva alone, up to 24% of cases experienced this problem.<sup>62</sup>

Even when scleral flaps are used this problem can occur in 15% of cases.<sup>62</sup> Epstein described a series of 22 scleral-sutured lenses in patients post ICCE. In this series, knots previously not visible under a scleral flap eventually became so, suggesting scleral flap atrophy in most cases with time. In one patient, a suture became exposed with subsequent endophthalmitis 6 years postoperatively.<sup>42</sup> Belluci et al noted scleral erosion in 27% of cases in their study, although none eroded through conjunctiva during follow-up of up to 45 months.<sup>13</sup> Only time will tell how many of these sutures which have eroded through sclera will eventually go through conjunctiva as well.

Although lens stability may become independent of suture integrity if the haptics become encased in fibrous tissue, this phenomenon cannot be relied upon. In a study by Lubnewski et al it was felt to be integrity of the suture rather than fibrous encapsulation contributing to lens stability.<sup>85</sup> Partial IOL dislocation into the vitreous as a result of suture loosening/rupture has been reported.<sup>18</sup> IOL dislocation can also occur if there is internal cheese wiring of the suture without actual polypropylene disintegration or disruption of knot integrity. Therefore, suture removal is not a safe option when it becomes exposed. Instead, ways described to address this problem include trimming or cautery of the knot and surgical coverage with a corneal or scleral patch graft.<sup>22,120</sup> Using a method whereby the knot is buried such as that described by Lewis<sup>81</sup> will significantly reduce the incidence of these complications, although this technique requires four suture passes, meticulous attention to the placement of sutures to avoid lens tilt, and may be associated with difficulties in rotating/burying the knot.

## COMPLICATIONS COMMON TO POSTERIOR CHAMBER LENSES

### Cystoid Macular Edema

This complication was noted to be the most common in some series.<sup>120,132</sup> In one series of secondary scleral sutured PCIOLs, the incidence was 5.5%<sup>132</sup> and in another it was 6.1%.<sup>82</sup> Angiographically evident CME has been demonstrated up to 9 months after surgery.<sup>75</sup>

Several factors contribute to its occurrence after scleral fixation of PCIOLs. These cases are invariably associated with vitreous loss, which could have occurred either at the initial event causing loss of

capsular support or at the time of scleral fixation where a careful anterior vitrectomy is required. Vitreous loss or rupture of the anterior hyaloid has been shown to be associated with vitreomacular traction and CME.<sup>121</sup> Besides this, light induced retinal injury may also be a contributory factor.<sup>75</sup> Although there are no published data of operating times in scleral PCIOL fixation, these procedures are associated with prolonged operating times because of time spent on creating scleral flaps, suturing the IOL haptics, vitrectomy and IOL implantation.<sup>75</sup>

Preventing and dealing with CME, whether for ACIOLs or PCIOLs, requires a knowledge of the postulated causative factors. Intraoperatively, careful attention to anterior vitrectomy where the anterior vitreous face has been disturbed avoids vitreous incarceration and traction. If present postoperatively, Nd:YAG laser vitreolysis of vitreous strands or repeat vitrectomy may be required. However, CME can still occur in the absence of any gross vitreous abnormalities, and commonly occurs 1–3 months after surgery. To reduce perifoveal vascular permeability, topical non-steroidal medications and topical steroids have been the mainstay of treatment. In particular, topical ketorolac has been shown in randomized, controlled studies to reduce angiographic CME<sup>50</sup> and improve vision in chronic CME.<sup>49</sup> In the stepwise approach to treatment suggested by some authors,<sup>1</sup> peribulbar steroid injections, systemic steroids, and oral acetazolamide have also been used for refractory cases, although there is a lack of prospective, randomized data on their use.

### Endophthalmitis

Endophthalmitis is a dreaded complication, which can happen after any intraocular procedure. Acute cases usually present in the early postoperative period,<sup>4</sup> while chronic endophthalmitis caused by organisms of low virulence may present months to years after the procedure.

Although pathogens can be introduced at the time of surgery, they can also gain access to the eye via exposed sutures in cases of suture-fixated PCIOLs. Schechter described a case of acute endophthalmitis occurring 1 month following secondary transscleral sutured PCIOL with penetrating keratoplasty.<sup>119</sup> At presentation, one suture had eroded through the conjunctiva. A similar case was described by Heilskov et al in a patient 5 months after transscleral fixation of a PCIOL.<sup>61</sup> Bacteria probably entered the eye through the suture wick. These cases illustrate the importance of avoiding exposed suture ends that can erode through partial-thickness scleral flaps and

conjunctiva with time. Methods of preventing this include leaving the suture ends long, rotating knots into the sclera, or tying the knot in the depths of a partial-thickness scleral incision.

### Hyphema/Vitreous Hemorrhage

Suturing PCIOLs require needle passes through vascular uveal tissue with the attendant risk of bleeding. In many cases, this is minor and resolves spontaneously.<sup>30,127,136</sup> This complication may lead to ghost cell glaucoma.<sup>91</sup> Keeping the suture anterior (0.5–1 mm behind the surgical limbus) and avoiding the 3 and 9 o'clock positions may reduce the risk of bleeding by avoiding vascular ciliary body tissue and the long posterior ciliary arteries.<sup>129</sup> In addition, taking care to maintain a pressurized globe and to minimize tissues traversed during transscleral needle passes will reduce the risk of intraoperative intraocular hemorrhage. In the latter respect, inserting the needles perpendicular to the ocular surface with an ab externo technique and using the minimum number of sutures for support (by utilizing existing capsular remnants) is particularly relevant.

Although many cases of intraocular bleeding are believed to be related to direct trauma during needle passes, wicking of extraocular blood into the eye may also occur along the suture.<sup>73</sup> Careful attention to hemostasis during dissection of conjunctiva and Tenon's capsule will help to avoid the occurrence of this complication.

### LENS TILT/DECENTRATION

Without the support of the lens capsule, the PCIOL can potentially tilt around the points it is sutured or decenter more easily. Tilt and decentration result in oblique astigmatism and can also cause myopic shift and lateral shift of focus.<sup>8,39,41,43,109</sup> In a study where a 7-mm diameter optic with a 5-mm optical zone was used, decentration of less than 2 mm was not associated with diplopia or deviation from intended refraction.<sup>18</sup> However, PCIOL tilt of greater than 5 degrees has been found to induce refractive error.<sup>143</sup> In Durak et al's study, the mean tilt and decentration were 6.09° and 0.67 mm, respectively.<sup>40</sup> These average figures are similar to those reported after ECCE using can-opener, envelope, and CCC with anterior capsule tear techniques.<sup>105</sup> However, they are approximately double that found after phacoemulsification surgery with PCIOL fixation in the bag.<sup>60</sup>

Significant lens tilt greater than 10 degrees can be found in 11.4–16.7% of patients after scleral sutured PCIOL implantation.<sup>40,60</sup> These results were obtained using 2-point scleral fixation of the PCIOLs.

Techniques where two points on one or both haptics are sutured to the sclera may reduce this complication.<sup>15,16,80</sup> However, in one series where each haptic was fixated at one point, only 1.9% of eyes had IOL decentration of more than 1.5 mm.<sup>145</sup> It is not clear what factors lead to lower rates of decentration in such two-point fixated lenses. One possibility is that in Durak et al's series, most cases of secondary transscleral IOL implantation were aphakic after complicated cataract extraction, and this may cause greater decentration and tilt because of the presence of extensive iridocapsular-cortical synechiae.<sup>40</sup> Uthoff and Teichmann had better results in a series including more planned cases of intracapsular surgery, although the percentage was not stated.<sup>144</sup> If such results can be achieved, three-<sup>15</sup> or four-point<sup>16,81,113</sup> fixation may not be required routinely and the number of suture passes through the eye can be minimized.

### Retinal Detachment

Retinal detachment is more common when the anterior hyaloid face has been disturbed with or without vitreous prolapse.<sup>82</sup> It is worth noting that some eyes having scleral-fixated lenses had suffered trauma and that it may be difficult to ascribe the cause for the detachment to the surgery itself.<sup>91</sup>

In a series of 122 eyes, 4.9% developed retinal detachment post-surgery with follow-up of up to 42 months.<sup>77</sup> Factors found to be significantly correlated with this complication were myopia greater than -1D and vitreous hemorrhage. In most cases, the location of the retinal tear corresponded to the IOL axis near the fixation sutures. This suggests trauma to the vitreous base by the needle or lens haptics. During IOL insertion, traction may also be exerted on pre-existing vitreoretinal adhesions. Damage to the vitreous base may result in giant tears, while traction on other adhesions may cause retinal holes or tears. These complications may be reduced by meticulous removal of vitreous prior to IOL implantation.<sup>77</sup>

### Suprachoroidal Hemorrhage

This is a rare complication considering the uveal manipulation that occurs during scleral fixation of a PCIOL. One case occurred intraoperatively in a patient with a microphthalmic eye, which predisposes to choroidal hemorrhage even in routine cataract extraction.<sup>13</sup> In another case, late suprachoroidal hemorrhage occurred 6 days after scleral fixation of a PCIOL.<sup>110</sup> Several factors could have contributed in this case: suture placement at 3 and 9 o'clock, posterior suture passes at 2 mm behind the limbus, and double suture passes at each fixation site.



**Discussion**

**RESULTS**

The results of IOL implantation in the absence of capsule support have been satisfactory in general when viewed with respect to visual results and complication rates.<sup>18,28,41,83,91,109,127,132,145,146,150</sup> These results are reviewed in Table 5. Due to the

multitude of methods for IOL implantation, several authors have conducted studies to compare results for the different ways of lens implantation.

Lass et al compared 25 patients who had Kelman style ACIOLs with 24 who had suture-fixated PCIOLs following penetrating keratoplasty (PKP).<sup>75</sup> They compared endothelial cell loss between the two groups and found that mean cell

TABLE 5

*Comparison of the Results of Different Methods of IOL Fixation*

Author	No. of Patients	IOL Location	↓ VA	Same VA	↑ VA	Comorbidity	Complications
Ellerton et al <sup>41</sup>	81	ACIOL (secondary implantation)					CME (1.2%)  RD (1.2%) PBK (1.2%) Wound leak (5%) Iris prolapse (1.2%) IOL subluxation (1.2%) Hyphema (2)
Mitra et al <sup>98</sup> Follow-up 2.5–54 months	7 (dislocation of PCIOL)	ACIOL	1	1	5	1 epiretinal membrane 1 ARMD  1 retinitis pigmentosa 2 prior RD 3 POAG	
Weene <sup>150</sup>	61 (18-ECCE + vitreous loss 43- secondary implantation)	ACIOL				2 recurrent iritis	CME (5)  RD (2) Corneal edema (5) Chronic uveitis (1) Glaucoma (3) Hyphema/ vitreous hemorrhage Partial dislocation of IOL into vitreous- probable suture breakage CME (2)
Bleckmann et al <sup>18</sup> Follow-up 14 months–2.6 years	48	PCIOL- transscleral fixation					
Chakrabarti et al <sup>28</sup> Follow-up 6–26 months	25	PCIOL- transscleral fixation		20	5	5 PAS  2 corneal scar  2 vitreous hemorrhage  1 angle recession 1 RP 1 POAG	Uveitis (1)  Healed macular choroidal tear (1)
Chang and Lee <sup>30</sup>	23	PCIOL- transscleral fixation		6	17	1 chronic uveitis	Transient intraocular bleeding (2)

(continued)

TABLE 5

*Continued*

Author	No. of Patients	IOL Location	↓ VA	Same VA	↑ VA	Comorbidity	Complications
Follow-up 12–21 months	15 secondary implants 5 primary after complicated ECCE					1 PBK	RD (1)
Holland et al <sup>62</sup>	3 Implants with PK 105	PCIOL-transscleral fixation (simultaneous PK)				1 myopic degeneration 39 preoperative glaucoma	secondary glaucoma (1) Graft rejection (1) Graft rejection (15)
Follow-up 6–43 months						6 ARMD	RD (4) CME (10) Exposed suture (21) New increased IOP (20)
Lindquist et al <sup>83</sup>	38	PCIOL-transscleral fixation	6	9	23		Hyphema/vitreous hemorrhage (2) SE (3) Failed trabeculectomy (1) Decentration (1) Slight tilt (1) CME (2)
Follow-up 2–25 months							SE (4) Hyphema (2) RD (1) IOL tilt (1) VH (1) Iridodialysis (2)
McCluskey et al <sup>91</sup>	32	PCIOL-transscleral fixation	2	7	23		SE (4) Hyphema (2) RD (1) IOL tilt (1) VH (1) Iridodialysis (2)
Follow-up 6–31 months							SE (4) Hyphema (2) RD (1) IOL tilt (1) VH (1) Iridodialysis (2)
Price and Whitson <sup>111</sup>	220 (71 secondary implants, 147 IOL exchange, 2 ECCE with loss of capsular support)	PCIOL-iris fixation (simultaneous PK)				201 PBK, 29 Fuch's dystrophy, 8 corneal scar, 3 keratoconus, 1 interstitial keratitis 30 macular degeneration	Dislocated IOL (2) Endophthalmitis (1) RD (2) CME (8) Uncontrolled glaucoma (4)
Follow-up 12–68 months							Dislocated IOL (2) Endophthalmitis (1) RD (2) CME (8) Uncontrolled glaucoma (4)
Solomon et al <sup>127</sup>	30	PCIOL-transscleral fixation				23 pre op corneal edema	SE: -Through sclera 22
Follow-up 6–42 months						3 preop glaucoma	-Through sclera 22

*(continued)*

TABLE 5  
Continued

Author	No. of Patients	IOL Location	↓ VA	Same VA	↑ VA	Comorbidity	Complications
						9 preop CME	-Through conjunctiva 5 IOL tilt/ decentration (3) New glaucoma (2) Choroidal hemorrhage (1)
Stark et al <sup>132</sup>	8	PCIOL- transscleral fixation (IOL exchange)	1		7	6 pre op CME	Hemorrhage from superior limbal incision
Sundmacher et al <sup>135</sup>	83	PCIOL- transscleral fixation	8	26	49	27 PBK	Transient:
Follow-up 2-23 months		27 simultaneous PK 42 secondary implantation 14 primary implantation					IOP ↑ (9) CME (5) Intraocular bleed (3) Long term, IOL related: Glaucoma (2) Chronic choroidal detachment (1) Chronic inflammation (2) IOL explantation (2)
Walter et al <sup>149</sup>	89	PCIOL- transscleral fixation (simultaneous PK)					Suture exposure (6.7%)
Follow-up 4-68 months							Suture breakage (2.2%) RD VH Choroidal hemorrhage
Uthoff et al <sup>145</sup>	624	PCIOL- transscleral fixation (secondary implantation)	8%	92%			CME (5.8%)
Case records reviewed one year after surgery							SE (17.9%)  VH (1%) RD (1.4%) IOL decentration > 1.5 mm (1.9%) Severe uveitis (0.5%)

ARMD = age related macular degeneration; CME = cystoid macular edema; ECCE = extracapsular cataract extraction; PK = penetrating keratoplasty; RD = retinal detachment; SE = suture erosion; VA = ; VH = vitreous hemorrhage.

loss at 1 year did not differ significantly. Both groups saw a progressive decrease in cell density, especially between 6 and 12 months postoperatively. This study also did not show any advantage of suture fixated PCIOLs over Kelman-style ACIOLs in terms of best corrected visual acuity, intraocular pressure control, corneal thickness, and CME. In another study comparing iris-fixated PCIOLs with Kelman-style ACIOLs during PKP, the endothelial cell loss at 1 year was actually lower with the ACIOL (11.2%) compared with the PCIOL (19%).<sup>59</sup> However, endothelial graft rejection occurred at a rate of 12.5% in ACIOL cases compared with 3.8% of iris sutured PCIOL cases within 24 months.

Schein et al describe a randomized study comparing ACIOL, iris-fixated PCIOL and transsclerally fixated PCIOL during penetrating keratoplasty for pseudophakic corneal oedema.<sup>120</sup> In their study of 176 consecutive patients, they found that there was a higher complication rate for scleral-fixated compared with iris-fixated IOLs while ACIOLs carried an intermediate risk.

This was based on a complications index looking at the major outcomes of glaucoma escalation, CME, IOL dislocation, and graft failure. There was a lower rate of CME (which was seen as early as 6 months postoperatively) for iris-fixated PCIOLs compared with ACIOLs or transsclerally sutured PCIOLs. Three scleral-fixated IOLs required re-fixation due to subluxation or tilt while there were no cases of dislocation among the iris-fixated lenses. There were no significant differences in the risk of graft failure or of glaucoma treatment escalation.

Lyle and Jin retrospectively studied 348 cases of secondary IOLs, comparing 234 eyes with ACIOLs with 114 eyes receiving PCIOLs.<sup>82</sup> Of these PCIOLs, 78 were scleral fixated. They found that the presence of corneal disorders increased the risk of poor vision in eyes with ACIOLs compared with PCIOLs. Of 19 eyes undergoing combined PKP and secondary IOL implantation, 50% (6 of 12) of ACIOL eyes compared with 14% (1 of 7) of PCIOL eyes had postoperative vision of 20/200 or less. Cystoid macular edema occurred with similar frequency in both groups of patients. Retinal detachments occurred in 0.9% of ACIOL eyes compared with 3.5% of PCIOL eyes. All retinal detachments occurred in eyes with vitreous prolapse and had undergone anterior vitrectomy during lens implantation. This compares with the study by Belluci et al where secondary implantation of ACIOLs (35 eyes) was compared with scleral fixated PCIOLs (33 eyes).<sup>13</sup> In this series, retinal detachments were also more frequent for scleral fixated PCIOLs(6%) compared with ACIOLs(3%). One ACIOL eye developed corneal decompensation.

Hayashi et al compared PCIOL tilt, decentration, AC depth, and refractive error after either scleral PCIOL fixation, secondary out-of-bag implantation, or phacoemulsification with in-the-bag fixation.<sup>60</sup> IOL tilt and decentration after scleral suture fixation was significantly greater than in the other two methods. There was an 11.4% incidence of severe tilting greater than 10 degrees, and the mean tilt angle was 6.35°. This is greater than the 5° tilt stated by Uozato et al to cause significant refractive error.<sup>144</sup> In this study the authors also showed AC depth to be shallower for out-of-bag IOLs and sutured IOLs and also for these to cause a myopic shift consistent with their placement anterior to the capsular bag.

Although the iris claw lens is not available in the USA, it has been used and studied in Europe. Menezo et al compared 75 cases implanted with the iris claw lens and 26 with sulcus scleral-fixated PCIOLs.<sup>95</sup> This study included both primary and secondary implantation. In eyes without preexisting pathology, a similar percentage of patients achieved 20/40 or better vision with both methods during primary implantation. With secondary implantation, 87.5% of patients achieved 20/40 or better vision with the iris claw lens versus 54.6% for the scleral sutured cases. In most cases, visual acuity was maintained or improved with both types of lenses. Although the incidence of complications was similar, certain problems including hyphema and vitreous hemorrhage only occurred in cases with scleral sutured PCIOLs. In a series of 19 cases where an iris claw lens was implanted during penetrating keratoplasty, peripheral anterior synechiae were noted near the site of iris fixation in three cases. One new case of glaucoma occurred postoperatively. One patient also had partial disinsertion of a claw that required IOL repositioning.<sup>116</sup> Recently, these lenses have also been used in the correction of myopia in phakic eyes. Fechner et al showed with a laser flare cell meter that in such eyes anterior chamber protein and cell count were as low as in eyes after endocapsular implantation.<sup>45</sup> Menezo et al also found only a slight decrease with no significant morphological changes in the corneal endothelium 2 years after implantation of iris claw phakic lenses.<sup>94</sup> However, concerns remain regarding the long-term consequences of having iris tissue entrapped within the claws.

#### ADVANTAGES/DISADVANTAGES

ACIOLs are technically easy to insert and involve little manipulation to the eye. They are also generally easier to remove or replace should this become necessary.<sup>86</sup>

The early rigid closed-loop ACIOLs were associated with many problems. These include the

uveitis-glaucoma-hyphema syndrome first described by Ellingson, increased endothelial cell loss associated with corneal decompensation, and glaucoma. They also had a tendency to become firmly enmeshed in uveal tissue.

The closed-loop ACIOLs were effectively removed from the USA market in 1986 when they were placed on investigative core status by the FDA.<sup>82</sup> In general, closed-loop ACIOLs were almost always removed at PK for pseudophakic bullous keratopathy while PCIOLs or open-loop ACIOLs may be retained if the PBK was believed to be due to preexisting corneal disease.<sup>40</sup>

The newer ACIOLs have been associated with fewer complications.<sup>5,82,98,118,128</sup> However, they are still contraindicated in cases of marked iris tissue loss or angle damage. They should also be avoided in cases where the anterior chamber is shallow. These factors apply largely to iris-fixated claw lenses as well.<sup>93</sup>

A PCIOL theoretically causes less damage to the cornea, iris and angle structures thereby reducing the chances of corneal decompensation, inflammation, and glaucoma.<sup>5,127</sup> However, inserting and fixating a PCIOL is technically demanding and could potentially cause a completely new spectrum of problems. It is still less technically difficult than the other alternative for optical rehabilitation, epiker-

atophakia.<sup>18</sup> Compared with epikeratophakia, it provides a more predictable postoperative refraction.

Suture fixing a PCIOL involves suture passes through uveal tissue, which could cause hyphema or vitreous hemorrhage, problems which may be compounded in patients with a bleeding diathesis. This procedure has also been known to liberate large amounts of uveal pigment intraoperatively.

Suturing a PCIOL to the iris allows the benefits of posterior chamber fixation and can be less technically demanding than scleral fixation. It avoids manipulation of more posterior uvea. Despite the risk of iris chafing and chronic uveitis, several studies have not found increased CME or corneal decompensation with this fixation method. In fact Schein et al found a lower risk of complications compared with ACIOLs and scleral-sutured PCIOLs.<sup>120</sup> However, like ACIOLs, they cannot be used in cases of marked iris tissue loss. There is also some restriction of pupillary dilation depending on how peripheral the sutures are placed. They are thus not ideal if there is co-morbidity such as diabetic retinopathy requiring good fundus visualization.

In scleral-sutured lenses, there is the potential problem of knot erosion and exposure. Although atrophy of the overlying scleral flap is relatively

TABLE 6

*Comparison of the Advantages and Disadvantages of Different Methods of IOL Fixation*

Implantation Method	Advantages	Disadvantages
ACIOL	<ul style="list-style-type: none"> <li>• Technically less demanding</li> <li>• Reduced operative time</li> </ul>	<ul style="list-style-type: none"> <li>• Requires mostly intact iris diaphragm</li> <li>• Unresolved concern regarding long-term effects on corneal endothelium and blood aqueous barrier</li> <li>• Potential for increased damage to angle, PAS, and glaucoma</li> </ul>
Iris claw lens	<ul style="list-style-type: none"> <li>• Technically less demanding</li> <li>• Reduced operative time</li> </ul>	<ul style="list-style-type: none"> <li>• Requires intact iris diaphragm</li> <li>• Unresolved concern regarding long-term effects on corneal endothelium and blood aqueous barrier</li> </ul>
Iris suture-fixated PCIOL	<ul style="list-style-type: none"> <li>• Physiological position near nodal point of eye</li> <li>• Physical separation from corneal endothelium</li> </ul>	<ul style="list-style-type: none"> <li>• Require intact iris diaphragm</li> </ul>
Transscleral fixated PCIOL	<ul style="list-style-type: none"> <li>• Physiological position near nodal point of eye</li> <li>• Physical separation from corneal endothelium</li> </ul>	<ul style="list-style-type: none"> <li>• Increased operative time</li> <li>• Increased risk of intraocular hemorrhage</li> <li>• Possibly increased risk of retinal detachment</li> <li>• Late suture erosion and exposure (unless knot rotated into eye)</li> <li>• Risk of suture related endophthalmitis</li> </ul>

common, the sutures have not always eroded through the conjunctiva. Only time will reveal how many more cases will do so. The important thing is that patients with sutured PCIOLs require long-term follow-up as prompt recognition and treatment of suture exposure would prevent the devastating complication of endophthalmitis.

As PCIOL implantation is technically difficult and relatively time consuming, it is not always desirable.<sup>82</sup> Lyle and Jin suggest the use of ACIOLs where possible and where the risks of complications are less.<sup>86</sup> These include elderly patients where there is a normal angle with no glaucoma, no corneal disorder, and an intact vitreous face. Those with bleeding disorders or severe conjunctival scarring would benefit from minimal uveal manipulation and conjunctival dissection and an ACIOL should be used if possible. On the other hand, younger patients, those with angle abnormalities, iris tissue loss, glaucoma, corneal disease, or simultaneous PKP should have a PCIOL. Scleral flaps for knot coverage may not be advisable in younger patients as the flap tends to atrophy with time. For these cases, it may be better to use a method involving rotation/burying of the knot (Table 6).

### Summary

Implanting an intraocular lens has become the standard of care in cataract surgery today. Although there have been many improvements since Sir Harold Ridley first implanted his lens, we still prefer to place the lens as he did, that is, in the capsular bag. There are numerous advantages to this, as have been described. Unfortunately, it is not always possible to do this due either to preexisting conditions or surgical problems. Many methods have been described to allow intraocular lens rehabilitation of the aphakic eye without capsular support. Each of these are different with regards to technical difficulty, potential postoperative problems and complications. With the many improvements in implant design and manufacture there is no longer the automatic aversion to anterior chamber lenses. Used appropriately, any one of the methods described can result in a good visual outcome. As each case is unique, so too the need for the clinician to take into account the different variables and to utilize the method which will result in the best outcome for the patient with the least potential complications while maintaining technical simplicity.

### Method of Literature Search

We performed a MEDLINE search via the website of the National Institutes of Health ([www.ncbi.nlm.nih.gov/entrez/medline.html](http://www.ncbi.nlm.nih.gov/entrez/medline.html)) searching for articles with the following key words: *intraocular lens, anterior chamber intraocular lens, capsule rupture, capsule support, subluxed lens, iris fixation, lens material, pupil fixated lens, zonular dehiscence, zonular dialysis, capsular tension ring, iris prosthesis*. The original search covered the period from 1966–2003 and an update of the search was covered material through 2005. The bibliographies of the articles generated were reviewed to search for additional articles not retrieved via the above search. The search was, in general, confined to articles in English. The single foreign language article (Fries UK, Ohrloff C. Ultraschallbiomikroskopie-Darstellung des Kapselspannrings bei Pseudophakie. *Klin Monatsbl Augenheilkd* 209: 211–214, 1996) was cited to illustrate a specific point, and for this article an English translation was obtained.

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Reprint address: M. J. Lavin, Manchester Royal Eye Hospital, Oxford Road, Manchester M13 9WL, United Kingdom.