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# Effect of factors on the space between the posterior capsule and IOL

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## Abstract

**Objectives** To evaluate the effect of factors on the space between the posterior capsule and IOL.

**Methods** A total of 126 patients were included in the study. All patients underwent AS-OCT examinations after surgery. The relationship between the posterior capsule-IOL (PC-IOL) adhesion range and various factors, including IOL type, follow-up period, axial length, and lens thickness, were analyzed.

**Results** When the follow-up period was shorter than 1 week, the proportion of PC-IOL adhesion range greater than 1/2 in the ZA9003, softec, SN6ATX, and 525 groups was 66.7%, 78.9%, 25%, and 53.8%, respectively. When the follow-up period was longer than 1 month, these proportions increased to 75%, 100%, 40.8%, and 100%, respectively. In the multivariate logistic regression analysis, only the IOL types and follow-up period were statistically significant, while axial length and lens thickness were not statistically significant.

**Conclusion** The follow-up period and IOL types affect the space between the IOL and the posterior capsule, whereas axial length and lens thickness do not. Among the four IOL types studied, the softec IOL has the strongest adhesive power, while the SN6ATX IOL has the weakest.

**Keywords** Posterior capsule-IOL space, AS-OCT, Posterior capsule opacification, IOL types

## Introduction

Posterior capsule opacification (PCO) is the most common complication following phacoemulsification surgery [1, 2]. Numerous studies have been conducted to explore the factors associated with PCO. These factors can be categorized into IOL-related and non-IOL-related factors [3]. The square edge of the IOL has been reported to reduce the formation of PCO [4–6]. However, there is no consensus on the impact of the diameter of the IOL, the angle of the haptic, or the number of haptics on PCO formation [3]. Hydrophobic IOL materials are believed to decrease the incidence of PCO [7, 8]. The effects of several non-IOL factors, such as axial length [9], the size of the capsulorhexis opening, rhexis/IOL overlap [1, 10], and capsular folds, on PCO formation remain controversial.

Lens epithelial cells originate from the equator of the lens capsule. Posterior capsule opacification (PCO)

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formation involves these cells overcoming the optic edge barrier, migrating to the posterior capsule, and proliferating to form pearls. According to the theory of "no space, no cell, no PCO" [11], the space between the intraocular lens (IOL) and the capsule may significantly influence PCO rates [3]. Several studies have focused on the posterior capsule-IOL (PC-IOL) space; for instance, Aizhu Tao [12] reported a gradual decrease in PC-IOL space within one month after phacoemulsification surgery, highlighting the influence of different IOL designs on space closure. However, previous studies typically had a short follow-up period of only one month and limited IOL types. Moreover, few studies have utilized long scan depth OCT instruments capable of capturing images from the cornea to the posterior capsule in a single scan. In our study, we employed SS-OCT, which has a scan depth of 10 mm, enabling comprehensive imaging from the cornea to the posterior capsule in a single OCT image.

Despite significant advances in intraocular lens (IOL) materials and designs, the relationship between IOL-posterior capsule (PC) adhesion and postoperative outcomes, such as posterior capsule opacification (PCO), remains underexplored. Previous studies have demonstrated the role of IOL surface properties in modulating PC adhesion; however, limited comparative research exists across a wide range of IOL types in a clinical setting. Our study aims to fill this gap by systematically evaluating the adhesive properties of four distinct IOL types using optical coherence tomography (OCT) and correlating these findings with key clinical parameters such as axial length, lens thickness, and postoperative outcomes.

## Patients and methods

This retrospective study included 126 patients and was conducted at Shanghai Sixth People's Hospital from January 1 to April 30, 2024. All procedures complied with the tenets of the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of Shanghai Sixth People's Hospital. The inclusion criteria were a diagnosis of age-related cataract and good general health. Exclusion criteria included uveitis, diabetes, glaucoma, a history of other ocular surgery or laser treatment, and postoperative uveitis requiring additional steroid treatment. Patients with systemic diseases such as diabetes or those with prior ocular surgeries were excluded due to the potential confounding effects these conditions may have on posterior capsule (PC) behavior. Diabetes, for example, is known to alter wound healing and may lead to increased fibrosis or unpredictable PC adhesion. Similarly, prior ocular surgeries, particularly involving the posterior segment, can alter the anatomical and physiological relationships between the IOL and the posterior capsule, introducing variability into the adhesion measurements.

This study has potential risks of bias due to its retrospective design, which may introduce selection bias. Patients were included based on strict inclusion and exclusion criteria to minimize variability; however, confounding factors such as variations in surgical technique and postoperative care cannot be entirely excluded. Additionally, differences in follow-up intervals among patients may have introduced observation bias, as not all patients underwent OCT examinations during the same periods. Efforts were made to mitigate these biases by employing standardized imaging protocols and statistical adjustments during data analysis.

We implanted four types of intraocular lenses (IOLs): ZA9003, 52501TY (525), SOFTEC (SOFT), and AcrySof Toric Single-Piece Natural (Alcon, SN6ATX). The ZA9003 group included 12 patients, the SOFTEC group included 40 patients, the SN6ATX group included 54 patients, and the 52501TY group included 20 patients.

The follow-up period was divided into three intervals: (1) the first week after surgery, (2) the 8th to the last day of the month after surgery, and (3) one month after surgery. Forty-two patients underwent OCT examination in the first period, 14 patients in the second period, and 70 patients in the third period.

### Surgical technique

All patients underwent phacoemulsification and IOL implantation performed by three skilled surgeons. The surgeries were conducted using a 3.0 mm corneal incision and a 5.5 mm continuous curvilinear capsulorhexis, which covered the edge of the IOL optic in all patients. All surgeries were successful without complications. Postoperatively, all patients received topical levofloxacin and prednisolone acetate eye drops four times a day for a month.

### Intaocular lenses

ZZA9003 (Johnson & Johnson Surgical Vision, Inc.): A three-piece posterior chamber biconvex IOL, hydrophobic acrylic aspheric optic with OptiEdge design and PMMA Mod C haptics. It has an optic diameter of 6.0 mm and an overall length of 13.0 mm.

SOFTEC HD (Lenstec Inc.): A one-piece posterior chamber biconvex IOL, hydrophilic acrylic aspheric optic with 360° square edge design and 0° haptic angulation. It has an optic diameter of 5.75 mm and an overall length of 12.0 mm.

SN6ATX (Alcon Laboratories, Inc.): A one-piece posterior chamber biconvex astigmatic IOL, acrylic aspheric

optic with double square edge design and 0° haptic angulation. It has an optic diameter of 6.0 mm and an overall length of 13.0 mm.

52501TY (Schweitzerlaan 15, 9728 NR Groningen, The Netherlands): A one-piece posterior chamber biconvex IOL, hydrophilic acrylic spheric optic with 360° square edge design and symmetrical ring haptics with 0° haptic angulation. It has an optic diameter of 6.0 mm and an overall length of 10.5 mm.

#### Preoperative examination by IOL-MASTER

The intraocular lens (IOL) power was calculated using the Barrett Universal II formula, a widely used and validated method for predicting postoperative refraction. This formula accounts for multiple biometric parameters, including axial length, keratometry, anterior chamber depth, lens thickness, and white-to-white distance, ensuring high accuracy in a variety of clinical scenarios. Preoperative biometric measurements were obtained using the IOLMaster (Carl Zeiss Meditec AG, Jena, Germany), and the derived data were input into the Barrett Universal II formula to calculate the most appropriate IOL power for implantation.

#### Postoperative examination by AS-OCT

Using the third generation of swept-source OCT (SS-OCT) with a central wavelength of 1050 nm, the SS-OCT achieved super scanning speed and penetration depth. The SS-OCT used in this study achieved a breakthrough of 16.2 mm super depth scanning, which can present panoramic anterior segment high-definition images of the cornea, anterior chamber, iris, lens, and anterior vitreous body in a single scan.

Patients sat in front of the OCT and fixated straight ahead. The instrument scanned consistently across the meridians, and we recorded images in the horizontal and vertical meridian directions. We also recorded vision and IOP on the first day after surgery.

#### Data analysis

A statistical package (SPSS 26.0) was used for descriptive statistics and data analysis. Multivariable logistic regression was performed to detect the effect of factors on the PC-IOL space (Fig. 1).

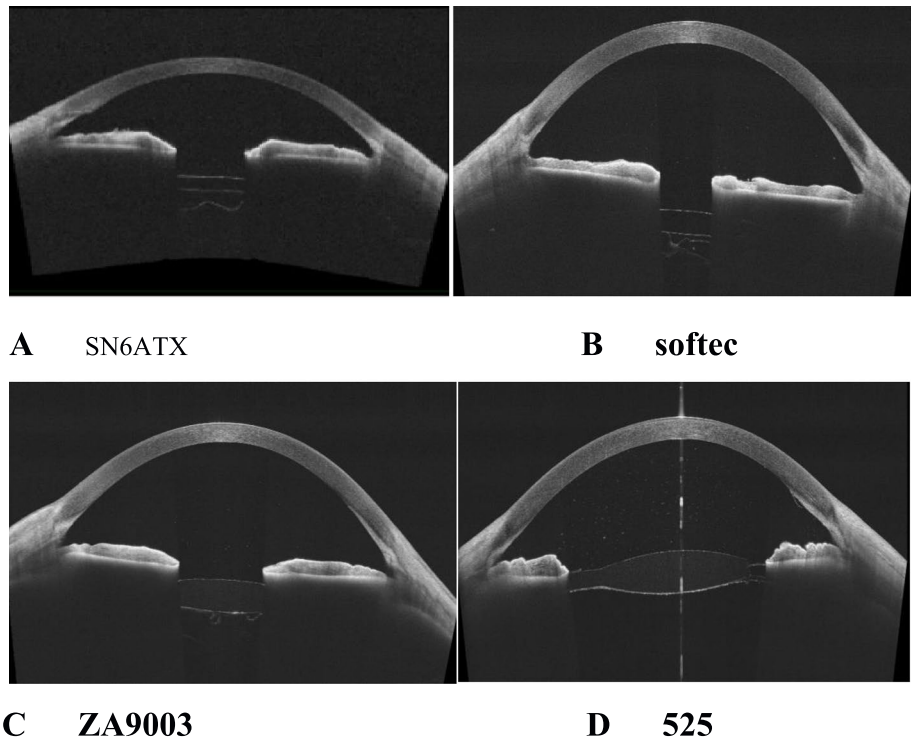


**Fig. 1** Posterior capsule-IOL adhesion at various follow-up times for each IOL type. The IOL types included SN6ATX, SOFTEC ZA9003, and 52501TY. Categories A to D represent increasing levels of posterior capsule (PC)-IOL adhesion: • Category A: No adhesion between the IOL and posterior capsule. • Category B: Adhesion range between the IOL and posterior capsule is < 1/2. • Category C: Adhesion range between the IOL and posterior capsule is > 1/2. • Category D: Complete adhesion between the IOL and posterior capsule

## Results

According to Table 1, using an adhesion range of greater than 1/2 as the reference standard: when the follow-up period is shorter than one week, the adhesion range of PC-IOLs greater than 1/2 in the ZA9003, SOFTEC, SN6ATX, and 525 groups is 66.7%, 78.9%, 25%, and 53.8%, respectively. When the follow-up period is longer than one month, the adhesion range of PC-IOLs greater than 1/2 in the ZA9003, SOFTEC, SN6ATX, and 525 groups is 75%, 100%, 40.8%, and 100%, respectively. This indicates that the SOFTEC IOL adheres more strongly to the posterior capsule than the other IOL types, while the SN6ATX adheres the least. Therefore, it can be concluded that the type of IOL may affect the adhesion between the IOL and the posterior capsule.

Table 2 shows that the adhesion range in the horizontal direction is not always identical to that in the vertical direction. In approximately 83.5% of cases, the adhesion range in the horizontal direction between the IOL and the posterior capsule is similar to that in the vertical direction. In 12.2% of cases, the adhesion range in the horizontal direction is larger than in the vertical direction.

Table 3 indicates that in the multivariate logistic regression equation, only IOL types and follow-up period are

**Table 2** The difference of PC-IOL adhension between horizontal direction and vertical direction

| | | frequency | percentage | Effective percentage | Cumulative percentage |
|---|---|---|---|---|---|
| effective | α | 5 | 4.0 | 4.3 | 4.3 |
| | β | 96 | 76.2 | 83.5 | 87.8 |
| | γ | 14 | 11.1 | 12.2 | 100.0 |
| | sum | 115 | 91.3 | 100.0 | |
| missing | | 11 | 8.7 | | |
| sum | | 126 | 100.0 | | |

α: the adhension range in horizontal direction between the IOL and posterior capsule is smaller than in the vertical direction

β: the adhension range in horizontal direction between the IOL and posterior capsule is as much as in the vertical direction

γ: the adhension range in horizontal direction between the IOL and posterior capsule is larger than in the vertical direction

**Table 1** The effect of IOL types on the adhension between posterior capsule and IOL

| Follow up perriod | | | IOL | | | | Sum |
|---|---|---|---|---|---|---|---|
| | | | ZA9003 | SOFT | SN6ATX | 525 | |
| 1.00 | IOL-PC category | I | 0 | 3 | 2 | 3 | 8 |
| | | II | 2 | 1 | 1 | 3 | 7 |
| | | III | 2 | 8 | 1 | 4 | 15 |
| | | IV | 2 | 7 | 0 | 3 | 12 |
| | Sum | | 6 | 19 | 4 | 13 | 42 |
| 2.00 | IOL-PC category | I | 0 | 1 | 1 | 0 | 2 |
| | | II | 1 | 3 | 0 | 1 | 5 |
| | | III | 0 | 1 | 0 | 1 | 2 |
| | | IV | 1 | 1 | 0 | 3 | 5 |
| | Sum | | 2 | 6 | 1 | 5 | 14 |
| 3.00 | IOL-PC category | I | 0 | 0 | 16 | 0 | 16 |
| | | II | 1 | 0 | 13 | 0 | 14 |
| | | III | 0 | 1 | 5 | 0 | 6 |
| | | IV | 3 | 14 | 15 | 2 | 34 |
| | Sum | | 4 | 15 | 49 | 2 | 70 |
| sum | IOL-PC category | I | 0 | 4 | 19 | 3 | 26 |
| | | II | 4 | 4 | 14 | 4 | 26 |
| | | III | 2 | 10 | 6 | 5 | 23 |
| | | IV | 6 | 22 | 15 | 8 | 51 |
| | sum | | 12 | 40 | 54 | 20 | 126 |

The relationship between posterior capsule and IOL is divided into four categories

I,there is no adhension between the IOL and posterior capsule in horizontal direction

II,the adhension range in horizontal direction between the IOL and posterior capsule < 1/2

III,the adhension range in horizontal direction between the IOL and posterior capsule > 1/2

IV,adhension completely between the IOL and posterior capsule in horizontal direction

**Table 3** Effect of factors on the adhension between the posterior capsule and the IOL

| | -2log likelihood of Reduced model | chi-square | df | Sig |
|---|---|---|---|---|
| intercept | 183.496 | .000 | 0 | |
| Axial length | 185.111 | 1.614 | 3 | .656 |
| LT | 185.038 | 1.541 | 3 | .673 |
| Follow up period | 202.157 | 18.660 | 6 | .005 |
| IOL style | 214.048 | 30.552 | 9 | .000 |

statistically significant, while axial length and lens thickness are not statistically significant.

## Discussion

The follow-up period affects the adhesion between the posterior capsule and IOL. With an increasing follow-up period, the adhesion range between the posterior capsule and IOL increases, which is consistent with other studies [13].

It has been reported that the PC-IOL space should gradually decrease and close within two weeks after IOL implantation [14]. In our study, when the follow-up period is longer than one month, there is no gap between the lens and the posterior capsule in most cases in the ZA9003, SOFTEC, and 525 groups, indicating complete adhesion of the posterior capsule to the IOL. However, in the SN6ATX group, complete adhesion is observed in only 30.6% of cases with a follow-up period longer than one month. When the follow-up period is less than one week, the adhesion range of PC-IOLs greater than 1/2 in the SOFTEC group is 78.9%, which is significantly higher than in the other groups. This suggests that the SOFTEC IOL has the strongest adhesive power, while the SN6ATX IOL has the weakest adhesive power among the four IOL types.

Some studies [3] have reported that haptic angulation and number affect the adhesion between the posterior capsule and IOL. In our study, these factors are the same in the SOFTEC and SN6ATX groups, so we can exclude their confounding effects on the PC-IOL space.

Other studies [3] have also reported that larger optic diameter and overall length improve adhesive power, which differs from our findings. In our study, the optic diameter and overall length are larger in the SN6ATX IOL than in the SOFTEC IOL, yet the SOFTEC IOL exhibits stronger adhesive power. This discrepancy may be due to other confounding factors.

The SOFTEC IOL is made of hydrophilic acrylic aspheric optic with a 360° square edge design and 0° haptic angulation. The SN6ATX is made of hydrophobic acrylic aspheric optic with a double square edge design and 0° haptic angulation. It has been reported [1, 12] that hydrophobic acrylic IOLs have a lower incidence of PCO, as they are believed to have stronger adhesive power with the posterior capsule than hydrophilic acrylic IOLs. However, our study shows that the SN6ATX is less adhesive to the posterior capsule than the SOFTEC IOL. This may be because hydrophilic IOLs with a 360° square edge design have better adhesive properties than older design hydrophobic models [15].

In our study, the adhesion range is similar in the horizontal and vertical directions in most cases. However, in 12.2% of cases, the adhesion range in the horizontal direction is larger than in the vertical direction, possibly because the haptic is always in the horizontal direction, and the mechanical tension from the haptic facilitates adhesion between the posterior capsule and the IOL.

Zhao reported weak and incomplete adhesion between IOLs and the posterior capsule in highly myopic eyes, possibly due to the larger PC-IOL space in these eyes. However, we did not find a relationship between PC-IOL space and axial length or lens thickness [16]. Interestingly, our findings showed that the Softec IOL exhibited the strongest PC adhesion, consistent with previous studies showing that hydrophilic IOLs, like Softec, typically demonstrate stronger adhesion compared to hydrophobic lenses. This stronger adhesion is likely due to the hydrophilic material, which interacts more effectively with the posterior capsule. Further investigation is warranted to explore the biological mechanisms driving this enhanced adhesion [17, 18].

This study has several limitations. The retrospective design may introduce selection bias, as participants were chosen based on existing records. Variability in follow-up intervals among patients could lead to observation bias, potentially affecting the consistency of posterior capsule-IOL adhesion assessments. Additionally, as a single-center study with a relatively small sample size, the findings may not be generalizable to broader populations. Despite statistical adjustments, residual confounders, such as unmeasured differences in surgical techniques, cannot be fully excluded. Future prospective, multicenter studies are needed to validate these findings.

In conclusion: (The follow-up period)duration of postoperative observation and IOL types affect the adhesion between the IOL and the posterior capsule, while axial length and lens thickness do not.Among the four IOL types studied, the SOFTEC IOL appears to have the strongest adhesive power, while the SN6ATX IOL may exhibit the weakest. These findings reflect observed trends based on our retrospective study and highlight potential differences in adhesion properties that warrant further exploration by other researchers to validate these results and investigate underlying mechanisms.

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**Authors' contributions**
N.C. and L.X. conceptualized the study, designed the methodology, and acquired funding. • N.C. performed the experimental procedures, analyzed data, and wrote the manuscript. • X.L. and P.H. contributed to the writing of the manuscript and interpretation of results. • X.W. and J.L. assisted with literature review and data collection. • Y.Y. provided statistical analysis and data presentation. • D.L. and Z.Z. supervised the project and reviewed the manuscript. • All authors reviewed the manuscript and approved the final version.

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**Data availability**
No datasets were generated or analysed during the current study.

## Declarations

**Ethics approval and consent to participate**
This stuy was conducted in accordance with the tenets of the Declaration of Helsinki. The protocol was approved by the Ethics Committee of Shanghai Sixth People's Hospital. Written informed consent was obtained from all participants prior to their inclusion in the study.

**Consent for publication**
All authors have read and approved the final manuscript and consent to its publication in BMC Ophthalmology.

**Competing interests**
The authors declare no competing interests.

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## Publisher's Note