Lens implant selection with absence of capsular support

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If contact lens or spectacle correction is not viable, little debate exists that the secondary placement of an intra-ocular lens (IOL) is the method of choice in the absence of capsular support. The choice of IOL mainly depends on the preoperative status of the eye (*eg*, aphakia in children) and the selected location for the implant. Theoretically, there are several IOL implantation approaches in cases without capsular support: an angle-supported anterior chamber (AC) IOL, an iris-fixated ACIOL, an iris-sutured or iris-fixated posterior chamber (PC) IOL and a transsclerally sutured PCIOL. No consensus exists, however, on the indications as well as on the relative safety and efficacy of these different options. Implantation of modern ACIOLs, like the refined open-loop or iris-fixated claw (toric) ACIOLs, have regained popularity and provide a valuable alternative to sutured PCIOLs. However, in the absence of capsular support, the transsclerally sutured PCIOLs offer numerous advantages for certain eyes. Because of its anatomic location, the sutured PCIOL is more appropriate for eyes with compromised cornea, peripheral anterior synechiae, shallow anterior chamber, or glaucoma. Moreover, sutured PCIOLs are appropriate if the patient with aphakia is young or has a life expectancy of 10 years or more. Recent technological advances, including PCIOL with iris diaphragm for aniridia, toric ACIOLs, and small-incision surgery with foldable, transsclerally sutured IOLs, seem to further improve clinical outcomes. Curr Opin Ophthalmol 2001, 12:47–57

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Abbreviations

ACIOL	anterior chamber intra-ocular lens
CME	cystoid macular edema
IOL	intra-ocular lens
OD	optic diameter
PCIOL	posterior chamber intra-ocular lens
PMMA	polymethylmethacrylate
PKP	penetrating keratoplasty
TD	total diameter

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For a long period of time, anterior chamber intra-ocular lenses (ACIOLs) have been the predominant type of lens used in secondary IOL implantation. In the mid-1980s, however, it became evident that the rigid closed-loop ACIOLs were associated with several complications, including irreversible endothelial cell loss leading to pseudophakic bullous keratopathy, intractable inflammatory sequelae with or without cystoid macular edema (CME), angle structure damage, formation of peripheral anterior synechiae, fibrosis of haptics into the angle, pupillary block with increased intra-ocular pressure, iris chafe, and hyphema (Table 1).

Since then, there has been a propagation of techniques using sutures to secure posterior chamber intra-ocular lenses (PCIOLs) [1]. Parry [2] first described the use of sutures to enhance IOL fixation almost 45 years ago, by threading the ends of a tantalum wire through an iridectomy and a hole drilled into the optic of a Ridley IOL. This was fastened to a corneoscleral stuture beneath the conjunctiva. In 1976, McCannel [3] reported the use of uveal fixation sutures to stabilize PCIOLs. Scleral-sutured PCIOLs are a more recent development than iris-sutured PCIOLs. Malbran *et al.* [4] were the first to describe transsulcus scleral fixation of PCIOLs in eyes with aphakia.

The indications, techniques, lens style, and incidence of complications associated with the use of either type of IOL in secondary implantation remain controversial. Several studies [5–27] demonstrated that secondarily implanted ACIOLs are associated with more complications and lower postoperative visual acuities than are PCIOLs. However, most of the relevant studies focused on either ACIOLs or PCIOLs alone. Only a few studies directly compared the results of patients receiving secondary ACIOLs with those receiving PCIOLs. We compared the results of previous reports of using both types of IOLs (Tables 2,3).

Presently, there are five primary methods for dealing with IOL requirements in the absence of capsular support, mainly depending on the preoperative status of the eye (Table 4): flexible open-loop ACIOLs and iris claw ACIOLs; iris-fixated retropupillary ACIOLs; iris-sutured PCIOLs; and transscleral-sutured PCIOLs. If both the iris and the capsule are absent or disrupted, sutured transscleral PCIOLs are the only option.

Today, considerable controversy remains over the relative efficacy and safety of the different implantation ap-

Table 1. Most common (mainly closed-loop) anterior chamber intra-ocular lenses frequently associated with pseudophakic bullous keratopathy (most anterior chamber intra-ocular lenses are no longer available)

Angle-supported ACIOL models	Iris-supported ACIOL models
ORC 11 Stableflex	Worst medaillion
Iolab 91Z (Azar IOL, Duluth, GA)	Binkhorst 2-loop and 4-loop
Surgidev style 10 (Leiske IOL)	Copeland
Hessburg	
Dubroff	
Choyce	
Novaflex	
Kelman flexible 4-point fixation	

ACIOL, anterior chamber intra-ocular lens; IOL, intra-ocular lens; PBK, pseudophakic bullous keratopathy.

proaches when capsular support is absent. Anterior chamber intra-ocular lens implantation is coming back into favor among some surgeons, thanks to improved, open-loop ACIOL designs and re-emergence of the iris-fixated claw IOL. Sizing is less critical with the flexible haptics of the open-loop ACIOLs, as opposed to the more rigid or closed-loop ACIOL designs. Several recent studies demonstrated improved results with these modern devices [28,30]. Nevertheless, concern remains that ACIOLs are more damaging to the corneal endothelium than PCIOLs. Although the complications associated with the closed-loop ACIOLs have decreased with the changeover to the modern ACIOL designs, they have not been eliminated.

There are many theoretical reasons for preferring one of these lens types over the other. Table 5 reviews the advantages and disadvantages of each of these IOL styles.

Anterior chamber lenses

Open-loop ACIOLs are capable of providing a vastly superior tolerance during a long-term period, as opposed to their closed-loop counterparts. An unacceptable complication rate was associated with closed-loop ACIOL designs, which correlates with a chronic, insidious process caused by excessive and irritative tissue touch [28].

Current ACIOLs have a footplate that prevents erosion and usually prevents fibrous overgrowth of the haptic. This type of design, whether with three- or four-point fixation, is preferable because it has minimal and stable areas of angle contact. The presence of fixation elements with small holes (Fig. 1) is undesirable. Such holes cause unwanted peripheral anterior synechia and tend to function in a cheese-cutter effect as micro-closed loops (Auffarth, Personal communication) [29,30]. Point fixation is possible with footplate designs because haptics may extend only small areas of the angle outflow structures (Fig. 2). Most styles are easy to implant or remove, if necessary, especially those with Choyce-like foot-plates, which usually are not completely surrounded by goniosynechias. The haptic area usually will slide out with undue difficulty or excessive tissue damage. The explantation rate of modern ACIOLs is between 0.06 and 0.16% [31]. Clinical and pathologic data strongly suggest a state-of-the-art model with solid, well-polished Choyce-style footplates (Fig. 2).

A rethinking of the often summary condemnation of all ACIOLs is warranted. The only resemblance of the modern, flexible, one-piece all-PMMA, open-loop designs to the older closed-loop and miscellaneous IOL designs is the anatomic site of implantation. Modern ACIOLs have a low rate of complication, and their association with pseudophakic bullous keratopathy is, at least in part, a result of their use in complicated cataract surgery, rather than inherent design flaws [32].

The vault engineered into modern ACIOLs is maintained even under high compression, which minimizes IOL touch against the cornea. Most common modern ACIOL models now implanted are the Clemente Optifit 13A, the 351C or 352C (Pharmacia & Upjohn, Kalamazoo, MI); Corneal AJPR, S122UV or L122UV (Bausch & Lomb, Claremont, CA); and AC 260 (Ophtec, Groningen, Netherlands), to name a few. The interest and number of refractive surgeries including phakic ACIOL implantation is consistently increasing.

Angle-supported lenses

The ACIOL Kelman Omnifit (Bausch & Lomb, Claremont, CA) has been modified to the open-loop flexible one-piece Clemente Optifit (Model 13A; Acritec, Glienicke). It has a 5.5 mm biconvex optic and 13.3 mm total diameter (TD; IOL power: 10 to 27 diopters). Additional improvements include the following:

- No positioning hole.
- Reduction of the compression force to 0.38 gm.
- Increase in haptic angulation from 11.8° to 14° (requiring a minimum anterior chamber depth of 3.4 mm).
- Enlargement and remodelling of the single footplate.
- Thinning of the horizontal haptic.

Since 1991, Clemente [30] analyzed 1000 examples of this new type of ACIOL (Fig. 3), implanted either consecutively after intracapsular cataract extraction (ICCE) or as a secondary procedure after uneventful surgery. He observed 0.5% retinal detachments, 0% pseudophakic bullous keratopathy, 0.5% chronic CME, and 0.4% worsening of pre-existing glaucoma. In contrast, in 5% of eyes after 2175 implantations of the Kelman Omnifit II ACIOL (between 1983 and 1990), Clemente found a slow ingress of fibro-uveal tissue into the small positioning hole (diameter, 0.5 mm). Therefore, complications occurred mostly later than 5 to 16 years in about 80% of eyes. Sixty-eight Kelman Omnifit II ACIOLs had to be

Table 2. Endothelial cell loss after secondary implantation of different intra-ocular lenses

Study	Location	Type of IOL	Eyes, *n*	Time, *mo*	PBK*/Endothelial cell loss, %
Bayamlar	Angle	Ophtec AC260T (Groningen, Netherlands)	22	Min. 12	1.0*
Hayward		Cilco Multiflex	52	Min. 26	1.9*
Lois			101		10.8
Sawada			86		14.0
Menezo	Iris	Worst iris claw (Ophtec, Groningen, Netherlands)	41	14	4.8*
Menezo	Posterior chamber	PMMA	13	14	7.6*
Oshima		MA60BM (Alcon, Ft. Worth, TX)	24	6	7.8
Price			75		26.3
Walter			89	–	3.3

IOL, intra-ocular lens; PMMA, polymethylmethacrylate [5,7,9,10,12–14,25].

explanted. Important aspects in ACIOL placement include the following:

(1) Correct sizing (overal diameter should be 1 mm greater than horizontal white-to-white distance.
(2) Avoid iris tuck and dialysis (*eg*, use of a Sheets guide).
(3) Check if the haptics rest securely at the level of ciliary body band.
(4) Rotate IOL away from iridectomies after insertion (haptics might rotate through them [Fig. 4]), or orient incision to place haptics away from peripheral iridectomies.

Iris-fixated lenses

Claw lenses

The Artisan aphakia IOL design (optic diameter [OD], 5 mm; TD, 8.5 mm), a modification of the Worst Iris Claw Lens, is substantially different from that of past iris-supported lenses (Fig. 5). The Artisan IOLs are fixated to the midperipheral portion of the iris, and, therefore, do not interfere with the normal physiology of the iris or the angle structures. Recent studies of eyes with phakia that had iris-fixated lens implantation to correct myopia showed excellent visual outcomes and stability with a low complication rate. Fourteen months after implanta-

Table 3. Cystoid macular edema, vitreal hemorrhage, and retinal detachment after secondary implantation of different intra-ocular lenses

Study	Location	Type of IOL	Eyes, *n*	Follow-up, *mo*	Cystoid macula edema, %	Vitreal/choroidal hemorrhage, %	Retinal detachment, %
Bayamlar	Angle	Ophtec AC260T (Groningen, Netherlands)	22	min. 12	13.6	0.0	0.0
Belluci	ACIOL	Kelman Omnifit II	35	12–44	3.0	0.0	3.0
Ellerton		Open-loop, one-piece Multiflex	81		1.2		1.2
Hahn		28 flexible, 15 rigid open-loop	43	10	9.3	–	23
Hayward		Open-loop, one-piece Multiflex	52	min. 26	7.7	–	1.9
Kraff			190	17	0.0		1.6
Lois			101		13.9		2.0
Lyle		Open-loop, one-piece PMMA	234	19	5.9	–	0.9
Sawada			86		4.6		0.0
Schein		Open-loop, one-piece Multiflex	60	min. 6	>PCIOL		3.3
Weene		33 Kelman, 10 Tennant	43	12	2.3	–	4.6
Wong		ORC Stableflex, Hessburg, Iolab 91Z (Duluth, GA)	35	18	5.7	–	5.4
Menezo	Iris ACIOL	Worst Iris claw	41	14	4.8	0.0	0.0
Schein		7 mm OD, PMMA	56	min. 6	<ACIOL	0.0	0.0
Belluci	Posterior chamber IOL	728 C, Pharmacia (Kalamazoo, MI)	30	12–44	9.0	3.0	6.0
Bleckmann		7 mm OD, 13.5 mm TD, 10°	48	21	–	25.0	–
Price			75			13.0	
Holland		7 OD, 13–14 TD, PMMA	105	27	9.5	1.1	3.8
Lanzetta			18		15.7	10.6	
Lee		PMMA	122	min. 12		10.7	4.9
Lyle		PMMA	114	21	6.1	–	3.5
Menezo			13	14	7.6	7.6	0.0
Oshima		MA60BM, Alcon (Ft. Worth, TX)	30	9	0.0	3.3	0.0
Schein			60	min. 6			1.6
Solomon			30	25	23.0	3.0	0.0
Uthoff			624	min. 12	5.8	1.8	1.4
Walter			89	–	10	1.1	1.1
Wong		Sinskey-style model J-loop PMMA	40	18	0.0	10.0	2.5

ACIOL, anterior chamber intra-ocular lens; IOL, intra-ocular lens; min., minimum; OD, optic diameter; PCIOL, posterior chamber intra-ocular lens; PMMA, polymethylmethacrylate; TD, total diameter [5–27].

Table 4. Indications for anterior chamber intra-ocular lens versus iris- or sulcus-sutured posterior chamber intra-ocular lens

ACIOL	PCIOL
Bleeding disorders	Endothelial dystrophy; corneal disorders (cornea guttata); PBK after ACIOL implantation (trabecular meshwork already compromised from the original ACIOL); surgery in conjunction with PKP
Extensive scleroconjunctival scarring (*eg,* after trauma)	Anterior chamber: peripheral synechiae, shallow (< 3.0 mm); abnormal angle
Intact anterior vitreous face	Defects of the iris; aniridia
	Glaucoma; surgery in combination with glaucoma filtering operation
	Young patients or relatively long life expectancy (≥10 *y*)

ACIOL, anterior chamber intra-ocular lens; PCIOL, posterior chamber intra-ocular lens; PBK, pseudophakic bullous keratopathy; PKP, penetrating keratoplasty.

tion in eyes with aphakia, the Artisan IOLs offered favorable visual outcomes, a low incidence of intra-operative and postoperative complications, and were easy to remove or replace if necessary [12]. The Artisan IOL can be fixated at the anterior and posterior iris surface [33], and is available in power from 2 to 30 diopters as well as for pediatric aphakia (OD, 4 or 5 mm; TD, 6.5, 7.5, or 8.5 mm).

Toric claw lenses

Effective intra-ocular correction of high preoperative astigmatism in aphakia can be achieved in some cases. Ophtec [Groningen, Netherlands] combined both spherical and cylindrical correction in a new ACIOL design, the Artisan toric PMMA IOL. The Artisan toric ACIOL is very similar to the Artisan myopia and hyperopia ACIOL. The available power depends upon request (+12 to −20 diopters; cylindrical correction, 1–7 diopters). Power calculation is performed by Ophtec [Groningen, Netherlands] using the Van der Heijde formula. To allow the surgeons to implant the toric ACIOL in the position to which they are accustomed, two toric models are available. For proper ACIOL placement (in the cylindrical axis or perpendicular to the axis), and to avoid placement errors, the surgeon receives an illustration of the situation *in situ* (Fig. 6). The authors' experience with this toric ACIOL in 14 eyes with phakia and with at least 6 months follow-up is most promising [oral presentation, 18th Congress of the European Society of Cataract and Refractive Surgeons, Brussels, Belgium, September 2000], with very satisfying functional and morphological results (Fig. 7).

Posterior chamber lenses

As an alternative to ACIOL implantation in inadequate capsular support, fixation of posterior chamber intra-ocular lenses (PCIOLs) at the iris with claws or sutures and in the ciliary sulcus with transscleral sutures has allowed safe and effective visual rehabilitation in the setting of both primary and secondary IOL implantation. There are two basic surgical techniques of suturing PCIOLs. Iris fixation is achieved by threading the suture either through the positioning holes of the IOL optic or around the proximal portion of the IOL loop. The second technique consists of tying a suture around the distal portion or tip of the IOL loop, passing the suture through the ciliary body, and tying it to the sclera. The ciliary ring has a mean diameter of 11.15 ± 0.5 mm [34,35].

Iris-fixated lenses

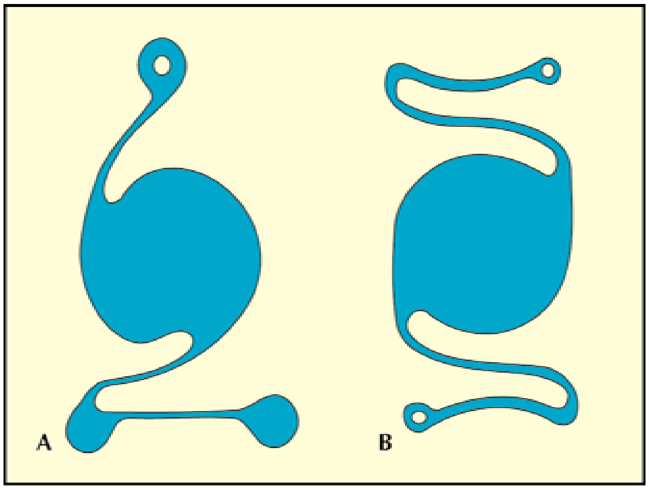
Iris-sutured PCIOLs offer such advantages as reduced surgical time. Fixation is relatively simple when performing penetrating keratoplasty (PKP). However, implementing this technique through a limbal approach is cumbersome. A modified C-loop PCIOL with a TD of 11.5 to 12.5 mm would conform well to the size and shape of the ciliary ring. A 13.5-mm TD of the IOL greatly exceeds the diameter of the ciliary ring, and the loops will extend into the pars plana. Apple [34] reported that in four cases using the iris-suture technique, only one of eight loops actually was found to be situated in

Table 5. Theoretical properties of anterior chamber intra-ocular lens versus posterior chamber intra-ocular lens

IOL type	Advantage	Disadvantage
ACIOL	Short operating time	Endothelial cell loss
	Easy insertion	Need for iridectomy/iridotomy
	Easy to remove or replace	
	No suture associated problems, *eg,* erosion, endophthalmitis	
	Placement far away from ciliary body (reduced risk of hemorrhage)	
Scleral-sutured PCIOL	IOL placement far away from the endothelium	Technically more complex
	Preserves the eye's anatomy (minimize aniseikonia)	Longer operating time (possible effect on complications)
	Independent of presence of iris tissue	Extensive vitrectomy often required (risk of RD, CME)
	Limited pseudophakodonesis	Long-term dependence on fixation of IOL by a suture
	Minimal uveal contact	Ciliary body erosion from haptics

ACIOL, anterior chamber intra-ocular lens; CME, cystoid macular edema; IOL, intra-ocular lens; PCIOL, posterior chamber intra-ocular lens; RD, retinal detachment.

Figure 1. Schematic illustration of one-piece, all-polymethylmethacrylate, open-loop anterior chamber intra-ocular lenses



Kelman designs: (A) flexible, three-point fixation; (B) flexible, four-point fixation. Note the small holes in the haptic.

the ciliary sulcus. With the optic sutured into the peripupillary iris, it is difficult to ensure true ciliary sulcus placement. Therefore, PCIOLs so implanted largely depend on the fixation sutures for stability. However, the attachments of sutures to the iris and ciliary body should not cause problems such as tearing, pseudophakodonesis, or low-grade inflammation, particulary in younger patients with highly mobile irides. Finally, attention must be paid to ensure that the sutures attain a long-term retention of integrity.

Scleral-fixated lenses

Transsclerally sutured PCIOLs reduce the risk of iris shafe, iritis, pigment dispersion, and cystoid macular edema, compared with iris-sutured PCIOLs. Any PCIOL used should have a well-polished, smooth-edged optic to minimize chafing of the epithelia of the posterior iris and ciliary body.

Our recommendations for sutured PCIOL include the following:

(1) *Total diameter 12.5 to 13.0 mm*: It is not necessary to have a TD of 14.0 m when the size of the ciliary ring is only 11.1 mm in an eye without high axial myopia [36]. However, the anatomical variability is known to be very high.

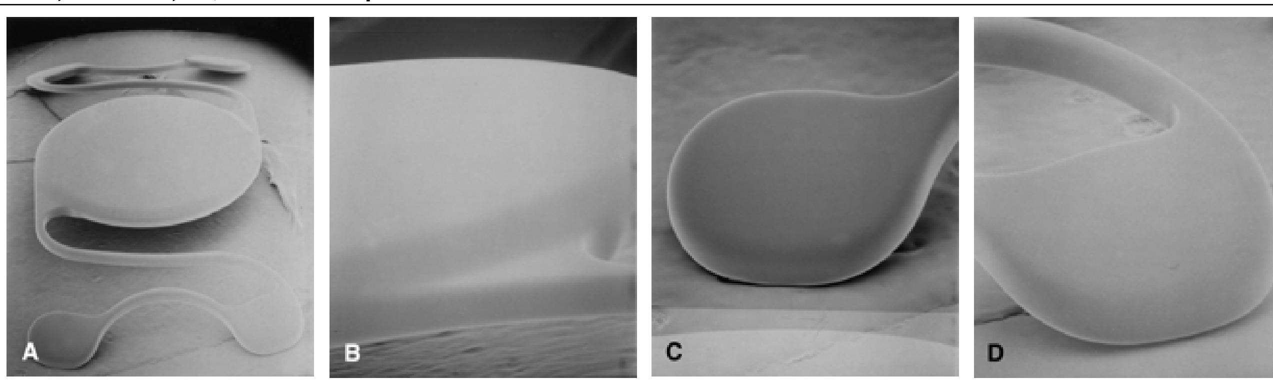
(2) *Large OD of 6 mm or more*: Lens tilt or decentration is found in 5 to 10% of patients after scleral-sutured PCIOL implantation. Intra-ocular lenses with large optics compensate for decentration. Proper suture placement and tension is important in avoiding this complication [37•].

(3) *Haptics: 10° angulation, eyelet*: Eyelets on the haptics prevent suture slippage and further decrease the potential for decentration and tilt [38•]. Before special PCIOLs were available, many surgeons used cautery to bread the tip of the haptics to avoid suture slippage. Hu *et al.* [39] suggested to use a PCIOL with a control tip or to create a club deformity at the end of the haptic with the use of thermal cautery to prevent suture slipping. Heat modification of IOL haptics may rarely lead to late vitreous hemorrhage [40]. Because this voids the warranty for the IOL and creates a rough surface, it is not recommended. Some commonly used models of scleral sutured IOLs include the P366UV (Bausch & Lomb, Claremont, CA), the 27SF (Acritec, Glienicke, Germany), and the PC279 (Ophtec, Groningen, Netherlands).

Foldable lenses

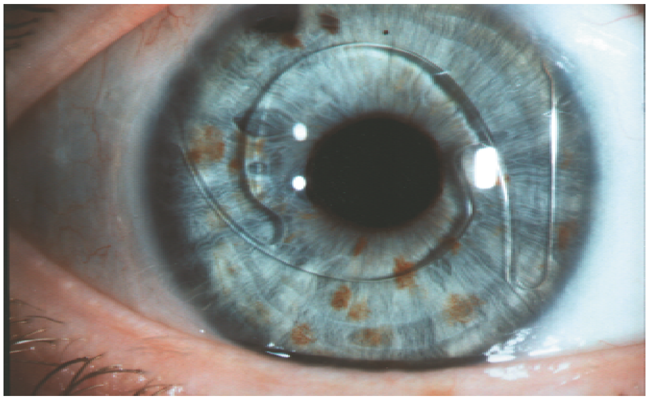
All published reports have in common the use of a relatively large, rigid PMMA optic. To accommodate smooth

Figure 2. Scanning electron micrograph of a flxible one-piece open-loop phakic anterior chamber intra-ocular lens (Nuvita, Bausch & Lomb, Rochester, NY) with four footplates



(A) The overview demonstrates excellent finish with well-polished smooth surfaces and rounded edges (original magnification, ×19.9). (B) The gentle optic haptic junction area leads to a much gentler tissue contact with less possibility of chafing (original magnification, ×70.0) (C,D) Improved quality of the Choyce-style four-point fixation of footplates in combination with Kelman's concept of flexible open loops (original magnification, ×61.0 and ×75.0, respectively).

Figure 3. Photograph of an anterior chamber intra-ocular lens



Modern three-point fixation, one-piece, all-PMMA open-loop biconvex ACIOL (Clemente Optifit 13A, Acritec, Glienicke, Germany) with modified solid Choyce-style footplates. The hole-free haptics provide improved long-term performance.

insertion, an incision of an even larger size is required. Regillo and Tidwell [41] first reported on a small-incision technique for suturing a PCIOL. A relatively large incision often results in significant egress of intra-ocular fluids, with resultant intraoperative hypotony. The frequent need to pressurize the globe, to work with a relatively soft eye during lens insertion, and wound suturing to ensure a watertight closure often makes this procedure difficult and time consuming. An additional postoperative inflammation might result from the added manipulations. Implantation of foldable PCIOLs in aphakic eyes without capsular support requires a smaller incision of 3.5 mm. The smaller, self-sealing incision, in combination with the use of adequate ophthalmic visco-surgical devices, allows better maintenance of the anterior chamber during PCIOL insertion and suturing [42•]. The greater intra-operative control might be less likely to cause intraoperative complications, especially in eyes that are at high risk. It also allows for a shorter operative time, minimized surgically induced astigmatism, and earlier visual rehabilitation [14]. One should be cautious about transscleral fixation of modern PCIOLs with sharp optic edge design, which are most commonly used in routine phacoemulsification (Fig. 8).

Schwenn *et al.* [43] first described their small-incision technique of transsclerally sutured, multifocal, foldable silicone Array IOLs (SA-40, Allergan, Irvine, CA) using the Unfolder (Fig. 9) and reported on satisfying results. These authors also achieved good outcome in some cases after transsclerally sutured, toric PCIOLs (PMMA and, more recently, foldable silicone toric PCIOLs [Dr. Schmidt-Intraokularlinsen, St. Augustin, Germany]) in high preoperative astigmatism and aphakia (Fig. 10).

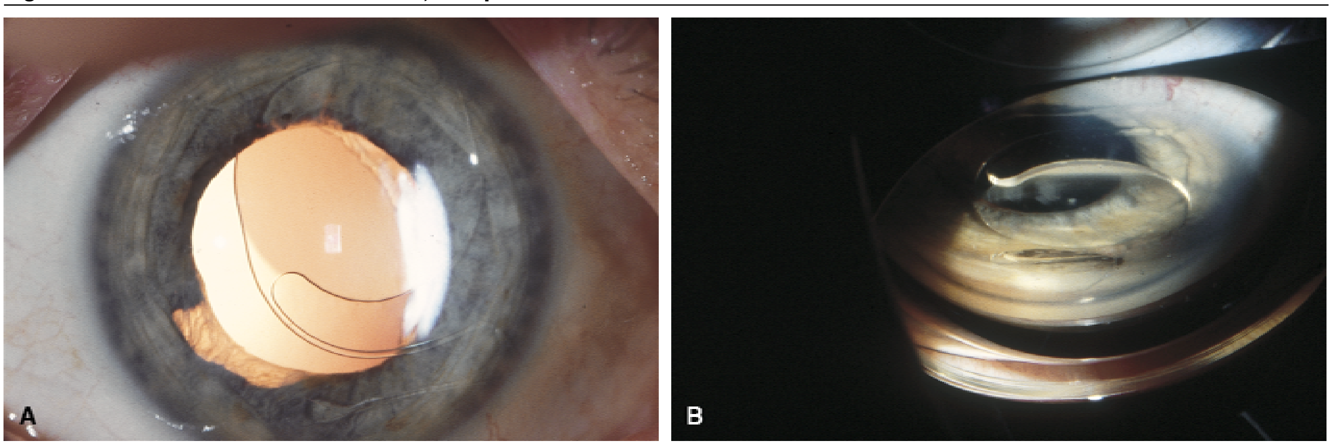
Use in iris defects or aniridia

Symptoms of aniridia range from decreased visual acuity and cosmetic concerns to incapacitating glare and photophobia. Various techniques have been used for treatment, including especially designed contact lenses or corneal tattooing.

Several iris–diaphragm PCIOLs are commercially available: The Morcher 67 A, F, G, L and S IOL (Stuttgart, Germany; TD, 12.5 mm; OD, 5 mm) with black diaphragm (diameter: 10.0 mm), and the Ophtec ANI 1 and ANI2 PMMA IOLs (Groningen, Netherlands; TD, 13.75 mm; OD, 4 mm; both IOLs differ in design) with green, brown, black or blue diaphragm (diameter: 9.0 mm). The ANI IOLs allow better cosmetic match with the fellow eye (Fig. 11). Most of these PCIOLs have two eyelets for suture fixation.

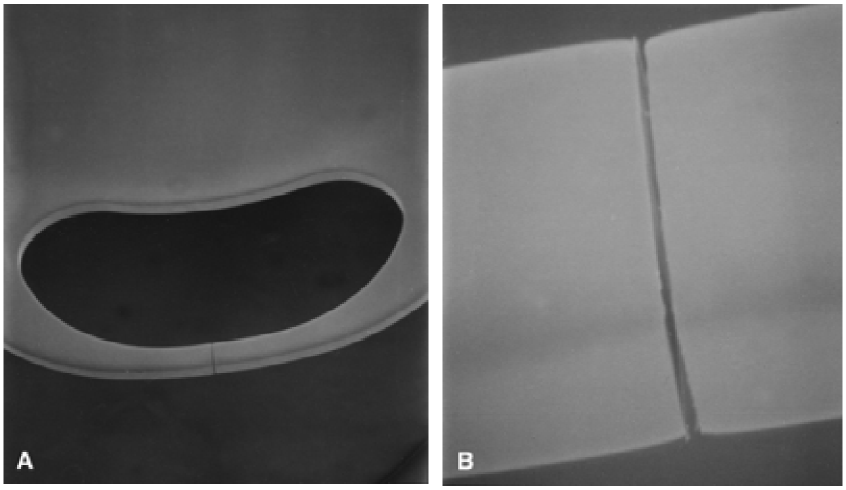
Iris–diaphragm aniridia PCIOLs are not without side effects. Colored PMMA is more breakable than standard PMMA. Persistent intra-ocular inflammation has been

Figure 4. Dislocation of a modern flexible, four-point fixation anterior chamber intra-ocular lens



(A) Dislocation of a modern flexible, four-point fixation ACIOL. (B) Gonioscopy reveals rotation of the haptics through iridectomy at 12 o'clock.

Figure 5. Scanning electron micrograph of the Artisan intra-ocular lens for iris fixation



(A) Haptic-optic junction area with homogenous and smooth surfaces (original magnification, ×38.0). (B) Claw ends show no sharp edges or irregularities (original magnification, ×470) (Ophtec, Groningen, Netherlands).

reported in some cases [44]. Functional results of iris–diaphragm PCIOL in both congenital and traumatic aniridia combined with aphakia were satisfactory [45].

The treatment of aniridia in a patient with aphakia who has contact lens intolerance presents a problem in the United States [46]. There are currently no US FDA–approved devices to treat these patients. It is unlikely that unrestricted use of this device will be allowed in the United States except on a compassionate-use basis.

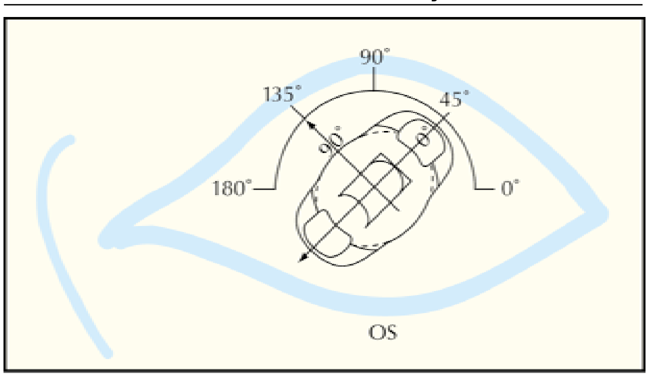
Use for pediatric aphakia

Contact lenses frequently are used after lensectomy to correct pediatric aphakia. However, they are associated with problems like infection and corneal vascularization, particulary in eyes with continous-wear soft lenses. Correction of unilateral traumatic aphakia by IOL in children resulted in better final visual acuities and binocularity, with smaller incidence of strabismus, than when correction was carried out by contact lens [47]. Intra-ocular lens implantation should be considered in children who have poor compliance or tolerance for contact lenses.

The question of implantation of an iris-fixated ACIOL in a child's eye has been raised by van der Pol and Worst [48]. The Artisan IOL, which is available with an OD of 4.0 to 6.0 mm and a TD from 6.5 to 8.5 mm, can be placed, replaced, and exchanged with little surgical trauma. Therefore, it is an interesting treatment modality in the correction of the developmental refractive changes of the growing aphakic eye.

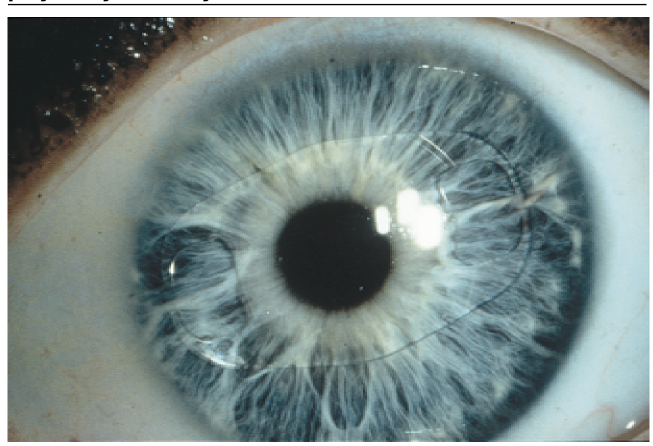
Because of possible long-term complications like endothelial cell loss, a transsclerally sutured PCIOL seems to be preferable to an angle-supported or iris-fixated ACIOL [49•]. To anticipate suture-related complica-

Figure 6. Illustration for proper placement of the toric Artisan anterior chamber intra-ocular lens in the cylindrical axis



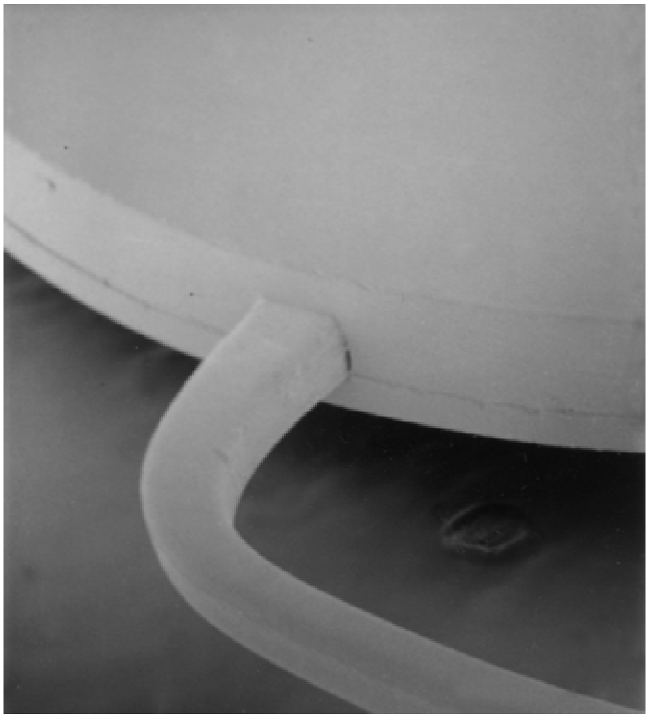
Refractive error: S +5.75 × C –4.5 × 45°; ACIOL to be implanted: S +7 × C –6 in axis 45°.

Figure 7. Slitlamp photograph of the toric Artisan polymethylmethacrylate intra-ocular lens



Artisan PMMA-IOL (Model 203, Ophtec, Groningen, Netherlands), which has a 5.0 mm OD and a 8.5 mm TD.

Figure 8. Foldable silicone posterior chamber intra-ocular lens



Scanning electron micrograph of the foldable silicone PCIOL (911, Pharmacia, Kalamazoo, MI) for implantation into the capsular bag. The sharp-edged optic shows small irregularities and molding flash (magnification × 78.0).

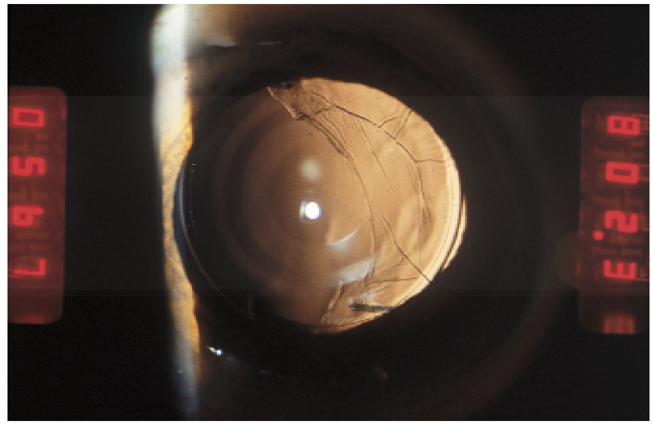
tions [50,51], Zetterström *et al.* [52•] recommended that all knots be rotated, buried in the scleral bed, and covered with conjunctiva. Because pediatric pupils have a diameter of 7.0 mm or more in darkness, a large OD with sufficient haptic angulation to avoid subluxation of the optic into the anterior chamber is needed.

Uncertainty about long-term safety of all treatment options for pediatric aphakia remains. There are many unresolved issues that require meticulous attention to detail, intensive long-term treatment, and lifelong follow-up.

Use for pseudophakic bullous keratopathy

If PKP is necessary because of pseudophakic bullous keratopathy, the surgeon faces a quandary: which IOL offers the best chance of avoiding further IOL-induced complications? A sutured PCIOL involves an obligatory anterior vitrectomy unless a large vitrectomy was done during earlier surgery. In specific cases with vitreous pathology, this is beneficial, but vitreous loss during PKP increases the incidence of CME. *Scleral fixation* requires suturing through the highly vascular ciliary body, possibly causing uveal irritation with low-grade chronic inflammation. An *iris-sutured* PCIOL causes even larger areas of uveal contact, which is the common denominator in the late-onset IOL syndrome of corneal endothelial

Figure 9. Foldable multifocal silicone posterior chamber intra-ocular lens

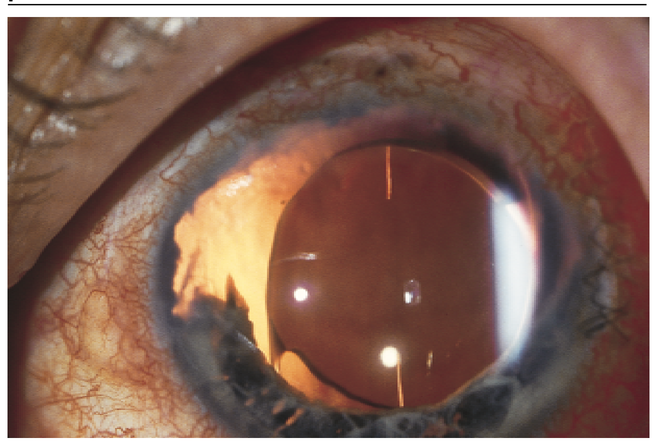


Well-centered transsclerally sutured foldable multifocal silicone PCIOL (SA-40N, Allergan, Irvine, CA) in aphakia, offering the advantages of small incision surgery and pseudoaccommodation.

decompensation and CME. Some surgeons try to reduce this contact by placing the knot between the optic and posterior iris [53]. Recent results [53–55] with sutured PCIOLs supported and extended earlier reports of favorable results with sutured PCIOLs. Unfortunately, the literature does not contain many series of PKP with secondary modern ACIOLs for comparison. Interestingly, there was no statistically significant difference in endothelial cell loss after PKP with scleral-sutured PCIOL versus modern ACIOL [56].

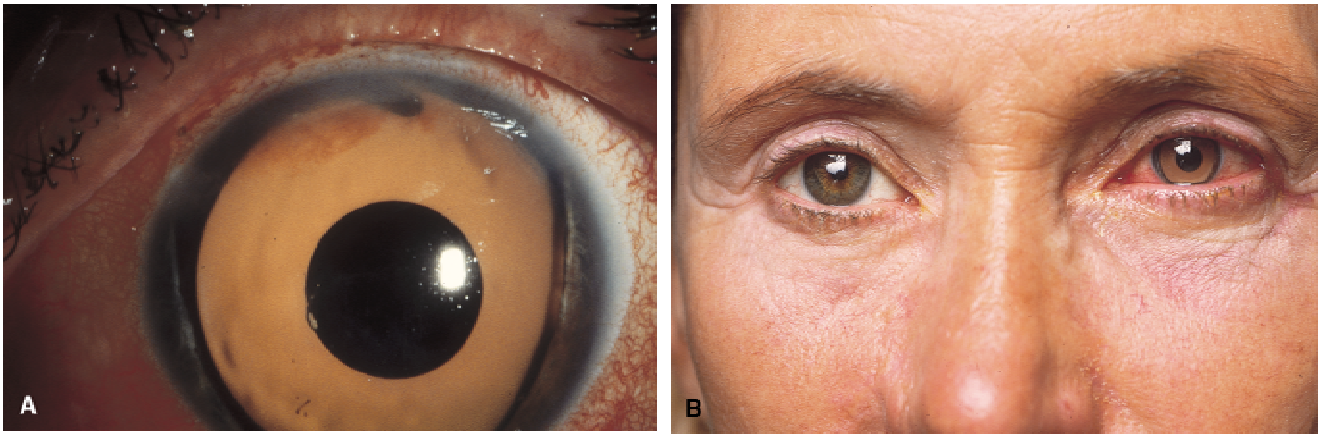
Some authors conclude that modern ACIOLs, scleral-sutured PCIOLs, and iris-sutured PCIOLs all achieve similar visual results if used with PKP [57,58]. Nevertheless, placement of PCIOLs at the time of PKP is likely to remain a frequent procedure [59,60].

Figure 10. Transsclerally sutured toric polymethylacrylate posterior chamber intra-ocular lens



Transsclerally sutured toric PMMA PCIOL (Dr. Schmidt-Intraokularlinsen, St. Augustin, Germany) to correct high corneal astigmatism (9.5 diopters) in traumatic aphakia.

Figure 11. Brown iris diaphragm intra-ocular lens



(A) Anterior segment 2 days after transscleral fixation of a biconvex PMMA-PCIOL (ANI 2, Ophtec, Groningen, Netherlands) with brown iris diaphragm (diameter, 9 mm), 4.0 mm OD, and 13.75 mm TD for traumatic aphakia with large iris defect. It has elliptical haptics (thickness, 0.13 mm) with two eyelets (Ø = 0.4 mm). (B) The brown iris diaphragm allows an acceptable cosmetic match with the fellow healthy eye.

Complications associated with posterior and anterior intra-ocular lenses

The relative rates of various complications among the different IOL options are summarized in Table 6, which extrapolates data derived from several studies. This table should be considered to be only a rough approximation of true complication rates. Most of the patients with good preoperative, corrected visual acuity and secondary PCIOL placement maintained their preoperative vision. However, eyes with previous complicated cataract surgery with vitreous loss have worse results regardless of IOL used at the second surgery, compared with an uncomplicated initial cataract surgery [61].

Endothelial cell loss

Kraff *et al.* [8] found that reduced preoperative endothelial cell count may increase the risk of losing additional cells during secondary lens implantation. Therefore, eyes with pre-existing corneal pathology have a higher risk of postoperative corneal complications and a poorer visual outcome than eyes without pre-existing pathology. Irreversible corneal irritation cannot be excluded in ACIOL implantation because of possible intermittent or permanent endothelial trauma provoked by the IOL [62].

Cystoid macular edema

Cystoid macular edema is one of the most common complications following secondary lens implantation. Cystoid macular edema occurred with almost equal overall frequency after PCIOL and modern ACIOL implantation, whereas it was more frequently associated with closed-loop ACIOLs than with open-loop ACIOLs [28]. Prolonged operating time, together with the lack of physiologic protective mechanisms of the eye (crystalline lens), probably plays a major role in excessive retina light levels, leading to light-induced injuries. Light from the operating microscope reaches the posterior pole through the dilated pupil, especially during the surgical procedure of sclerally fixated PCIOL [23].

Retinal detachment

Vitreous prolapse and anterior vitrectomy is associated with a high risk of retinal detachment, which seems to be similar both in eyes in which ACIOLs have been implanted, and in eyes in which PCIOLs have been implanted. Vitreous loss during complicated cataract surgery is more likely to cause retinal complications than during secondary implantation [11]. Retinal detachments are more closely related to the surgical technique than to the IOL design. With more surgical experience and new techniques, such as intraoperative endoscopic sulcus verification [63], it is possible to localize more precisely the ciliary sulcus to assure the haptics are positioned there [64]. Retinal detachment rates after PCIOL im-

Table 6. Relative frequency of complications associated with secondary intra-ocular lenses

Complication	ACIOL	Iris-sutured PCIOL	Scleral-sutured PCIOL
Corneal edema	++	(+)	(+)
Long-term graft failure	+ (+)	(+)	–
Glaucoma	++	+	(+)
Synechia	++	+	–
Uveitis/iritis	++	++(+)	(+)
IOL tilt/decentration	+	++	++
Intraop bleeding	+	++(+)	+++
Choroidal detachment	+	+	++
Acute CME	+	++	+(+)
Chronic CME	+	+(+)	+
Retinal detachment	+	+	++
Polypropylene knot erosion	NA	NA	+(+)
Polypropylene suture failure	NA	+	+

–, not associated; +, mildly associated; ++, mediumly associated; +++, strongly associated; ACIOL, anterior chamber intra-ocular lens; CME, cystoid macular edema; IOL, intra-ocular lens; NA, not applicable; PCIOL, posterior chamber intra-ocular lens [5–27].

plantation may decrease, if the haptics are in the sulcus and away from the pars plana.

Conclusions

Current indications for ACIOL or PCIOL implantation include large ruptures of the posterior capsule during cataract surgery or secondary implantation after previous intracapsular procedure. It is rare to find an elderly patient with aphakia, because primary IOL implantation is the rule in modern cataract surgery. The choice of method and sucess of the IOL implantation depends on the state of the eye.

Implantation of ACIOL in patients older than 80 years without corneal disease is an alternative to PCIOL implantation, especially if general health problems contraindicate prolonged surgical procedures or increase the risk of bleeding. The use of modern ACIOLs is justified ethically and medically in many cases, especially for surgeons who do not have extensive experience with alternative techniques, such as transscleral or iris fixation of PCIOLs.

Cataracts are the leading cause of blindness in the rural developing countries where microsurgical technology is limited. A backlog of several million patients suffers from mature cataracts. Therefore, implantation of modern ACIOL after an uncomplicated ICCE is a viable alternative to aphakic spectacle correction. The modern ACIOL will play a very useful role in these cases.

A number of techniques have been proposed, but none has clearly emerged as the optimal method for IOL fixation. With recent advances in IOL designs, surgical techniques, instruments, and maneuvers, and also by the use of ophthalmic viscosurgical devices, IOL implantation in the absence of capsular support now is usually associated with good visual outcomes.

Sulcus-fixated PCIOLs remmain the preferred procedure to correct aphakia in eyes without capsular support that have significant loss of iris tissue from surgery or trauma. Sutured PCIOLs continue to play an important clinical role, especially in younger patients and eyes with glaucoma, peripheral anterior synechia, or corneal problems. Recent technological advances such as foldable PCIOL insertion with new designs, iris-diaphragm PCIOLs, or toric iris-fixated ACIOLs, seem to improve care of the patient with aphakia.

Prospective, randomized studies are needed to determine which IOL (ACIOL, iris-fixated claw IOL, or PCIOL) is safest and most effective for the correction of uncomplicated aphakia. Because of the potential complications of surgery, we advise secondary IOL implantation only when satisfactory vision cannot be achieved with glasses or contact lenses.

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