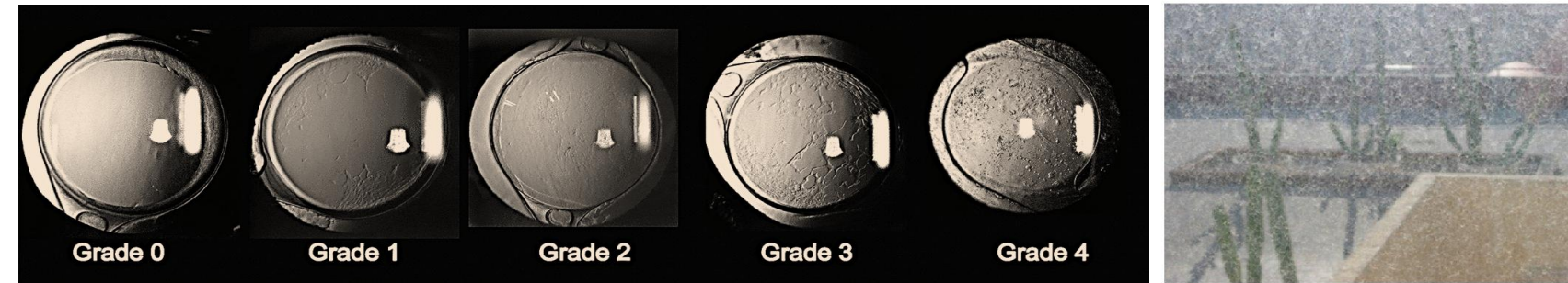


Reducing Post-Cataract Complications in Myopic Eyes Through Optimized IOL-Lens Capsule Interactions

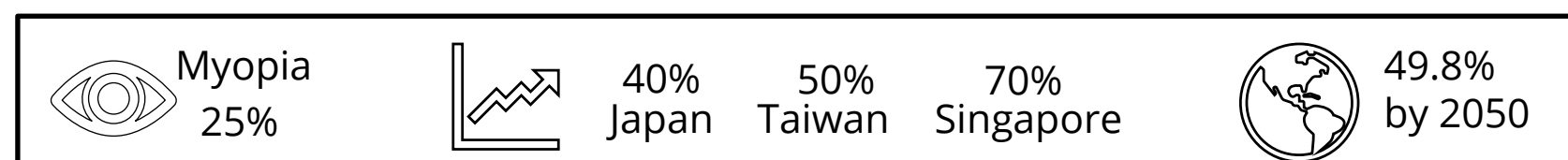
Executive Summary



Posterior capsule opacification (PCO) is highly incident in severely myopic eyes that are implanted with low diopter IOLs; however, the underlying mechanism is unclear. Standard low-diopter IOLs have a flat posterior curvature, or a high posterior radius of curvature (PRC). Additionally, the anatomical lenses of myopic eyes are large. We hypothesize that curvature mismatch between flat IOLs and the large posterior lens capsule (PLC) compromises IOL-PLC contact. This was tested directly using a model. By implanting commercial IOLs in a simulated myopia PLC, we found that **low PRC IOL designs** increased IOL-PLC interactions and reduced cell responses *in vitro*, suggesting their potential to improve IOL safety in myopia patients.

Background

- **Posterior Capsule Opacification (PCO)** is the most common complication of cataract surgery.
- Caused by the infiltration and proliferation of lens epithelial cells (LECs), PCO creates vision loss.
- Young age and **myopia** are major risk factors for PCO.



- Myopia rate estimated to reach 50% by 2050.
- **Incidence of PCO increases with severity of myopia.**

Table 1. Clinical incidence of PCO for different power IOLs. Increased IOL PRC/decreased IOL power are accompanied by increased Nd:YAG capsulotomy rate.

Ref.	Samples (eyes)	Clinical Incidence of PCO		
		Low Power	Mid Power	High Power
Hecht, et al., 2020	14,264	29.9% (≤ 10 D)	12.4% (15.5–20.0 D)	10.1% (≥ 20.5 D)
Lindholm, et al., 2020	15,375	27.4% (5–16.5 D)	14.6% (17–24.5 D)	13.6% (25–30 D)

- IOL design factors such as material and edge sharpness influence PCO incidence.
- Low power lenses have high posterior radius of curvature (PRC).

What about IOL PRC?

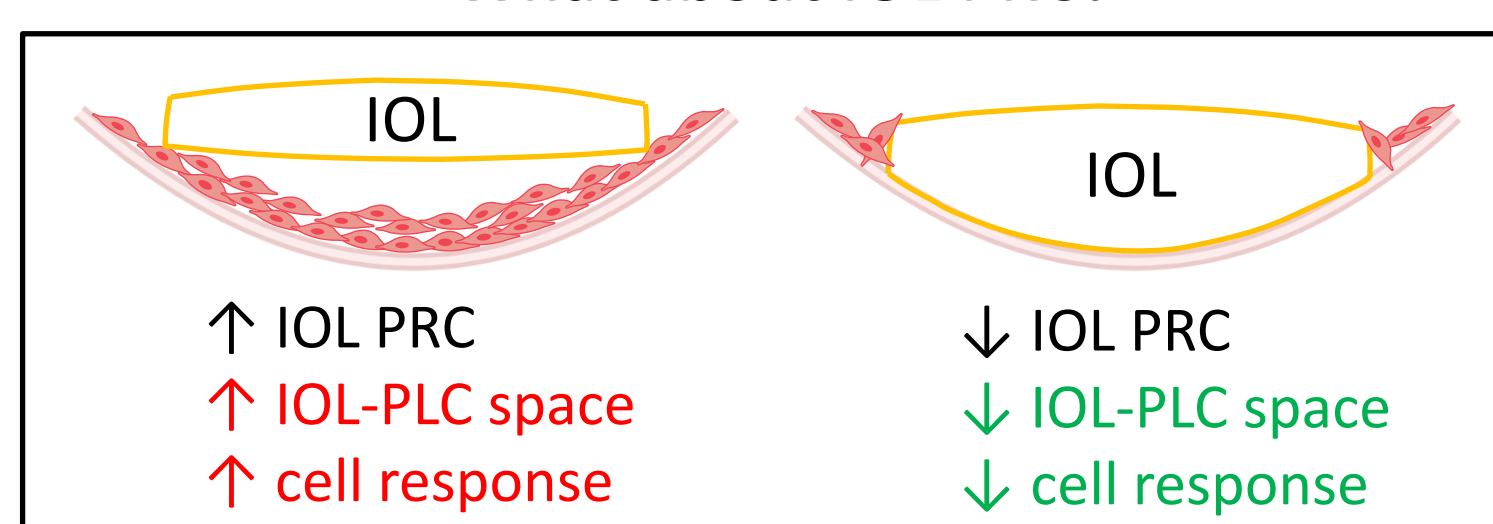


Figure 1. Schematic of high cell response with high PRC IOL and low cell response with low PRC IOL.

Experimental Setup

Hypothesis: Lower physical interactions between low power (high myopia) IOLs and large myopia PLC lead to higher cell responses and higher PCO incidence (Figure 1).

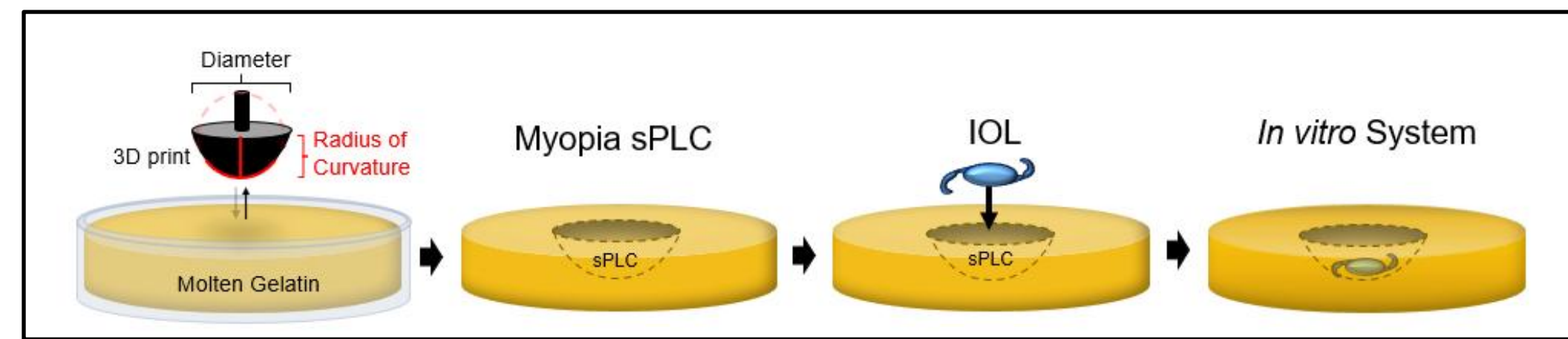


Figure 2. Schematic of simulated posterior lens capsule (sPLC) fabrication process and implantation of IOL to generate the testing system.

Table 2. Commercial IOLs chosen for testing.

Myopia severity	High	Medium	Low
Optic Power	6.0 D	20.0 D	30.0 D
Posterior Radius of Curvature	88.33 mm	26.50 mm	17.67 mm
Optic Material	Acrylic foldable		
Index of Refraction	1.55		
Optic Type	Biconvex, Square edge		
Optic Diameter	6.0 mm		
Overall Length	13.0 mm		
Haptic Material	Acrylic foldable		
Haptic Angulation	0°		

To test the hypothesis, a 3D simulated PLC (sPLC) model mimicking the large lens diameter of severely myopic eyes was fabricated (Figure 2). We tested three distinct size IOLs (Table 2). The sPLC was fabricated using 10% porcine gelatin and 0.25% glutaraldehyde as the crosslinker to obtain biomechanical properties similar to native lens capsule.

Experimental Test Plan

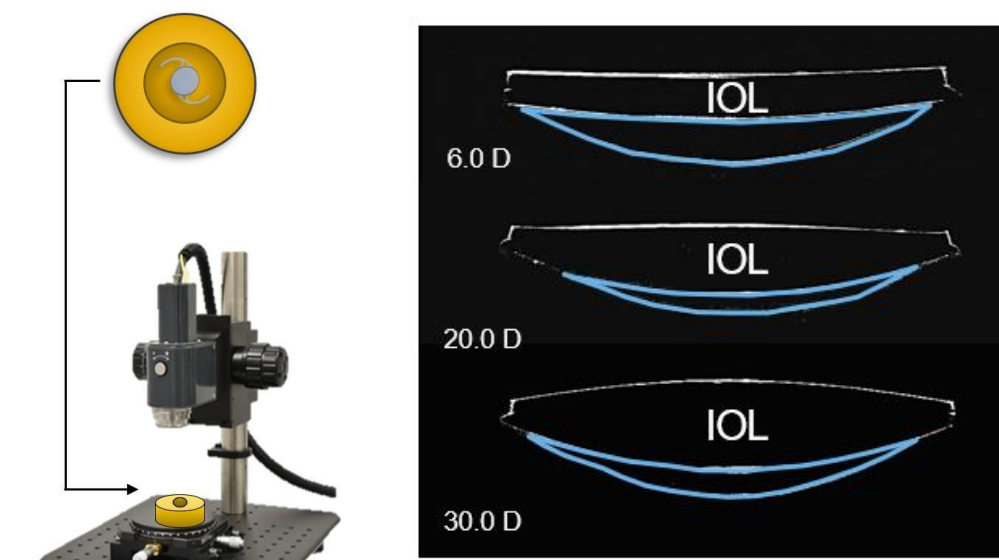


Figure 3. OCT imaging machine and representative OCT images. Blue indicates open area between IOL and sPLC.

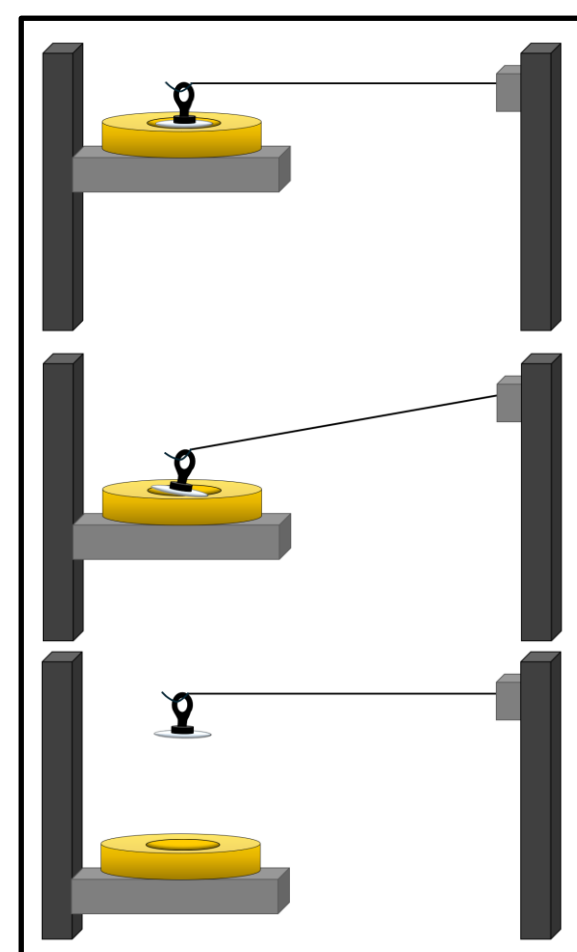


Figure 4. Schematic of adhesion force test.

- Spectral domain optical coherence tomography (SD-OCT) was used to observe the influence of IOL diopter and PRC on the IOL:sPLC interface space. After images were taken at different time points (0, 24, and 48 hours), the IOL/sPLC interface space distance, surface area, and percentage of contact were quantified in the 6 mm optic region using ImageJ software.
- The adhesion force of the IOLs to the sPLC was measured using a custom-made adhesion force apparatus based on an established procedure. First, the IOL/sPLC assembly was placed on a motor-driven stage, and a horizontal bending bar was hooked onto the IOL. As the stage descended, it caused a deflection of the bending bar. The distance the IOL traveled when it detached from the sPLC was captured by camera and used to estimate the maximum adhesion force using the following equation:

$$F_{max} = \frac{y \times 6 \times E \times I}{2 \times L^3}$$

F_{max} = maximum adhesion force
 y = distance traveled by stage
 E = Young's modulus
 I = area moment of inertia
 L = length of bending bar

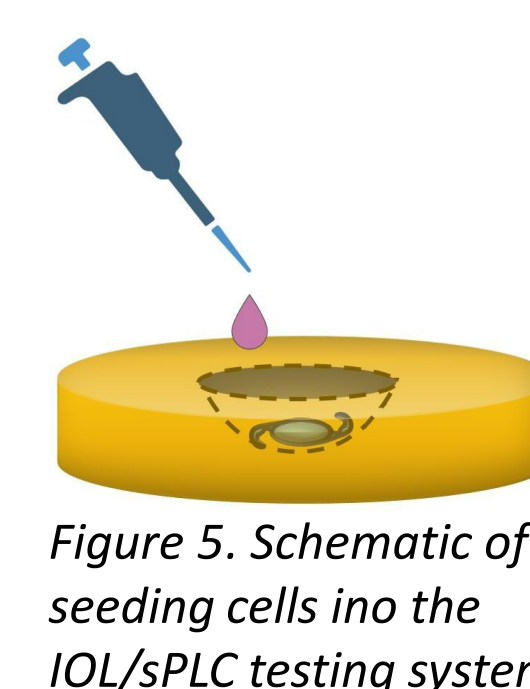


Figure 5. Schematic of seeding cells into the IOL/sPLC testing system.

Experimental Results

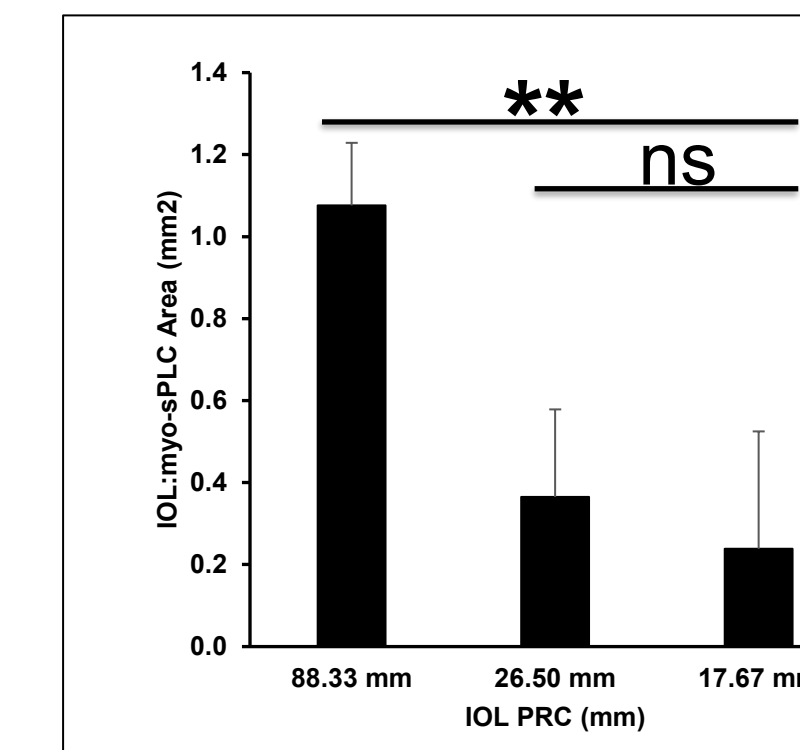


Figure 6. Space between IOL and sPLC quantified through OCT imaging.

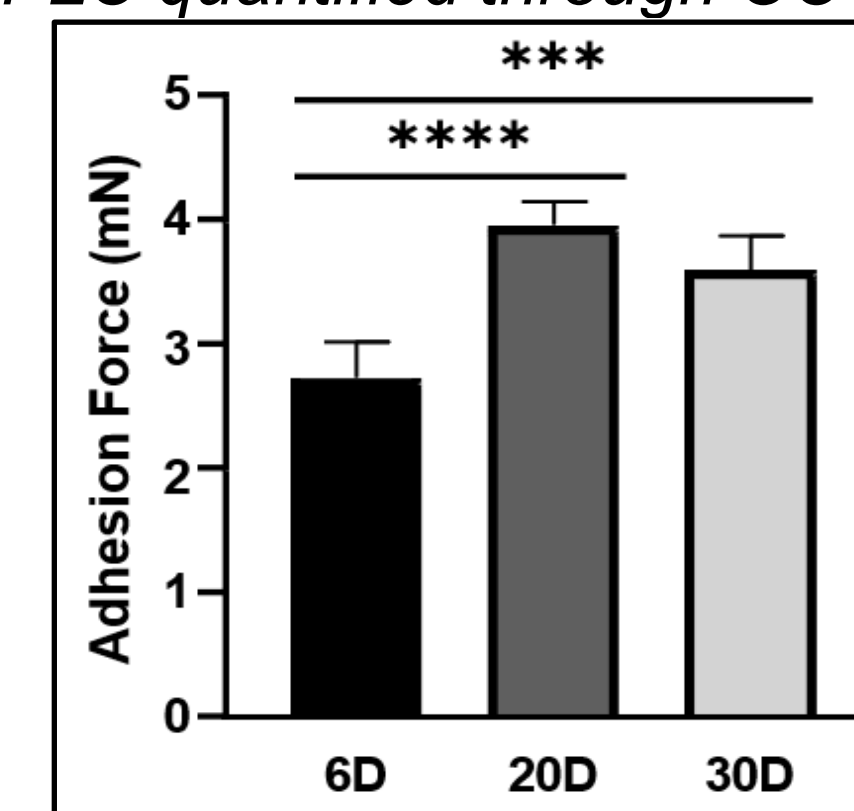


Figure 7. Binding force between IOL and sPLC.

- OCT analysis showed the standard high-PRC IOL resulted in the largest interface space (0.77 ± 0.09 mm) (Figure 6). Reducing the PRC significantly reduced the space: 20D (0.04 ± 0.02 mm) and 6D (0.01 ± 0.01 mm).
- Conversely, the adhesion force was highest for the low-PRC IOL (5.38 ± 0.43 mN) and the lowest for the high-PRC IOL (3.14 ± 0.07 mN), confirming an inverse relationship (Figure 7).

- Cell responses also increased with IOL PRC (Figure 8).

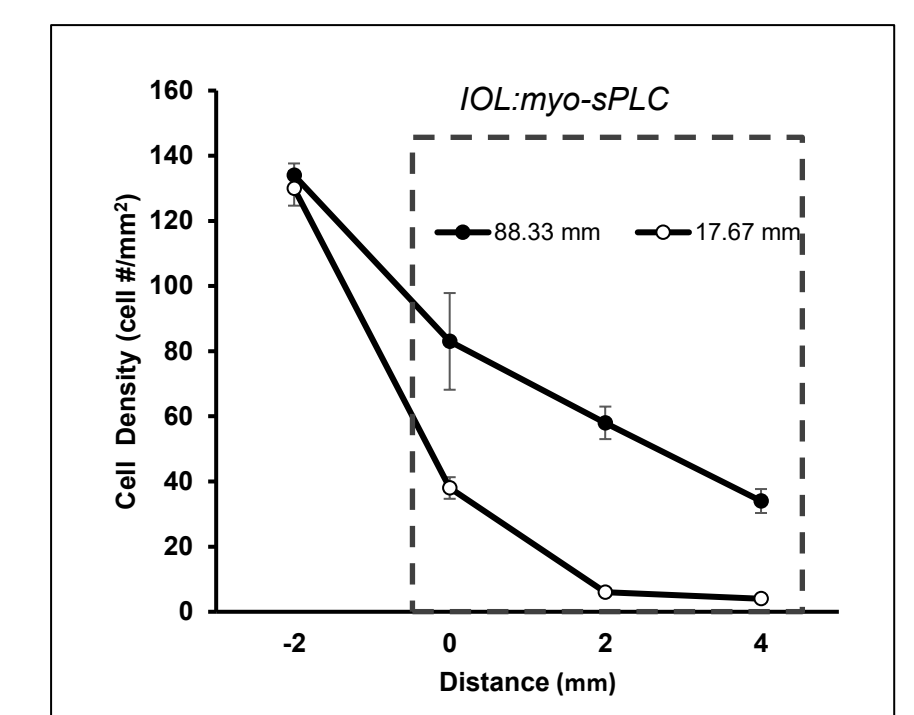


Figure 8. Cell infiltration from outer to central area under the IOL.

Conclusions

- Our results identify that current low-diopter IOLs create a significant mismatch with the myopic PLC, resulting in a large IOL-capsule interface space and compromised IOL-capsule adhesion. This poor contact directly facilitates increased LEC infiltration, providing a mechanistic explanation of myopia-specific IOLs' high PCO incidence. Improved IOL designs with a reduced PRC (more convex posterior design) to enhance IOL-PLC contact and minimize the potential space for LEC migration may lower PCO formation in highly myopic patients.
- In future work, we plan to design, print, and test different IOLs to investigate whether certain IOL dimensions are more suitable for different levels of myopia.

References

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