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ARTICLE

Intraoperative OCT for the assessment of posterior capsular integrity in pediatric cataract surgery

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Purpose: To study the morphology of the posterior lens cortex and posterior capsules (PCs) in pediatric patients with posterior lens opacities using intraoperative optical coherence tomography (iOCT).

Setting: Zhongshan Ophthalmic Center, Sun Yat-sen University, Guangzhou, China.

Design: Prospective observational study.

Methods: Pediatric patients with posterior lens opacities were imaged using iOCT during cataract surgery. The morphology of the posterior lens cortex and PC, along with the common patterns to indicate PC integrity, was assessed. Moreover, PC rent during surgery was observed.

Results: A total of 62 eyes from 53 patients were included. The mean age of patients was 3.8 years. 4 morphological variants of posterior lens opacity were observed: type I (34/62 [54.8%]) with an intact PC; type II (20/62 [32.3%]) with an intact PC, which protruded into the anterior vitreous; type III (3/62 [4.8%]) with a deficient PC and an inability to delineate the PC; and type IV (5/62 [8.1%]) with dense opacity and an inability to characterize the posterior cortex and PC. Phacoemulsification could be performed in types I and II. In types III and IV, manual nucleus removal was performed instead of phacoemulsification. 3 cases (100%) of type III PC dehiscence developed during surgery, whereas no cases developed PC dehiscence of other types.

Conclusions: The morphology of the PC and posterior lens cortex in pediatric posterior lens opacities could be categorized, and PC integrity could be assessed using iOCT, which was useful to guide surgical strategies and increase safety in pre-existing PC dehiscence in pediatric cataract surgery.

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Pediatric cataracts are one of the common causes of childhood blindness and are responsible for approximately 10% to 20% of blindness in children worldwide.[1] Despite the rapid development in recent years of techniques for pediatric cataract surgery, posterior lens opacity remains a considerable challenge even for experienced cataract surgeons because of the higher risk of posterior capsule rupture (PCR).[2,3] For example, in patients with posterior polar cataracts, previously reported PCR rates remain between 6% and 30% despite efforts to improve surgical techniques.[4] Posterior lenticonus is also characterized by weakness of the posterior lens capsule.[5] PCR can occur anytime during hydrodissection, nucleus emulsification, or spontaneously after sudden fluctuations in intraocular pressure. If posterior lens capsule weakness could be identified preoperatively, modified surgical techniques could be used to minimize the intraoperative stress on the fragile PC, including avoidance of hydrodissection and layer-by-layer phacoemulsification.[6–10] Therefore, accurate detection of preexisting PC dehiscence in posterior lens opacities preoperatively would be very beneficial.

In previous studies, anterior segment optical coherence tomography (AS-OCT) was applied in posterior polar

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cataracts and proved to be useful to predict the risk for PCR in adult patients.[11] However, such preoperative evaluation was not always possible to complete in children who did not cooperate during examination. In recent years, intraoperative optical coherence tomography (iOCT) has been used during phacoemulsification to facilitate the assessment of the integrity of corneal incisions, the depth of trenching, and the dynamics of various cataracts.[12–14] Titiyal et al. reported the intraoperative dynamics and safety in posterior polar cataract with iOCT-guided cataract surgery in adult patients.[15] However, to our knowledge, no study has assessed the PC during surgery in pediatric patients with posterior lens opacity. In this article, we evaluated the role of iOCT in understanding the integrity of the PC in pediatric cataracts with posterior lens opacity.

METHODS

Study Population

This prospective study was conducted at the Zhongshan Ophthalmic Center, Sun Yat-sen University, China. Ethical clearance was obtained from the institutional review board, and the study adhered to the tenets of the Declaration of Helsinki. Written informed consent was obtained from all patients.

Children with congenital posterior lens opacity who needed cataract surgery were enrolled in this study from July 2019 to January 2021. Eyes with pre-existing corneal opacities or inadequate pharmacomydriasis interfering with imaging were excluded from the cohort. All patients underwent routine preoperative examinations. Cataract extraction combined with or without intraocular lens (IOL) implantation was performed by an experienced congenital cataract specialist (W.R.C.).

iOCT Imaging

An integrated microscope with iOCT (OPMI Lumera 700 and RESCAN 700; Carl Zeiss Meditec AG) was used to assess the morphology of lens opacity and the posterior capsular status just after general anesthesia with tracheal intubation during surgery. The RESCAN 700 provides real-time 3D OCT images of the ocular structures that are projected onto the surgical field and directly viewed through the oculars of the microscope by the operating surgeon. In addition, the high-definition OCT images are also displayed on the attached Callisto Eye monitor, which enhances the features of the OCT images and performs a detailed real-time analysis. iOCT was used to assess the morphology of lens opacity, the relation of the opacity to the PC, and the integrity and continuity of the PC.

Surgical Technique

After iOCT imaging, a standard 2.2 mm scleral tunnel incision was made, and then, an anterior continuous curvilinear capsulotomy was performed. In monocular patients aged 1 year or older or binocular patients aged 2 years or older, IOL implantation was performed along with cataract extraction.

In patients with a distinctly delineated PC, gentle hydrodissection was performed by injecting 1 to 2 mL of balanced salt solution in the subcapsular plane. Hydrodissection was avoided in cases wherein the posterior polar opacity could not be delineated from the PC or in cases wherein the continuity of the PC could not be adequately assessed.

Unlike adult cataract patients, the nucleus in pediatric patients was always soft. In cases with a distinctly delineated PC, a slow-motion phacoemulsification was performed. By contrast, a manual method of nucleus removal was performed instead of phacoemulsification wherein the posterior polar opacity could not be delineated from the PC. A cohesive ophthalmic viscosurgical device (OVD) was used to inject beneath the nucleus while pressing the post lip of the incision softly. After nucleus removal, the cortical matter was gently aspirated using coaxial irrigation-aspiration. The integrity of the PC was examined by the surgeon intraoperatively through the operating microscope. Subsequently, a central continuous posterior capsulotomy was performed manually in combination with a limited anterior vitrectomy. A foldable single-piece IOL (SA60AT, Alcon Laboratories, Inc.) was implanted in the bag, and another foldable single-piece IOL (Rayner, Rayner Intraocular Lenses Ltd.) was used when implanted in the sulcus.

Statistical Analysis

Statistical analysis was performed using SPSS Statistics software (v. 20.0, IBM Corp.). Continuous variables are shown as mean ± SD. Categorical variables such as sex, cataract type, intraoperative complications, and IOL placement were described as percentages.

RESULTS

This study comprised 62 eyes from 53 patients. The mean age of the patients was 3.8 ± 3.2 years (range 3 months to 14 years). Nine patients (18 eyes) underwent bilateral surgery. Of these, 3 eyes had posterior capsular rent.

iOCT was used to assess the integrity of the PC and the morphological variants of the posterior lens opacity during the surgery, and 4 morphological variants of the PC and the lens opacity were observed (Table 1).

Type I was characterized by an intact PC that included 3 subtypes. In type Ia, the PC was clearly identified in the

Table 1. Clinical Characteristics in Varied Morphological Characteristics of Posterior Lens Opacity.

Characteristics	Type I	Type II	Type III	Type IV
Age	3 mo to 13 y	7 mo to 11 y	10 mo to 14 y	5 mo to 3 y
Proportion of cases, % (n)	54.8 (34/62)	32.3 (20/62)	4.8 (3/62)	8.1 (5/62)
iOCT morphological characteristics	PC distinct or partly adherent tightly to the lens opacities	PC with localized protrusion, V shape, U shape, or “double-line” signs	Deficient PC beneath the lens opacity	PC not visible, dense opacity with shadowing
Hydrodissection	Yes	No	No	No
Hydrodelineation	Yes	Yes	Yes	Yes
Use of phacoemulsification	Yes	Yes	No	No
Incidence of PCR (%)	0	0	100	0
IOL placement (%)				
In the bag	100	100	50	100
In the sulcus	0	0	50	0

iOCT = intraoperative OCT; PCR = posterior capsule rupture

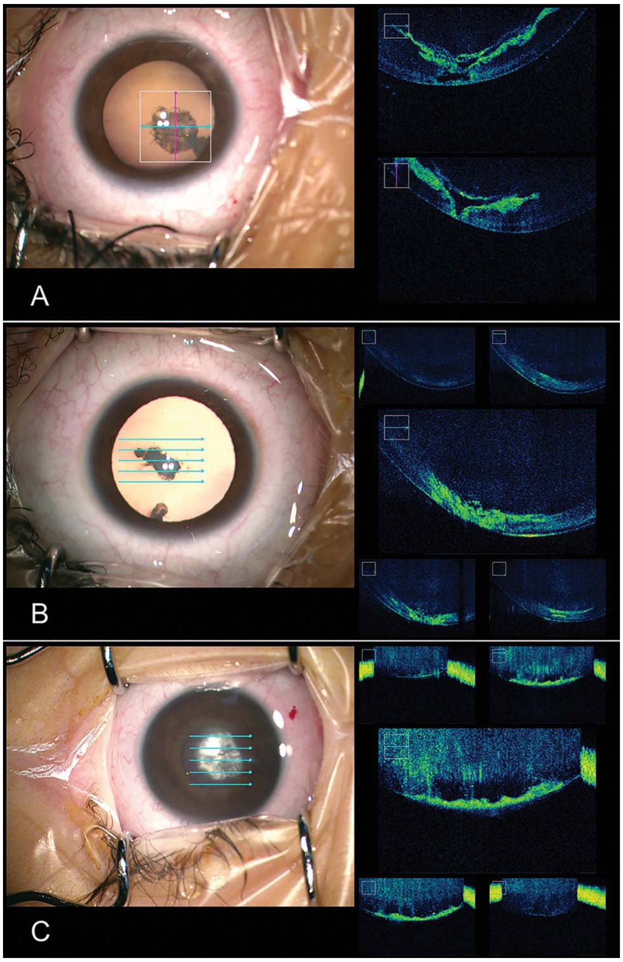

Figure 1. Morphological variants of type I posterior lens opacity observed on iOCT. *A*: Type Ia characterized by the PC was clearly identified in the entire lens opacity. *B*: Type Ib characterized by the PC could not be clearly delineated in the areas of dense opacities that apparently adhered to the PC. *C*: Type Ic characterized by the PC was apparently thickened as highly reflective dense opacities adherent tightly to the PC. iOCT = intraoperative OCT; PC = posterior capsule

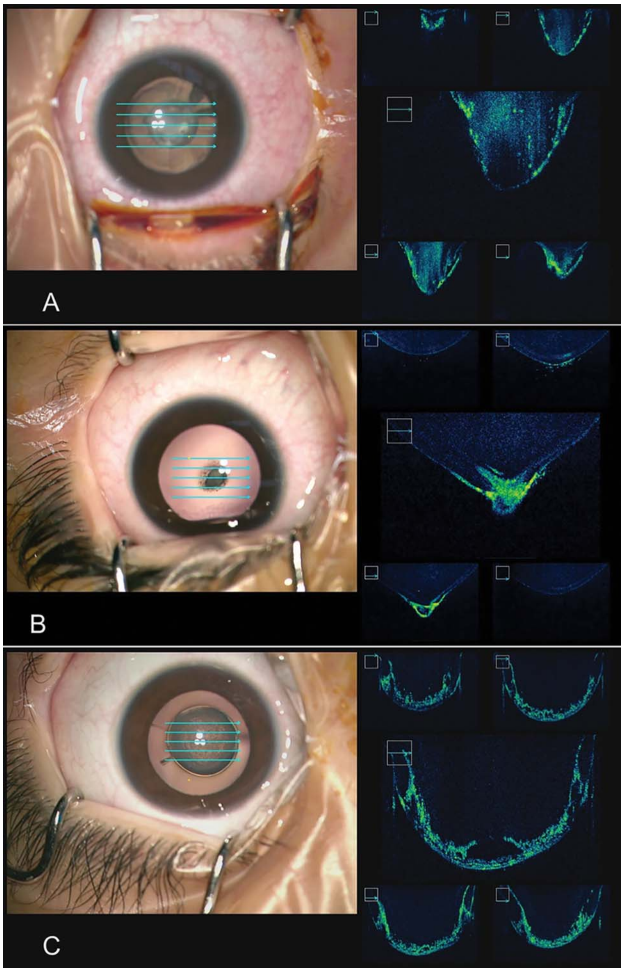

Figure 2. Morphological variants of type II posterior lens opacity observed on iOCT. Type II characterized by the PC and the cortex bulged along the anterior vitreous, showing a V shape (*A*, *B*) or a U shape (*C*). iOCT = intraoperative OCT; PC = posterior capsule

entire lens opacity (Figure 1, A). In type Ib, the PC could not be clearly delineated in the areas of dense opacities that apparently adherent to the PC (Figure 1, B). In type Ic, the PC was apparently thickened as the highly reflective dense opacities adherent tightly to the PC (Figure 1, C).

The PC in type II was also distinct but localized bulging with the posterior lens cortex, which was identified as posterior lenticonus. The PC and the cortex bulged along the anterior vitreous, showing a V shape or a U shape (Figure 2, A–C).

Type III was characterized by a deficient capsule beneath the opacity. The posterior opacity showed a morphology of the moth-eaten appearance of the edge of the leaves in 2 cases. In the third case, the PC was deficient beneath the bulged lens opacities (Figure 3, A–C).

In type IV, the PC was not visible, and the features of posterior lens opacity could not be characterized owing to the dense lens opacity (Figure 4).

Type I posterior polar opacity was observed in 34 eyes (54.8%), type II was observed in 20 eyes (32.3%), type III was observed in 3 eyes (4.8%), and type IV was observed in 5 eyes (8.1%). The age of patients with type I opacity ranged from 3 months to 13 years; the age of patients with type II opacity ranged from 7 months to 11 years; the age of patients with type III opacity ranged from 10 months to 14 years; and the age of patients with type IV opacity ranged from 5 months to 3 years (Table 1).

In type I posterior lens opacity, gentle hydrodissection was performed in all cases in addition to hydrodelineation. Normal-motion phacoemulsification was performed in type Ia and slow-motion phacoemulsification in other types. No case developed an intraoperative posterior capsular defect. In type Ib lens opacity, the PC was observed with localized opacity; however, the PC remained intact until the end of surgery. In type Ic, after the removal of the lens cortex, the PC showed a morphology of "membrane cataract." After the removal of the membrane-like lens opacity that tightly adhered to the PC, the PC remained intact (Supplemental Figure 1, http://links.lww.com/JRS/A434).

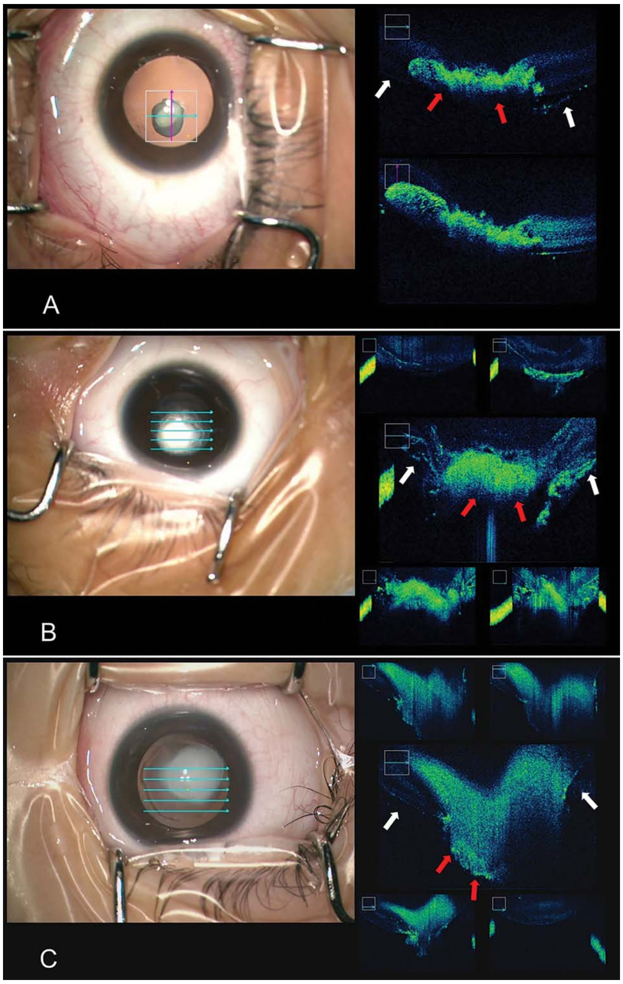

Figure 3. Morphological variants of type III (deficient PC) observed on iOCT. *A* and *B*: The posterior opacity showed a morphology of the moth-eaten appearance of the edge of the leaves in 2 cases. *C*: The PC in the third case was deficient beneath the bulged lens opacities. Intact PC was visible in periphery of the opacity (*white arrow*) while deficient in the center of opacity (*red arrow*). iOCT = intraoperative OCT; PC = posterior capsule

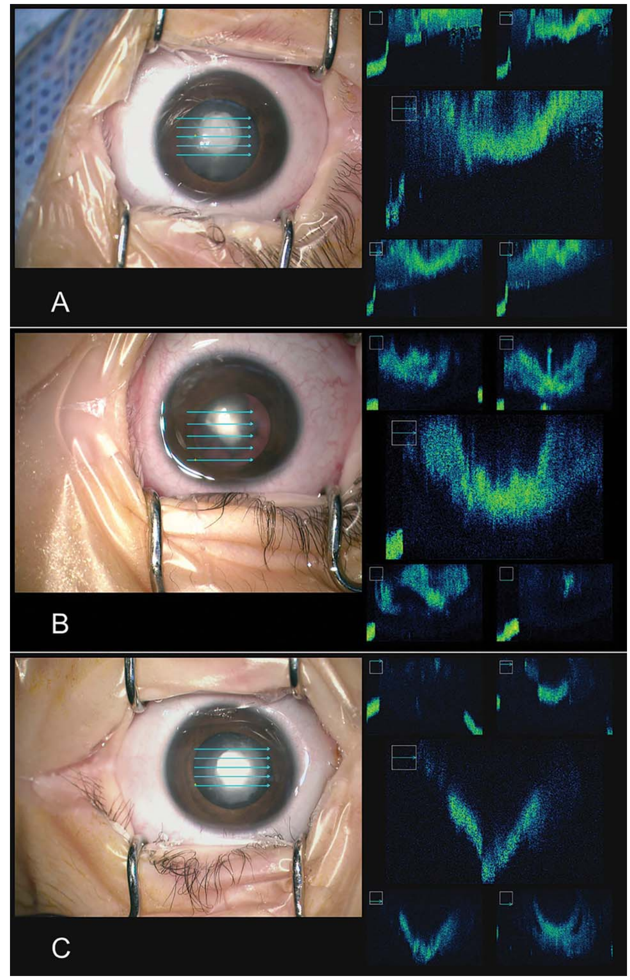

Figure 4. *A–C*: The posterior lens cortex and the PC were not visible in type IV. PC = posterior capsule

In type II posterior lens opacity, only hydrodelineation was performed in all cases, and hydrodissection was avoided. Slow-motion phacoemulsification was performed in all cases. These 19 patients had an intraoperative ectatic PC that was very thin and fragile after cortex removal, as perceived by the surgeon. However, the PC remained intact until the end of surgery.

In type III posterior lens opacity, only hydrodelineation with a cohesive OVD was performed in the 3 cases, and hydrodissection was definitely avoided. The PC defect was immediately detected after manual nucleus removal, and the OVD was used to inject beneath the nucleus while pressing the post lip of the incision softly (Figure 5).

In type IV posterior lens opacity, the surgical procedures were similar to those in type III. Hydrodissection was also avoided, and manual nucleus removal was used in these cases, although the PC remained intact until the end of surgery.

No case had a posterior drop in nuclear fragments or an inability to implant an IOL. Thirty-nine eyes of 37 patients (62.9%) underwent IOL implantation. The IOLs were all implanted in the bag in cases with an intact PC. In type III patients with a deficient PC, 2 underwent IOL implantation. One was implanted in the bag, and the other was implanted in the sulcus.

DISCUSSION

The present prospective study was intended to define the possible signs of deficient capsules using iOCT during cataract surgery in pediatric patients with posterior lens opacity. We observed 4 morphological variants of posterior lens opacity based on the visibility and morphology of the PC. The PC could be clearly delineated in 13 eyes (21.7%, type Ia), partially delineated in 15 eyes (24.2%, type Ib), thickened in 7 eyes (11.3%, type Ic), localized protrusion in 19 eyes (32.3%, type II), not delineated in 3 eyes (4.8%, type III), and invisible in 5 eyes (8.1%, type IV). In type I, type II, and type IV, no case developed an intraoperative posterior capsular defect. In type III, the PC defect was detected during surgery.

Successful management of posterior polar cataracts remains a challenge because it carries a high risk for intraoperative PCR (6% to 30%) compared with the lower

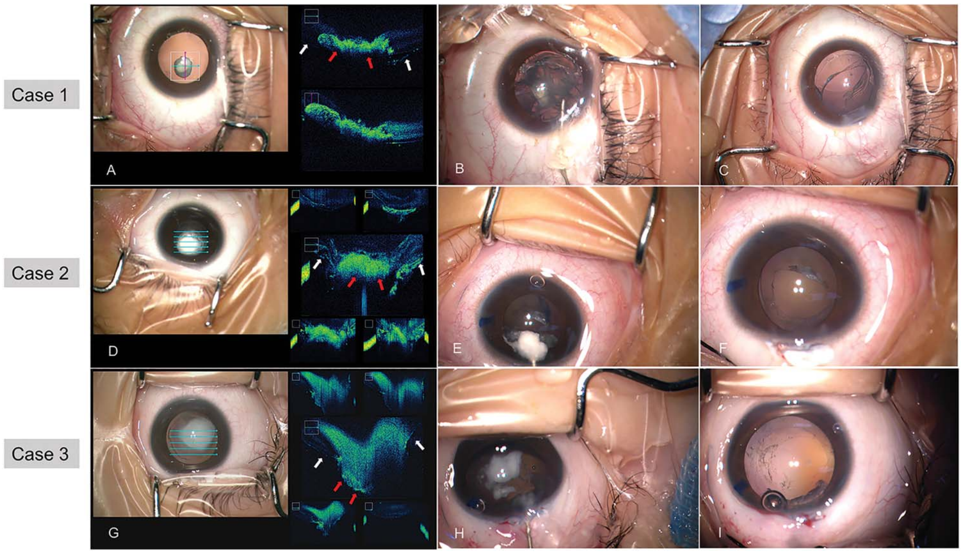

Figure 5. In the 3 cases of type III, (*A, D, G*) manual nucleus removal was performed. The OVD was injected beneath the lens opacity, and then, the post lip of the incision was pressed softly to extract the lens opacity (*B, E, H*). A deficient posterior capsule was observed during surgery (*C, F, I*). OVD = ophthalmic viscosurgical device

incidence of PCR (1.0%) in general cataract surgery.[16] A reliable means of identifying the integrity of the PC and the strength of capsule adhesion to the posterior polar opacity would allow for the customization of preoperative counseling for each posterior polar cataract patient. Moreover, it provides valuable preoperative information to the surgeon and thus decreases the likelihood of severe complications during phacoemulsification for posterior lens opacity.

In previous studies, Chan et al. first used AS-OCT to grade posterior polar cataracts depending on the amount of clearance between the posterior opacity and the capsule, which helped to identify eyes at high risk for PCR with good sensitivity and specificity.[17] Subsequently, Kumar et al. used AS-OCT to assess the integrity of the PC, which was graded as "intact" or "dehiscent," and a high negative predictive value was proven.[11] In addition, preoperative 25 MHz ultrasonography may help to detect pre-existing PC dehiscence in cases with posterior polar cataracts.[18] Recently, using the new AS-OCT (CASIA2), Pujari et al. classified the deficient morphology of the PC in posterior polar cataracts into 3 categories: conical, moth-eaten, and ectatic, which help to manage cataract surgery.[19] Recently, Titiyal et al. used iOCT to assess real-time PC integrity of posterior polar cataracts and proved that it characterized high-risk morphological features, which were consistent with the deficient morphology detected by AS-OCT in their previous report.[15]

Unlike adults, varied ophthalmic examinations were not always possible to complete in the children. Therefore, it was difficult for clinicians to distinguish posterior polar and posterior lenticonuses; however, these 2 had different visual outcomes. In a previous study, Travi et al. observed that 72% of patients with polar cataracts achieved a good visual outcome compared with 32% in the posterior lenticonus group, which was statistically significant.[20] Similarly, our recent study found that patients with posterior lenticonus achieved less improvement of visual acuity than patients with posterior polar cataract.[21] Consequently, the correct diagnosis of these 2 diseases is conducive in evaluating the prognosis of the patient's vision acuity and is better for patient counseling.

In this study, we observed characteristic features of the PC morphology in posterior polar cataracts and posterior lenticonuses. Gentle hydrodelineation and phacoemulsification could be performed safely in cases with type I posterior polar cataracts. However, hydrodelineation was avoided in other types to decrease the risk of rupture of the weak PC or the enlargement of the deficient PC. Slow-motion phacoemulsification could be safely performed in type II posterior lenticonus with an intact PC; however, in type III with a deficient PC and type IV with an invisible PC, manual nucleus removal was recommended, and an OVD was used to inject beneath the nucleus while pressing the post lip of the incision softly.

It is worth noting that PCR occurred in 2 eyes (5.4%) in the posterior polar cataract group and 1 eye (4.8%) in the posterior lenticonus group in this study population. The PCR rate was relatively lower in pediatric patients than in adult patients. For example, in the study by Chan, PCR occurred in 8 eyes (21.6%) in adult patients with posterior polar cataracts.[17] Recently, in Pujari's report, abnormal/deficient PC was identified in 10 eyes (9.9%) in a total of 101 adult eyes.[19] The possible reasons for the lower PCR rate in pediatric patients might be as follows. First, the PC of pediatric patients was more resilient than that of the adults. Second, the lens nucleus in congenital cataracts was soft in most cases. Therefore, less phacoemulsification time was consumed in pediatric patients than in adults. Third, manual nucleus removal was performed instead of phacoemulsification in certain cases in this study, possibly decreasing the risk of PCR.

This study does have limitations. First, it is unable to visualize the PC and posterior lens cortex in cases with total cataracts or extremely dense lens opacities. Second, the cost of the machine limits its availability to every clinical setup.

Despite these limitations, to our knowledge, this study is the first to evaluate and characterize the morphology of posterior lens opacities in pediatric patients using iOCT. The morphological characteristics of iOCT could assist in the differential diagnosis of posterior polar cataract and posterior lenticonus. Moreover, PC integrity could be assessed during surgery to guide surgical strategies and approaches, which increases the safety of pre-existing posterior capsular dehiscence in pediatric cataract surgery.

WHAT WAS KNOWN

- Management of posterior lens opacity is surgically challenging owing to the potential risks of posterior capsular (PC) dehiscence.
- Different morphological patterns to indicate the integrity of the PC in posterior lens opacity of pediatric patients are largely unknown.

WHAT THIS PAPER ADDS

- Intraoperative OCT (iOCT) helps to classify posterior lens opacity into 4 types based on the morphology of the posterior lens cortex and PC.
- Posterior polar cataract and posterior lenticonus can be distinguished according to the different morphological characteristics assessed by iOCT in pediatric patients.
- PC integrity of posterior lens opacity can be assessed by iOCT, which guides surgical strategies and approaches in pediatric cataract surgery.

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