Intraocular lens optic capture in pediatric cataract surgery

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INTRODUCTION

Over the past decade, the treatment of children’s cataracts has undergone rapid development[1-5]. However, due to the specific biological characteristics of children’s eyeballs, posterior capsule opacification (PCO) is still a serious complication of pediatric cataract surgery, and it seriously threatens the recovery of visual function after surgery. Current efforts to prevent PCO include primary posterior capsulotomy (PPC) with or without anterior vitrectomy[6-7], intraocular lens (IOL) optic capture[8-10], use of perfusate containing heparin and heparin-surface-modified (HSM) IOLs[15,17]. Chemical prevention of PCO by irrigation with antimetabolite has also been tested in animal models[18]. Despite these efforts, there is still no clear optimal treatment option for effective prevention and reduction of the occurrence of PCO.

In 1994, Gimbel and DeBroff[11] was the first to publish the IOL optic capture technique and use it to prevent PCO in pediatric patients with congenital cataracts. This technique has been featured in reports by many other researchers, but there is currently no professional consensus on the exact preventive effect of PCO, especially on the need for anterior vitrectomy at the same time. In 2017, Vasavada et al[19] reported 26 eyes with pediatric congenital cataracts that were subjected to IOL optic capture operation without anterior vitrectomy. After 12mo of follow-up, eyes were examined for visual transparency, which confirmed the clinical effect of the operation to prevent visual axis obscuration (VAO). Recently, Zhou et al[20] published a Meta-analysis of 282 eyes with pediatric cataracts that were subjected to IOL optic capture and showed that the technique can significantly reduce the VAO rate and eccentricity of IOL.

In this report, we reviewed literatures related with optic capture technique since its first report by Gimbel and DeBroff[11]. We here discuss the topics including applications of optic capture in pediatric cataract management, complications after optic capture IOL, typical types and features of IOLs which have been used for optic capture technique.

HISTORY OF INTRAOCULAR LENS OPTIC CAPTURE

In 1991, Neuhand and Neuhand described a technique involving placing the IOL in the sulcus and then placing the optic of the IOL through the opening in the anterior capsulorhexis to achieve capture and stable fixation when the posterior capsule tears during adult cataract surgery[21]. In 1994, Gimbel and DeBroff[11] modified the technique and used it to prevent PCO in pediatric cataract surgery. This technique involves implantation of polymethylmethacrylate (PMMA) IOL in the capsular bag following anterior curvilinear capsulorhexis (ACCC) and posterior curvilinear capsulorhexis (PCCC), capturing the IOL optic through the PCCC opening, and placing of the anterior and posterior capsule leaflets in apposition. This maneuver seals the residual cortex within the bag and eliminates the need for an anterior vitrectomy. Since the initial report, this technique has been used for the prevention of PCO in pediatric cataract treatment (Table 1).

INTRAOCULAR LENS USED FOR OPTIC CAPTURE TECHNIQUE

IOLs, which have been used for optic capture in pediatric cataract, mainly include single-piece PMMA IOLs[10,17,22-23,25] and three-piece acrylic IOLs[12,14,16,19,24] (Table 2).
Polymethylmethacrylate (PMMA) is the first material used for intraocular lens (IOL) manufacture. It has the best optical quality among synthetic transparent materials. Before 2001, most of the IOLs used in optic capture were made of PMMA. PMMA material has excellent biocompatibility, low tissue reactivity, a high refractive index, and excellent optical properties. However, PMMA material cannot endure high temperatures or pressures, and it is relatively rigid and unfoldable. As a result, PMMA IOL has been used less and less in pediatric cataract surgery[27].

Heparin-surface-modified Polymethylmethacrylate Intraocular Lens Heparin-surface-modified (HSM) PMMA IOL has been reported to reduce the incidence of VAO and iris inflammation after cataract surgery[15,28]. Heparin is a naturally occurring anticoagulant produced in animals. It inhibits the formation of fibrin, outgrowth of fibroblasts, and polymerization of type I collagen. Pediatric eyes usually have

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BP: Behind the posterior curvilinear capsulorhexis; CS: Ciliary sulcus; PCO: Posterior capsule opacification; -: No available data.

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#: No available data; PMMA: Polymethylmethacrylate.

Polymethylmethacrylate Intraocular Lens PMMA, also known by the trade name Plexiglas, is the first material used for IOL manufacture. It has the best optical quality among synthetic transparent materials. Before 2001, most of the IOLs used in optic capture have been made of PMMA. PMMA material has excellent biocompatibility, low tissue reactivity, a high refractive index, and excellent optical properties. However, PMMA material cannot endure high temperatures or pressures, and it is relatively rigid and unfoldable. As a result, PMMA IOL has been used less and less in pediatric cataract surgery[27].

Heparin-surface-modified Polymethylmethacrylate Intraocular Lens Heparin-surface-modified (HSM) PMMA IOL has been reported to reduce the incidence of VAO and iris inflammation after cataract surgery[15,28]. Heparin is a naturally occurring anticoagulant produced in animals. It inhibits the formation of fibrin, outgrowth of fibroblasts, and polymerization of type I collagen. Pediatric eyes usually have
stronger postoperative fibrinous reactions due to the immaturity of the blood-aqueous barrier and insufficient fibrinolytic activity[28-30]. HSM IOL has been used to reduce anterior chamber reaction. Basti et al[34] evaluated the performance of HSM IOLs in 90 pediatric eyes after cataract surgery. Cellular deposits on the IOL surface and postoperative inflammation were significantly less pronounced in HSM IOL implantation patients. Gimbel[15] reported PCCC with optic capture of the heparin-coated IOLs in 16 eyes. No VAO occurred at 35.5mo follow-up.

**Acrylic Intraocular Lens** Acrylic IOL is less irritrating to intraocular tissue than other substances, causes less inflammation than PMMA IOL.[31] and offers excellent biocompatibility.[16] Another advantage of acrylic IOL is foldable design, which makes implantation possible with an incision under 3 mm in length, rather than the traditional 5.5 mm incision required for PMMA IOL. Primary implantation of foldable acrylic IOLs in paediatric eyes may allow fewer rate of perioperative complications[32-33]. Moreover, hydrophobic acrylic IOL have a strong tendency to adhere to the lens capsule, which contributes to posterior and anterior capsule clarity and prevent lens decentration[34]. Acrylic IOL have been reported as having very low rates of PCO[31,35-37]. So far, almost all acrylic IOLs used for pediatric cataract IOL capture are three-piece design. Vasavada et al[19] concluded that this design of three-piece, in particular its optic-haptic junction, allowing almost 360 degrees of capsular fusion and might be better suited for optic capture. Faramarzi and Javadi[12] emphasized that for the approach of implantation of IOL haptics in the ciliary sulcus and optic capture through the capsule opening, only the three-piece IOL with PMMA haptics is applicable and one-piece AcrySof IOL is not indicated for sulcus fixation. Solebo et al[38] conducted national postal questionnaire surveys of consultant ophthalmologists in the UK and Ireland. All surgeons (100%) who performed primary IOL implantation used hydrophobic acrylic lenses in children < or =2y, with 90% using an AcrySof model.

**INTRAOCULAR LENS OPTIC-HAPTIC INSERTION ANGLE DESIGN**

The design of the insertion angle between the haptic and optic is believed to affect the ability of optic capture to prevent postoperative PCO. For the Gimbel’ capturing mode[11], the site at which the haptics enter the capsular bag creates an area in which the posterior capsule is posterior to the optic, in which residual cortex may find their way into the posterior chamber and cause PCO. Some scholars believe that this gap at the optic-haptic junction may be reduce by the right-angle design of optic-haptic junction. Gimbel and DeBroff[11] and Raina et al[39] postulated that using an IOL with a distinct right-angle departure of the haptic from the optic may help in achieving a tighter seal than a traditional lens design. In their study, all eyes had a clear central visual axis during the follow-up period even in the absence of vitrectomy. In contrast, Vasavada and Desai[17] observed opacification of the anterior vitreous face in all 3 eyes that had optic capture without an anterior vitrectomy and a secondary pars plana anterior vitrectomy was required, in which the haptic-optic angulation of PMMA IOL of in their study is oblique. Koch and Kohnen[21] also used a PMMA IOL that had an oblique haptic-optic junction. In their study, 4 of the 5 eyes that had optic capture without vitrectomy developed secondary cataracts.

**LOCATION OF INTRAOCULAR LENS**

**Haptics in the Bag with the Optic Capture Through Posterior Curvilinear Capsulorhexis** This technique involves IOL implantation in the capsular bag following ACCC and PCCC, capturing the IOL optic through the PCCC opening. Gimbel and DeBroff[11] first reported this technique in children’s cataracts in 1994. After closure of posterior and anterior capsules, the migration of remnant cortex out of capsule is inhibited, which in turn inhibits PCO formation and eliminates the need for anterior vitrectomy. The IOL optics, together with continuous curvilinear capsulorhexis between posterior and anterior capsules, creates a stable barrier. After optic capture, both posterior and anterior capsules are located in the anterior surface of IOL. In this case, small amounts of migrating cortex were unable to reach the posterior of IOL to form PCO. Five months postoperatively, the anterior vitreous face was clear and no precipitates had formed on the anterior or posterior IOL surface. In 1996, Gimbel[99] conducted a study in 13 pediatric eyes using posterior capsulorhexis with optic capture technique, and no VAO occurred. In 1997, Gimbel[15] conducted PCCC with optic capture of the Heparin-coated IOLs in 16 pediatric eyes, the visual axis remained clear in all eyes.

**Posterior Vertical Capsulotomy with Optic Entrapment**

Grieshaber et al[23] reported a modified surgical technique, namely posterior vertical capsulotomy with optic entrapment, in 68 pediatric cataract eyes. In this technique, the anterior and posterior capsules were opened by capsulotomy with a diamond knife and straight Sutherland microscissors in a vertical direction with length comparable to that of IOL. A one-piece PMMA IOL was implanted in the bag and the optic was then entrapped centrally behind the bag. According to Grieshaber, this technique maximizes the contact area between anterior and posterior leaflets and offers an almost congruent fusion area. All 68 eyes maintained a clear visual axis for 5 to 12y postoperatively. In all eyes, the IOL remained well centered and entrapped. However, there is some disadvantage of this technique. Although vertical capsulotomy maximized contact of both leaflets and increase the barrier effect, there may be more encroachment on the visual axis than in the PCCC method developed by Gimbel, which may affect vision under dim illumination when the pupil is wider.
Optic capture in children

Haptics in the Ciliary Sulus with the Optic Capture through Posterior Curvilinear Capsulorhexis  Another approach to preventing PCO is to implant the haptics of IOL in the ciliary sulcus, after which the optic is captured through the posterior capsulorhexis[12]. This technique is easier to perform than the optic capture technique developed by Gimbel and DeBroff[11]. In addition, optic capture of the IOL through the PCCC provides complete fusion of the anterior and posterior capsule leaflets, which is beneficial to reduce PCO. Vasavada et al[10] suggested that this technique could also be applied to cases of incomplete anterior capsulorhexis because it could decrease the total area of optic contact with the iris, reducing the uveal inflammatory response. In 2009, Faramarzi and Javadi[12] applied this technique in 14 pediatric cataract surgeries and followed up the patients for 22.2mo. No PCO was noted in this series.

APPLICATION OF CAPSULAR DYSES IN CAPTURE TECHNIQUE IN PEDIATRIC CATARACT

Capsular dyes have been successfully used to stain the anterior capsule in adult patients with an absence of a red fundus reflex[19], as well as to enhance visualization in cases of cataracts with corneal haze/opacification[20]. The pediatric capsule is thin, transparent, and elastic. As a result, capsule staining has been used to visualize anterior and posterior capsule flaps during pediatric cataract surgery and to facilitate capsule plaque removal[21-22]. In 2006, Sharma et al evaluated the efficacy of trypan blue in posterior capsulorhexis with optic capture in pediatric cataracts. Optic capture was possible in 17 out of 18 eyes (94.4%) in the group that received trypan blue dye assisted procedures but in only 11 out of 17 (64.7%) in the group not given trypan blue assistant. Sharma et al concluded that trypan blue facilitates visualization of posterior capsulorhexis and consequently increases the success rate of optic capture of IOL. Cicik et al carried out a study of 52 eyes pediatric cataract with or without IOL optic capture and suggested that the anterior capsule was stained with trypan blue for better visibility when necessary.

DECISION TO UNDERGO SIMULTANEOUS ANTERIOR VITRECTOMY IN PEDIATRIC CATARACT CAPTURE SURGERY

Whether or not to perform anterior vitrectomy during cataract surgery in pediatric patients has been a controversial topic, and it has drawn attention from many scholars. So far, there is debate regarding whether to conduct anterior vitrectomy alongside IOL optic capture or not. Gimbel[9,15] conducted posterior capsulorhexis with optic capture without anterior vitrectomy using PMMA IOL in 13 eyes in 1996 and heparin-coated IOL in 16 eyes in 1997, respectively. There was no PCO after surgery. Dada et al suggested that lens aspiration using intracameral heparin, combined with primary posterior capsulorhexis and optic capture of a heparin-coated IOL, is a useful means of preventing secondary VAO in pediatric cataracts. Raina et al observed no PCO in 16 eyes that underwent IOL optic capture procedure. Dada et al used IOL optic capture in 14 eyes and followed up for 36mo. The visual axis remained clear in all the eyes in the IOL optic capture group, but 57.14% of the eyes in the non-capture group developed PCO. Argento et al[44] reported that eight eyes of 5 children had cataract extraction with AcrySof IOLs optic capture, the visual axis remained clear in all cases during the follow-up period. It was posited that the adhesive properties of AcrySof IOLs to the capsular bag played an important role in preventing PCO. Grieshaber et al[42] evaluated 68 eyes that underwent the IOL optic capture technique. The visual axis remained clear in all eyes during postoperative follow-up. In 2005, Zhou et al[40] conducted a Meta-analysis covering 282
eyes and found the IOL optic capture technique to be safe and to significantly reduce the incidence of PCO in pediatric cataract surgery. Vasavada et al.\(^{[19]}\) recently published a report of 26 eyes that were subjected to pediatric cataract surgery and found the optic capture of a 1-piece PMMA IOL.\(^{[22]}\) In the current study, they found that this phenomenon did not occur during the 12mo of follow-up. They concluded that this might be attributable to the design of the 3-piece IOL, allowing almost 360 degrees of capsular fusion and the fusion of the anterior and posterior capsules leads to sequestration of LECs within the capsular fornices and prevents their migration to the intact anterior vitreous face. Furthermore, with better techniques, ophthalmic viscosurgical devices (OVDs), and instrumentation there might be lesser iris manipulation, thus reducing postoperative inflammatory sequelae.

**Glaucoma** Secondary glaucoma is an important postoperative sight-threatening complication of pediatric cataract surgery.\(^{[46-47]}\) The incidence has been variably reported as between 10% and 21% in the literature.\(^{[48-51]}\) Patients undergoing cataract surgery at an early age are at high risk for the development of glaucoma. According to IATS report,\(^{[52-53]}\) when operating on an infant younger than 7mo of age with a unilateral cataract, IOL implantation resulted in more actual and suspected glaucoma than leaving the eye aphakic, although the difference was not significant at 1y postoperative follow-up. However, there were no reports of glaucoma after IOL optic capture technique.\(^{[10,19,25]}\) Grieshaber et al.\(^{[23]}\) used optic entrapment of the IOL in 68 eyes and followed the patients up for 9y. Vasavada et al.\(^{[20]}\) reported optic capture in 41 pediatric eyes and followed up for 21.04mo. Glaucoma was not observed in either study. In 2017, Vasavada et al.\(^{[19]}\) also published a report of 26 eyes of children under 4 years old who underwent cataract IOL capture. They were followed up for 12mo, and no glaucoma was observed. A recent Meta-analysis concluded that the risk of postoperative glaucoma after cataract surgery in infants less than 1 year of age may be influenced by the timing of surgery, primary IOL implantation, and additional intraocular surgery.\(^{[46]}\) The mechanism underlying the relatively low incidence of glaucoma after IOL optic capture might involve backward movement of the optic part of IOL and an increase in the anterior space. This hypothesis will need further investigation.

**Intraocular Lens Decentration** IOL decentration is not uncommon after IOL implantation after pediatric cataract surgery and can be caused by the rupture of or injury to the suspension ligaments. In some cases, abnormal IOL location, *e.g.* one haptic placed in the capsular bag while the other placed in the ciliary sulcus, which may also cause IOL decentration. Some IOL decentration may be caused by unsymmetrical shrinkage of the capsular bag. Since the introduction of IOL optic capture technique, the decentration of IOL has not been reported to be attributed to the satisfactory capsular fixation from ACCC and PCCC. Vasavada et al.\(^{[20]}\) performed IOL optic capture in 41 pediatric eyes. Excellent IOL centration was maintained in all the eyes. This study and others\(^{[12,14,19,22]}\) demonstrated that the optic capture technique provides stability and long-term centration of the IOL.

**Inflammation and Iris Synechia** Pediatric eye usually has higher tissue reactivity, which pose a risk of severe inflammation response and formation of iris synechia or PCO after surgery.\(^{[54-55]}\) The incidence of inflammation and iris synechia after pediatric cataract IOL capture ranged from 0 to 100%, with an average of 13.87% (38/274).\(^{[8,10,11,13,16,19,22-23,25-26]}\) However, the effects of IOL optic capture on the risk and severity of iris inflammation are still debated. Some studies have proposed that since the IOL position is moved backward in IOL optic capture technique, the distance between the posterior surface of the iris and IOL increases. As a result, the chaffing and rubbing between iris and IOL decreases and so does the iris’ inflammatory reactions.\(^{[12,56]}\) In 2005, Grieshaber et al.\(^{[23]}\) performed IOL entrapment procedure in 68 pediatric cataract eyes. The incidence of posterior synechia was 8.8%. Vasavada and Trivedi\(^{[20]}\) reported a 71.4% incidence of uveal inflammation and posterior synechia in 14 eyes that underwent IOL optic capture. Most synechia formed at fixated haptics and at sites of optic capture through the posterior capsulorhexis. Based on this finding, Vasavada and Trivedi\(^{[22]}\) concluded that IOL optic capture actually increases the post operational inflammatory reactions of the iris. However, Vasavada et al.\(^{[29]}\) recently published a report covering 26 eyes of children with cataracts who underwent capture implantation and 30 eyes that were subjected to conventional capsule implantation and there were no statistically significant differences in the incidence of posterior synechiae or cell deposits between the two groups. In 2018, Cicik et al.\(^{[26]}\) reported 26 eyes of pediatric cataract IOL optic capture, and there was no uveitic reaction, posterior synechiae occurred after operation. According to Zhou et al.\(^{[20]}\) Meta-analysis in 282 eyes, IOL optic capture has no significant effect on the incidence of posterior synechia after pediatric cataract surgery.

**Pupillary Capture** Pupillary capture is a common complication after pediatric cataract surgery, which occurs most often in children under 2 years of age, when an optic size of less than 6 mm is used and the lens is placed in the ciliary sulcus.\(^{[57]}\) The IOL optic capture technique involves drawing an IOL optic through a PCCC opening, and apposition of the anterior and posterior capsule leaflets. This maneuver ensures the anterior and posterior capsule leaflets are closely in contact and closed on the front surface of IOL. In this way, the risk
for pupil capture is greatly reduced. This is one of important advantages of IOL optic capture. So far, complication of pupillary capture after IOL capture are rarely reported.

**Intraocular Lens Surface Deposits** The typical IOL deposits that develop after cataract surgery include small cells, giant cells and erythrocytes, and pigment granules. IOL deposits usually do not affect visual acuity significantly. Pediatric patients with darker irises or who are less compliant with postoperative medication regimens are more likely to develop IOL deposits. The small round-shaped cellular deposits that occurred soon after the operation are typically associated with impairments in the intraocular blood-aqueous barrier, while the giant cell deposits that develop later are associated with iris inflammatory responses. The incidence of IOL surface deposits after pediatric cataract IOL capture ranged from 0 to 100%, with an average of 15.31% (32/209). Vasavada and Trivedi conducted a study covering 40 eyes and reported that deposits on the anterior IOL surface occurred in all eyes in the optic-capture group and in 61.5% in the no-capture group. The deposits in the optic-captured group were greater in number and persisted longer than those in the no-capture group. They proposed a possible explanation that the both anterior and posterior capsule openings were located at the front surface of IOL. The deposits may include pigments, inflammatory cells, or lens cortex. Grieshaber performed IOL entrapment procedure in 68 pediatric cataract eyes, no pigment deposits were observed in all eyes. Zhou et al. performed IOL entrapping procedure in 68 pediatric cataract eyes and reported 10 out of 27 eyes (37%) developed aphakic CME. However, later literature reposts contradicted these findings and attribute the uncommon CME to current fine microsurgical techniques, the lack of hypotony during surgery and postoperative apply of steroids, cycloplegics and non-steroidal antiinflammatory drugs (NSAIDs).

**Cystoid Macular Edema** There is no report of cystoid macular edema (CME) in children who underwent IOL optic capture with or without vitrectomy to date. A few early works reported the occurrence of CME after pediatric cataract surgery. Hoyt and Nickel reported 10 out of 27 eyes (37%) developed aphakic CME. However, later literature reposts contradicted these findings and attribute the uncommon CME to current fine microsurgical techniques, the lack of hypotony during surgery and postoperative apply of steroids, cycloplegics and non-steroidal anti-inflammatory drugs (NSAIDs).

**Retinal Detachment** The most common risk factors of retinal detachment (RD) include male, myopic, and intellectual disabled child. A recent review of the Agarkar et al. of 481 eyes showed that the risk of RD was expected to be 5.5% for the first 10y after cataract surgery in children with no known eye and systemic abnormalities. Rabial reported an overall 3.2% frequency of RD. Haargaard et al. reported following up 1043 pediatric patients after cataract surgery for 20y in Denmark. The frequency of RD was 7%, with 3% occurring in patients with simple cataracts. There is no report of RD in pediatric patients who underwent IOL optic capture to date.

**CONCLUSION** Reducing or avoiding PCO, the most common complication occurs after pediatric cataract surgery, has been a serious goal for ophthalmologists. To date, the critical factors contributing to the initiation of PCO and the effective managements of PCO are debatable. Whether and when to perform anterior vitrectomy and how anterior vitrectomy will affect the development of PCO are the subject of much discussion. The IOL optic capture technique leaves the anterior and posterior capsules with more contact area and can be united more closely. Good centralization of the IOL is achieved and consequently the incidence of PCO is reduced. Meanwhile, IOL optic capture technique does not increase the incidence of other post-operative complications, which appears to be a promising alternative to the standard surgical technique for the treatment of pediatric cataracts and it might allow clinicians to avoid the additional step of anterior vitrectomy.

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**REFERENCES**


Optic capture in children


