

Review

The Correction of Aphakia Using Anterior Chamber Intraocular Lens

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Abstract. *Senile cataract is the leading cause of severe vision loss and blindness worldwide, affecting approximately 20 million people. Anterior chamber intraocular lens (AC IOLs) remain a surgical option for visual rehabilitation required after surgical extraction of the cataract lens. Relevant publications in the PUBMED database were searched for articles regarding the types, visual outcomes and the complications followed the surgical implantation of AC IOLs. AC IOLs, which can be iris- (iris-claw) or angle-supported, increase visual acuity in most patients. However, complications, such as raised intraocular pressure, hyphaema, distorted pupil shape, iris pigment precipitates, endothelial cell loss, corneal oedema, neovascular glaucoma, retinal detachment and cystoid macular oedema, can unfavorably affect the surgical outcome. Although AC IOLs have been found to improve the visual acuity of patients with cataract, they have been also implicated in several complications.*

The crystalline lens is a transparent biconvex structure, participating in the refractive system of the eye. Any metabolic disturbance in the lens result in localized or diffuse opacification, called a cataract (1). Senile cataract is the leading cause of severe vision loss and blindness worldwide, affecting approximately 20 million people (2-6). The visual rehabilitation required after cataract surgery is usually treated

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with aphakic glasses, contact lenses, and intraocular lenses (IOLs), which can be placed in the anterior or posterior chamber (7). The use of anterior chamber IOLs (AC IOLs) for the correction of aphakia was first reported in the 1960s (8, 9). However, this method was abandoned for about 20 years due to the high incidence of complications and the progression of cataract surgery (10). In 1996, AC IOLs were implanted in 1.09% of patients who underwent cataract extractions; this percentage had increased to 43% by 2000 (11). Since the development of AC IOLs, their design has been frequently modified, ultimately changing from a biconcave form to a convex-concave one (12, 13). The latter is designed to protect the corneal endothelium, which is usually vulnerable to lens-induced damage. The indications for the use of AC IOLs include extracapsular cataract extraction with intraoperative complications, intracapsular cataract extraction, secondary implantation and penetrating keratoplasty (11).

To our knowledge, this is the first article focusing on aphakic AC IOLs, and reviewing their visual outcome and complications.

Outcomes and Complications Following Implantation of AC IOLs in Aphakia

AC IOLs can be iris-(iris-claw) or angle-supported. The angle-supported IOL is fixed with four haptic points in the anterior chamber, while the iris-fixed IOL is trapped in the anterior iris surface (14). The Worst-Fechner lens (Artisan), which was developed in 2004 and approved by the US Food and Drug Administration, remains a widely used type of AC IOL (15). AC IOLs also include the retropupillary fixated Artisan, foldable acrylic IOLs, the angle-supported Kelman Multiflex (ALCON, Hemel Hempstead, UK) and other open-loop AC IOLs.

Artisan iris-claw AC IOLs. The Artisan lens (Artisan IOLs, Ophtec BV) was first introduced in the 1970s to correct aphakia (16). It is 8.5 mm in length, and the central 5-mm

optic is supported by two unique flexible haptic 'claws' for iris fixation. It is a polymethylmethacrylate (PMMA) lens available in refractive powers ranging from 2 D to 30 D in 1-D increments, and from 14.5 D to 24.5 D in 0.5-D increments. It is fixed to the mid-peripheral iris and centered over the pupil, protecting the function of mydriasis, iris vasculature and the delicate structures of the angle. The support of the lens requires no sutures but sufficient iris tissue; suture pupilloplasty may be employed if needed to reform the pupil, and the IOL may be placed in any axis desired. The phakic platform of Artisan is marketed as Verisyse and exhibits difference in sizing from the Artisan aphakic model. The phakic Verisyse models are available in the following sizes: 7.5 mm with a 5-mm optic (-3 D to -23.5 D, in 0.5-D increments), 8 mm with a 5-mm optic (-1 D to -23.5D, in 0.5-D increments), and 8 mm with a 6-mm optic (-1 to -15.5, in 0.5-D increments) (17).

A comparative study of AC and retropupillary implantation of iris-claw IOLs (Artisan) revealed a notable improvement of visual acuity in both aphakic groups. The prevalence of pupillary irregularity was similar (3% and 5%, respectively) in both groups, while a significant and temporary increase in intraocular pressure was also observed. The results were not significantly different between the two fixation techniques for iris-claw lens (18). Similarly, Teng *et al.* determined no statistically significant difference in endothelial cell loss following iris claw (Artisan) or posterior chamber IOLs (PC IOLs) at 3 months, 6 months and 1 year after surgery. Moreover, they revealed that the best corrected visual acuity (BCVA) was higher in the iris-claw lens group (mean=0.40, SD=0.12-0.80) compared to the PC IOLs (mean=0.30, SD=0.08-0.60), whereas the intraocular pressure (IOP) was much lower in the latter (11.63±2.29 mmHg) compared to the former (13.61±3.37 mmHg) at 1 day after surgery. No differences in BCVA and IOP were observed at 1 month and 3 months after surgery between the two groups. The postoperative complications of group one were anterior uveitis, iris depigmentation, pupillary distortion and spontaneous lens dislocation. Patients in the PC lens group experienced choroidal detachment, intraocular haemorrhage, IOLs decentration and retinal detachment (19, 20).

The promising visual outcome of iris-claw IOLs (Artisan IOLS, Ophtec BV) was also defined in 128 aphakic eyes lacking capsular support. The BCVA was improved 1 year postoperatively (0.52 logMAR from 0.67 logMAR) and remained stable for up to 5 years. The mean endothelial cells density decreased slightly over the years. Pupillary block, transient increase in intraocular pressure, IOL replacement, penetrating keratoplasty and cystoid macular oedema were the referred complications of the implantation (21). Kheirkhah *et al.* also proposed iris-claw Artisan IOLs for the correction of aphakia in Fuchs' heterochromic iridocyclitis. A patient with Fuchs' heterochromic iridocyclitis achieved a

BCVA of 20/20 one month postoperatively, although a few deposits on the IOL surface were noted. The IOL remained stable with no subsequent iris atrophy, subluxation, or pupil ovalization, and glaucoma, vitreous inflammation, or clinical cystoid macular oedema were not observed (22). Li *et al.* observed that combined coreoplasty and Artisan IOL implantation in post-traumatic vitrectomized aphakic eyes enhanced the visual acuity of the patients without significantly affecting IOP (23).

Chen *et al.* performed a cohort study to assess the efficacy and safety of secondary anterior iris fixation of the Artisan iris-fixed IOL to correct aphakia in eyes lacking capsule support. They recruited 72 patients who were followed-up for 3 years. The visual acuity was improved in all patients, except for two who experienced postoperative ischaemic optic neuropathy or retinal detachment. The mean postoperative IOP was not significantly increased throughout the follow-up, whereas the mean rate of endothelia loss was 9.78%. The observed complications included glare and halos during night driving (16.7%) and iris pigment precipitates (5.6%) (24).

The outcome of intraocular implantation of an iris-claw aphakic IOL during primary lens surgery or following a dislocated PC IOL or as a secondary procedure was studied in 116 eyes for a period of around 22.4 months. The visual acuity was 6/12 or better in 69% of the eyes, whereas the referred complications included postoperative increase in intraocular pressure (9.5%), cystoid macular oedema (7.7%), iris-claw IOL subluxation (6.0%), wound leak requiring re-suturing (2.6%), corneal decompensation (1.7%) and retinal detachment (0.8%) (25). Cagini *et al.* supported that simultaneous keratoplasty (Descemet's stripping automated endothelial keratoplasty, DSAEK) and aphakic iris-fixed IOL implantation in patients with aphakia and bullous keratopathy was safe, resulting in stable IOL without referred postoperative complications (26). Similarly, Koss and Kohnen ascertained that the loss of corneal endothelial cells was not significant in 18 aphakic eyes which received AC iris-claw lenses. The rate of loss was negatively correlated with the axial length, being negligible for eyes with axial length of 24 mm or more (27).

The use of Artisan-Verisyse intraocular lens for secondary implantation and correction of aphakia has been estimated to be safe, also achieving a BCVA of 20/40 or better in 37.5% of eyes treated by Güell *et al.*; corneal endothelial cell loss was mainly observed within the first year (7.78%), whereas cystoid macular oedema was diagnosed in two out of a total of 16 patients in a follow-up of at least 3 years (28). A customized PMMA iris print and iris-clipped AC IOL (Ophtec BV) has been proposed to repair aniridia along with correction of aphakia and corneal astigmatism (29). The vertical placement of an aphakic Artisan (Ophtec) IOL in the anterior chamber of a patient who had a perforating injury

to the cornea led to a BCVA of 0.9 3 months later without complications. Traumatic aniridia was the cause for the vertical location of the lens (29).

Open-loop AC IOLs. The fixation of open-looped AC IOLs to the iris has been suggested as surgical approach for correcting the instability of such IOLs and subsequent progressive corneal damage (30). Dai *et al.* noted the causes of a flexible open-loop anterior chamber IOL extraction in 28 eyes which kept the lenses for a mean of 6 years. They found that bullous keratopathy was the most common cause, accounting for 42.9% of the eyes, followed by secondary glaucoma (32.1%), retinal detachment (17.9%) and lens dislocation 7.1% (31). An earlier study comprised 18 patients (20 aphakic eyes) who had secondary flexible, open-loop (Coburn 120 UV[®]) AC IOL implantation, detecting no visual deterioration during the follow-up (mean time 93.8 months). The observed complications included corneal decompensation (one patient), retinal detachment (one patient) and pupil distortion (five eyes). The postoperative IOP was significantly reduced (32).

Evereklioglu *et al.* compared surgical outcomes following the secondary implantation of a flexible, open-loop, single-piece, PMMA AC IOL (AC260T, Ophtec, or OPAB16, Hanita) (group 1) and a flexible, open-loop (haptics with eyelets), scleral-fixated, PMMA PC IOL (CZ70BD, Alcon) (group 2) in 124 aphakic eyes with insufficient capsule support. The comparison revealed no statistically significant difference in the visual outcome between the groups. However, the visual acuity was higher in group 1. On the other hand, the referred complications following the implantation were more frequent in the AC IOL group and included early transient corneal oedema, increased IOP, cystoid macular oedema, hyphaema, secondary glaucoma, and iris capture or pupil decentralization (33).

An older study compared the surgical outcome of AC IOL implantation using open-loop lenses or closed-loop designs. Open-loop AC IOLs led to a significantly lower rate of complications, while closed-loop designs were related to almost 80% of corneal pathology (34). Drolsum and Haaskjold also noted that open loop AC IOLs can achieve a visual acuity of 5/5 or better and a postoperative refraction within 1 diopter of emmetropia. There was only one case of cystoid macular oedema among 20 aphakic eyes (35). The combination of an open-loop AC IOL implantation with penetrating keratoplasty in patients suffering from pseudophakic or monocular aphakic bullous keratopathy had good postoperative visual outcome even in the early 1990s. The referred causes of failed visual improvement (less than 20/200) were cystoid macular oedema, glaucoma, and immunological graft failure (36).

Foldable acrylic IOLs. The use of an angular supported foldable acrylic IOL in 21 patients with unilateral aphakia

revealed the improvement of visual acuity (1.26 ± 0.46 logMAR pre-operatively and 0.78 ± 0.57 logMAR post-operatively, $p=0.003$), which can be achieved with the implantation of AC IOLs. The observed complications included intraocular hypertension (over 21 mmHg) in 14.3% of the patients, macular oedema (5%), pupillar ovalization (5%), and retinal detachment (5%). They concluded that an angular support foldable lens in the AC is a useful technique for the correction of aphakia in eyes without capsular support (37). The application of a new foldable acrylic AC IOL (Acri.Lyc 15A, Acritec) through a small incision has also been found to result in increased visual acuity, being accompanied by several complications. The latter include reduction in endothelial cell density, corneal oedema, Descemet folds, raised IOP, hyphaema, distorted pupil shape, 'iris bombe', blood in the vitreous, displaced IOL and cystic macular oedema. However, the authors noted that these complications had no effect on the final visual outcome (38).

Kelman Multiflex AC IOLs. Similarly, the inverted insertion of a Kelman Multiflex AC IOL in four cases was followed by chronic iritis, cystoid macular oedema, pupil capture, iris adhesions, and corneal decompensation (39). At the Lahan Eye Hospital, Southern Nepal, 2000 people with bilateral cataracts underwent intracapsular extraction with aphakic correction or with an AC IOL implantation in their first operated eye. They used a single-piece four-point fixation (19.0 or 19.5 dioptre) CILCO Kelman Multiflex III AC IOL (ALCON). The functional visual acuity was 6/60 or less in approximately 5% of the AC IOL group 1 year after surgery in comparison to 5.4% for the controls. The poor vision was attributed to uncorrected refractive error in the majority of patients, whereas it was related to surgical complications in only 2% of them. Uveitis and glaucoma were the common causes of decreased visual acuity in the AC IOL group (40).

Other studies. Similarly, Suelves *et al.* supported the safety and efficacy of MTA3UO AC IOLs (Alcon Laboratories, Inc.) and L122UV AC IOLs (Bausch & Lomb) in uveitic patients with inadequate capsule support and in patients without a history of intraocular inflammation. PMMA is an acrylic biomaterial made from one type of monomer. It contains both hydrophobic (methylene) and hydrophilic (carbonyl) groups. The MTA3UO is a convex-plano open-loop PMMA IOL. The L122UV is a PMMA IOL that has a vaulted equiconvex design (41, 42). Besides the common complications following AC IOL (MTA3UO ALCON) implantation, Farah *et al.* reported the fracture of such IOL after Nd:YAG laser iridotomy (43).

Air-assisted AC IOL implantation has been suggested as a safe and effective technique for implantation of these lenses in cases with progressive lens subluxation. The mean BCVA was found to be raised 6 months postoperatively

(from 0.67 to 0.25 logMAR), with no negative effect on IOP (14.54±1.38 mmHg at baseline and 15.16±1.15 mmHg at 6-month follow-up). The mean corneal endothelial count at 6 months was reduced (2,947±194.9 cells/mm²) compared to that at baseline (3,151±240.49 cells/mm²) (44). Esquenazi *et al.* evaluated endothelial cell survival 2 years after DSAEK in the presence of an AC IOL. They estimated that although the AC IOL was well-centered, the mean endothelial cell loss in the first and second year were 24% and 28%, respectively (45). Hazar *et al.* compared the visual outcome and endothelial cell loss among AC iris-fixed IOL, retropupillary iris-fixed IOL, and scleral-fixed PC IOL implantation. The visual acuity was 20/40 or better in 62.9%, 50% and 58.1% of eyes after implantation, respectively. Although the visual improvement was higher in the AC iris-fixed IOL group, the scleral-fixed PC IOL group exhibited the lowest loss of endothelial cells (5.9%) compared to AC iris-fixed IOL (7.2%) and retropupillary iris-fixed IOL (11.4%) groups (46). Ravalico *et al.* confirmed the corneal endothelial loss in eyes undergoing cataract surgery with primary or secondary AC IOL implantation. Moreover, they concluded that the endothelial cell difference was significantly greater in aphakic patients who had a secondary compared to primary AC IOL implantation (47).

AC IOLs have proven to be safe and useful for visual rehabilitation, when they are implanted in combination with silicone oil removal: 87.5% of eyes exhibited improved or unchanged visual acuity compared to 85.3% of eyes in which PC IOLs were used. No statistically significant differences in the incidence of complications, including corneal oedema, elevated intraocular pressure, hypotony, and retinal detachment, between the two groups were found (48). On the other hand, a clinicopathological report on Choyce Mark VIII anterior chamber IOL was made by Ollerton *et al.*, using an enucleated eye that was blind and painful. The microscopic features revealed the presence of corneal decompensation and vascularization, the formation of peripheral anterior and posterior synechiae, significant alterations in the iris (thinning, fibrous tissue) and the development of Soemmerring ring in the remnants of the capsular bag. The IOL surface was smooth and regular, partially covered by various cells, including giant cells intermixed with pigment (49). The secondary implantation of an AC IOL seemed to attain a visual acuity of 20/40 or better in 71.4% of the eyes, compared to 92% and 57.1% of patients where PC and scleral-fixed PC lenses, respectively, were used. The same study noted that corneal endothelial cell loss and other complications, such as cystoid macular oedema, persistent fibrinous membrane formation, and neovascular glaucoma were more frequent in patients where an AC IOL was used (50).

Artaria estimated the complications followed the secondary implantation of an AC IOL of Symflex type after

uneventful intracapsular cataract extraction in 45 aphakic eyes. The 40-month follow-up revealed minimal (12 cases) or advanced pupillary deformation (three cases), formation of peripheral anterior synechia (one case), pupillary block glaucoma (two cases), worsening of the BCVA (eight cases), retinal detachment (two cases) and cystoid macular oedema (one case) (51). Spirig and Jenny observed retinal detachment (two cases), cystoid macular edema (one case), corneal dystrophy, glaucoma or lens dislocations in aphakic eyes undergoing secondary implantations of AC IOLs (52). Retinal detachment and bullous keratopathy are severe complications which can impair the visual outcome after AC IOL implantation (53).

Conclusion

Although AC IOLs have been found to improve visual acuity, they have been also implicated in several complications, including loss of corneal endothelial cells and corneal decompensation, increase in IOP, pupillary distortion, cystoid macular oedema and retinal detachment.

Conflicts of Interest

None of the Authors has any conflict of interest to declare and no financial support was offered for the present review. The Authors alone are responsible for the content and writing of this article.

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