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Impact of lens capsule status on pupillary capture following intrascleral intraocular lens fixation: a retrospective study

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Abstract

Background Pupillary capture can cause complications after intrascleral intraocular lens (IOL) fixation; however, no method has been established to definitively prevent pupillary capture. Therefore, we aimed to examine the differences in the incidence of pupillary capture in patients who underwent intrascleral IOL fixation and had intraoperative lens capsule preservation or lens capsule loss.

Methods This single-center, retrospective study, conducted at a University Hospital, included 83 eyes from 83 patients. The eyes were allocated to the capsule and no-capsule groups based on the presence or absence of capsule, respectively. Patient demographics, causative diseases, incidence of pupillary capture at 1 year postoperatively, anterior chamber depths (ACDs), IOL tilts, and decentrations of the two groups were analyzed and compared.

Results The capsule and no-capsule groups comprised 26 and 57 eyes, respectively. The indications for intrascleral IOL fixation were: IOL dislocation in 6 (23.1%) and 41 (71.9%), artificial aphakia in 4 (15.4%) and 2 (3.5%), conversion during cataract surgery due to complications (zonular dialysis or posterior capsule rupture) in 14 (53.9%) and 3 (5.3%), lens dislocation in 0 and 11 (19.3%), and IOL opacification in 2 (7.7%) and 0 eyes in the capsule and no-capsule groups, respectively ($P < 0.05$). The postoperative outcomes including ACD, magnitude of tilt, or decentration of the fixed IOL did not differ between the two groups ($P > 0.05$). Pupillary capture was observed in eight eyes, all in the no-capsule group ($P < 0.05$).

Conclusions When performing intrascleral fixation in cases where the lens capsule remains, preserving the capsule and fixing the IOL under the capsule may prevent postoperative pupillary capture.

Keywords Intraocular lens, Intraocular lens scleral fixation, Pupillary capture, Lens capsule, IOL dislocation

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Background

Intrascleral intraocular lens (IOL) fixation has recently become an increasingly common treatment for lens dislocation, aphakia, and IOL dislocation [1], using various surgical techniques [2, 3]. Postoperative complications such as corneal edema, IOL dislocation, vitreous hemorrhage, and pupillary capture have been reported [4–6]. Pupillary capture can cause further complications, such as postoperative inflammation, increased intraocular pressure, cystoid macular edema, astigmatism, and reduced visual function [7, 8]. Moreover, pupillary capture is more likely to occur in younger patients and those with Marfan syndrome, IOL dislocation, floppy iris, and a large mesopic pupil [7, 9].

Despite the use of iridotomy, an established prevention strategy for preventing pupillary capture [10, 11], recurrent cases of this phenomenon have been reported [7]. Similarly, block suturing [12–15] to create a barricade between the iris and IOL is effective for preventing pupillary capture. However, it reportedly causes anterior chamber inflammation due to friction between the suture and the iris [16]. In contrast, a previous case study reported that the anterior capsule was preserved and intrascleral IOL fixation was performed below the capsule to release the friction between the IOL and the iris in a patient who developed pigment dispersion syndrome after sulcus fixation of the IOL when the posterior capsule ruptured [17]. Nevertheless, no method has been established to definitively prevent pupillary capture. Therefore, we hypothesized that the anterior capsule serves as a barrier between the iris and IOL. Consequently, in this study, we aimed to examine the differences in the incidence of pupillary capture in patients who underwent IOL scleral fixation with residual lens capsule and those with loss of the lens capsule.

Methods

Participants

This retrospective cohort study included 83 eyes of 83 patients (45 women, 38 men; mean age: 73.6 ± 15.2 years) who underwent IOL scleral fixation for IOL dislocation, lens dislocation, artificial aphakia, and intraoperative complications and had their lens capsule residual state confirmed using intraoperative videos at our university hospital between January 2020 and January 2022. Existing systemic or ocular comorbidities were not observed in the cohort.

Intraoperative complications included posterior capsule rupture and partial tearing of Zinn's zonule during previous cataract surgery. IOL opacification included cases in which the IOL was removed, and intrascleral fixation was performed owing to vision loss resulting from severe glistening and sub-surface nano glistening.

Surgical technique

Preoperative anesthesia was induced using 2% xylocaine (Sandoz K. K., Tokyo, Japan) administered via 2.0 mL of sub-Tenon's anesthesia. The CONSTELLATION® Vision System (Alcon Laboratories, Fort Worth, TX, USA) was used to perform the surgery.

In case of IOL dislocation, the IOL was folded and removed through a 4.0-mm scleral incision. In case of IOL dislocation where the entire lens capsule was dislocated, the capsule was removed along with the IOL. In cases of IOL dislocation alone, only the IOL was removed, while the capsule was preserved. In case of lens dislocation, intracapsular cataract extraction was performed to remove the lens through a 12-mm sclerocorneal incision. In case of intraoperative complications, the scleral incision was enlarged to 5 mm, and the nucleus was delivered via visco-extraction. Whereas, anterior vitrectomy (AV) with a vitreous cutter was performed in cases with residual vitreous. All patients underwent scleral IOL fixation (NX-70 S; Santen Pharmaceutical, Osaka, Japan).

The double-needle method described by Yamane et al. [5] was used for intrascleral IOL fixation. An angle sclerotomy was performed using a 30-G thin-walled needle (TSK ultrathin wall needle; Tochigi Seiko, Tochigi, Japan) 2.0 mm from the limbs, followed by 180° from the first sclerotomy. The leading haptic was inserted into the lumen of the needle using the anterior capsule forceps. The trailing haptic was inserted into the lumen of another needle, and the IOL was inserted under the anterior capsule. Both haptics were pulled out of the conjunctiva together with 30-G needles, and the ends of the haptics were cauterized to create a flange with a diameter of 0.3 mm using an ophthalmic cautery device (Accu-Temp Cautery; Beaver Visitec, Waltham, MA. USA). The flange was pushed back and fixed to the scleral tunnel.

In cases where the lens capsule remained connected to the ciliary body zone, only the portion of the capsule within 5 mm of the pupil center was removed using a vitreous cutter. When angle sclerotomy was performed using a 30-G thin-walled needle, the needle tip was adjusted such that it was inserted under the remaining lens capsule, and intrascleral fixation was performed such that the haptic and optics of the IOL were positioned below the remaining lens capsule.

Specification of the implanted IOL

The NX-70 S is a yellow-tinted hydrophobic IOL composed of 4% water, hydroxylethylacrylic acid, polyethylene glycol phenyl ether acrylate, and styrene cross-linked with ethylene glycol dimethacrylate. The optics have a square-edge shape with an optical diameter of 7.0 mm and a total length of 13.5 mm. A large optic diameter IOL is frequently used for combined cataract and vitrectomy

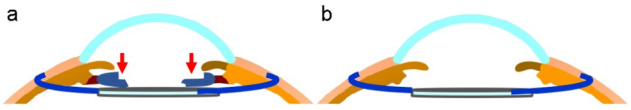

Fig. 1 Allocation into the capsule (**a**) and no-capsule (**b**) groups. The red arrows indicate the remnant lens capsule in the capsule group

surgery due to its good visibility during vitrectomy [18, 19]; it is also used for intrascleral IOL fixation [5].

Group classification

Figure 1 shows the differences in the IOL and capsule positions in the capsule and no-capsule groups. The final capsular status after IOL fixation was confirmed using surgical videos. Eyes with a preserved lens capsule with an IOL fixed under it (red arrows) were allocated to the capsule group (Fig. 1a), whereas those without a lens capsule were allocated to the no-capsule group (Fig. 1b).

Ocular examination of capsule and no-capsule groups

The patient demographics, causative diseases, and incidence of pupillary capture at 1 year postoperatively of the two groups were compared.

Analysis of IOL dislocation

The intraocular lens tilt, and decentration of the capsule and non-capsule groups were analyzed and compared for cases with anterior segment optical coherence tomography (AS-OCT) imaging data available one week postoperatively. Three-dimensional analysis of the IOL position was performed using the built-in software (version SS2000) after AS-OCT images were acquired using the IOL Scan mode to obtain data on IOL tilt and decentration [20].

Sample size and statistical analysis

The sample size was calculated using the EZR software (version 1.61; Jichi Medical University, Saitama, Japan) [21]. Based on a previous study, the number of patients was determined to detect a difference in the pupillary capture rate of 23% between the groups [22] using an α error of 0.05; therefore, at least 22 patients were required for a power of 0.8. Twenty-six patients were included in this study, accounting for a dropout rate of approximately 10%. Welch's t-test and the chi-squared test were used for statistical analyses. The chi-squared test was used to compare the patient demographics and incidence of pupillary capture. Statistical significance was set at $P<0.05$.

Results

The capsule group comprised 26 eyes, and the no-capsule group comprised 57 eyes. The mean age and sex of the two groups were comparable ($P>0.05$). Table 1 presents the patient demographics and outcomes.

The preoperative conditions necessitating intrascleral fixation were analyzed in both groups. We detected IOL dislocation in 6 and 41 eyes, artificial aphakia in 4 and 2 eyes, intraoperative complications during previous cataract surgery in 14 and 3 eyes, crystalline lens dislocation in 0 and 11 eyes, and IOL opacification in 2 and 0 eyes in the capsule and no-capsule groups, respectively. Cases of IOL dislocation and crystalline lens dislocation were significantly more common in the no-capsule group ($P<0.001$ for both), whereas intraoperative complications during previous cataract surgery and IOL opacification were significantly more common in the capsule group ($P<0.001$ and $P=0.02$, respectively). All six eyes with IOL dislocation in the capsule group had undergone IOL sulcus fixation during previous cataract surgery, with subsequent dislocation occurring several years later. The

Table 1 Group allocation and baseline characteristics

Parameter	Groups (Condition of capsule)		*P*-values
	Capsule group ($n=26$) (%)	No-capsule group ($n=57$) (%)	
Mean age (y)	71.0 ± 14.2	71.2 ± 15.7	0.253
Sex (n)			
Male	13 (50)	32 (56.1)	0.603
Female	13 (50)	25 (43.9)	0.603
Causes of scleral fixation (n)			
IOL dislocation	6 (23.1)	41 (71.9)	< 0.01
Postsurgical aphakia	4 (15.4)	2 (3.5)	0.052
Intraoperative complication	14 (53.9)	3 (5.3)	< 0.01
Lens dislocation	0	11 (19.3)	0.0162
IOL opacification	2 (7.7)	0	0.034
Postoperative pupillary capture rate (n)	0	8 (14.0)	0.044

IOL = intraocular lens

Means ± standard deviation

*Statistically significant difference

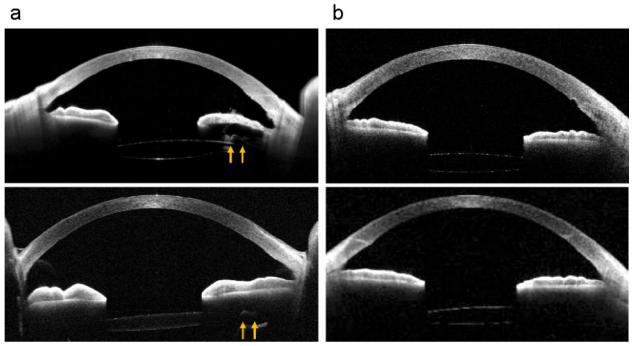

Fig. 2 Anterior segment optical coherence tomography images of two cases in both groups. (**a**) Case in the capsule group. (**b**) Case in the no-capsule group. The yellow arrows indicate the remnant lens capsule in the capsule group

causes of IOL dislocation in the no-capsule group were pseudo exfoliation in 15 eyes (36.6%), previous vitreoretinal surgery in 9 eyes (22.0%), axial myopia in 4 eyes (9.8%), atopic dermatitis in 2 eyes (4.9%), trauma in 2 eyes (4.9%), and unknown etiology in 9 eyes (22.0%). The pupillary capture rates were 0% and 14.0% (8 eyes) in the capsule and no-capsule groups, respectively.

Pupillary capture case details

Pupillary capture was observed in 8 eyes, all of which were in the no-capsule group, and the chi-squared test showed significant differences ($P = 0.044$). The mean age of the patients with pupillary capture was 49.92 ± 13.15 years, and that of those without pupillary capture was 71.82 ± 14.41 years ($P = 0.0006$).

The causal conditions included IOL dislocation in six eyes (two atopic, two traumatic, and two unknown causes) and lens dislocation in two eyes (one traumatic and one atopic).

Analysis of IOL position

IOL dislocation was analyzed using AS-OCT images for 12 eyes in the capsule group and 25 eyes in the no-capsule group. The mean ACD was 3.41 ± 0.69 mm for all the cases, 3.27 ± 0.65 mm for the capsule group, and 3.53 ± 0.70 mm for the no-capsule group. The mean IOL tilt was 7.18° ± 5.47° for all the cases, 6.71° ± 5.09° for the capsule group, and 7.34° ± 7.18° for the no-capsule group. The mean IOL decentration was 0.44 ± 0.39 mm for all the cases, 0.48 ± 0.54 mm for the capsule group, and 0.42 ± 0.41 mm for the no-capsule group. No statistically significant differences were observed between the two groups. Figure 2 shows the AS-OCT images of two cases in the capsule and no-capsule groups, in which the IOL was observed beneath the remaining lens capsule (yellow arrows).

Discussion

Among patients who underwent intrascleral IOL fixation, pupillary capture occurred those in the no-capsule group but not in the capsule group. Pupillary capture is more likely to occur in cases with deeper ACD [7, 23]. However, our AS-OCT analysis showed no difference in ACD between the two groups, suggesting that the presence of the lens capsule, rather than the ACD, was the key factor in preventing pupillary capture. In the capsule group, where the anterior capsule was preserved and the IOL was fixed beneath it, the capsule appeared to act as a physical barrier to prevent iris–IOL contact and reduce the risk of pupillary capture. This barrier effect of the preserved lens capsule was observed in our AS-OCT images, which showed the capsule positioned between the iris and IOL optic. In the no-capsule group, the iris acted as a flap valve, allowing the aqueous humor to pass from the posterior to the anterior chamber but not in the opposite direction. The aqueous humor trapped in the anterior chamber caused retroflexion of the peripheral iris [24], resulting in pupillary capture. Inoue et al. reported no significant changes in the refractive error or visual acuity in patients who underwent suture bridging to prevent pupillary capture [21]. Similarly, the refractive error did not differ for the capsule and no-capsule groups in this study, suggesting that the capsule had no effect on the IOL position.

Pupillary capture is more likely to occur in young people, which is thought to be because they are more likely to have pupil dilation in dark places [7]. In this study, pupillary capture occurred significantly more in younger participants compared to older participants. Among those patients who developed pupillary capture, three had a history of atopic dermatitis and three had previous trauma. Iris inflammation and dysfunction may occur in such cases. Pietruszyńska et al. reported that chronic eye rubbing and scratching in patients with atopic dermatitis can cause mechanical trauma to the eye, contributing to ocular complications, even when skin symptoms are well-controlled [25]. Similarly, Karabaş et al. demonstrated that traumatic mydriasis and iris defects cause significant functional limitations requiring surgical intervention for repair [26]. Therefore, preexisting iris dysfunction due to mechanical trauma in patients with atopy or direct trauma may have contributed to the development of pupillary capture in our study. However, further investigation including measurements of pupil diameter and shape are required to verify these relationships.

This study had some limitations that warrant consideration. First, the long-term prognosis was unknown because the follow-up of this study was limited to 1 year. Various wound-healing reactions may occur in the tissues surrounding the IOL optic and haptic areas in patients with the capsule. These are attributed to the

adhesion of the remaining capsule and formation of a Soemmering ring by the proliferation of residual lens epithelial cells over time after surgery [27, 28]. IOL deviation due to Soemmering ring formation and associated uveitis-glaucoma-hyphema syndrome and pupil block have also been reported [29, 30], thus, careful follow-up is needed. Second, we used AS-OCT to evaluate IOL position and the residual capsule. AS-OCT provided valuable information about anterior segment structures; however, ultrasound biomicroscopy (UBM) would be more suitable for observing structures behind the iris, including the detailed position of the IOL haptics and the entire capsule status. Additionally, the extent and shape of the lens capsule in the capsule group varied among the cases, however, their detailed assessment was limited because these structures were located under the iris. Therefore, future studies using UBM could provide more comprehensive information about the relationship between the residual capsule and IOL position. Moreover, detailed experimental verification using a simulated or porcine eye would be valuable for understanding the mechanical interaction between the capsule and IOL.

Conclusions

When performing intrascleral fixation in cases with remaining lens capsule, preserving the capsule and fixing the IOL under the capsule may prevent postoperative pupillary capture. However, the lens capsule may not always remain intact after the procedure. Therefore, it is necessary to develop a method to prevent pupillary capture, even in cases without a residual lens capsule.

Abbreviations

ACD	Anterior chamber depth
AS-OCT	Anterior segment optical coherence tomography
AV	Anterior vitrectomy
IOL	Intraocular lens
UBM	Ultrasound biomicroscopy

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Author contributions

Mayumi Nagata: Conceptualization, Methodology, Software, Validation, Investigation, and Writing - Original Draft. Hiroyuki Matsushima: Methodology, Resources, and Writing - Review & Editing. Norifumi Chiba: Data Curation, Visualization. Tadashi Senoo: Supervision, Project administration. All authors have read and approved the final manuscript.

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Data availability

The data that support the findings of this study are available from the corresponding author [M.N] upon reasonable request.

Declarations

Ethics approval and consent to participate

This study involved human participants and human data. This study was approved by the Institutional Review Board of Dokkyo Medical University (No. R-67–7 J), which waived the requirement for informed consent due to the retrospective nature of the study. This study followed the tenets of the Declaration of Helsinki.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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