ORIGINAL ARTICLE

A Comparative Study of Manual Small Incision Cataract Surgery Versus Phacoemulsification in Glaucoma Patients with Hard Cataract: An 18-Month Follow-Up

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Background: Cataracts and glaucoma are prevalent in the elderly, often co-occurring. Cataract surgery in glaucoma patients reduces intraocular pressure (IOP), improves visual acuity (VA), and enhances glaucoma monitoring. Two main surgical techniques exist, phacoemulsification (PE) and manual small-incision cataract surgery (MSICS).

Objective: To compare the outcomes of MSICS and PE in Primary open angle glaucoma (POAG) patients with hard cataracts, focusing on postoperative corneal edema, IOP, and corneal endothelial cell density (CECD).

Materials and Methods: The present study was a retrospective cohort study that analyzed 80 eyes from 71 POAG patients with hard cataracts, of LOCS III N3, C3, or higher, who underwent either MSICS or PE at Prapokklao Hospital between November 2020 and December 2022. Exclusion criteria included IOP greater than 25 mmHg despite medical treatment, acute angle closure glaucoma, glaucoma secondary to trauma, and other comorbidities. Central corneal thickness (CCT) and CECD were measured pre- and post-operatively at day-1, day-7, month-1, -3, -6, -12, and -18. IOP and glaucoma medication were also tracked.

Results: One day postoperatively, CCT increased significantly more in the PE group, at 53 µm, than in the MSICS group, at 40 µm (p=0.022). However, both groups returned to near preoperative CCT levels by one month. Both surgical methods significantly reduced IOP at 1, 3, and 12 months postoperatively, but the reduction was significantly greater in the MSICS group at 1 month (p<0.001). VA significantly improved in both groups at 3 months postoperatively. CECD decreased in both groups at 18 months, but the difference was not statistically significant (p=0.058). At 6 and 18 months, significantly more patients in the MSICS group used only one glaucoma medication (p=0.009, 0.015).

Conclusion: PE resulted in a significantly greater increase in CCT one day postoperatively compared to MSICS. Long-term changes in CECD were not significantly different between the groups. Both surgical methods resulted in significant IOP reduction at 1 month postoperatively, with MSICS showing a greater reduction.

Keywords: Glaucoma; Cataract; Corneal thickness; Corneal endothelial cell loss

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Cataracts and glaucoma are common diseases in the elderly, and it is not unusual for both conditions to coexist in the same patient[1]. Therefore, the treatment of cataracts in conjunction with glaucoma is crucial. The primary benefit of cataract surgery in patients with glaucoma is its ability to lower intraocular pressure (IOP) postoperatively[1,2], while also improving visual acuity (VA). This, in turn, enhances optic disc examinations, increasing the accuracy of glaucoma diagnosis and the monitoring of disease progression[3]. Currently, cataract surgery is performed using two methods, 1) phacoemulsification (PE), a widely practiced method that uses ultrasound to dissolve cataracts, particularly effective for soft cataracts and 2) manual small-incision cataract surgery (MSICS), another effective method, particularly suitable for patients with harder cataracts, offering good surgical outcomes. In patients with very hard cataracts, PE requires a large amount of energy to break the cataract. Some of this energy can damage the corneal endothelial cells, potentially leading to a decrease in endothelial cell density and postoperative corneal edema[4]. Corneal edema can be assessed by measuring the central corneal endothelial cell density (CECD) and central corneal thickness (CCT) using

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pachymetry or anterior segment optical coherence tomography. A natural reduction in CCT[5-7] and CECD[6] is observed in primary open-angle glaucoma (POAG) and primary angle-closure glaucoma (PACG) patients, due to both the disease itself and anti-glaucoma medications. Therefore, in glaucoma patients with hard cataracts, cataract surgery may further reduce CECD and increase the risk of postoperative corneal edema.

The MSICS method is a viable alternative for the surgical treatment of hard cataracts. Prapokklao Hospital is renowned for its expertise in performing MSICS[4,8-12]. Hard lens cataracts are particularly challenging, and there have been no comparative studies of surgical outcomes between MSICS and PE in patients with POAG. Therefore, the present study investigated postoperative corneal edema, IOP, and CECD in POAG patients with hard cataracts following MSICS compared to PE.

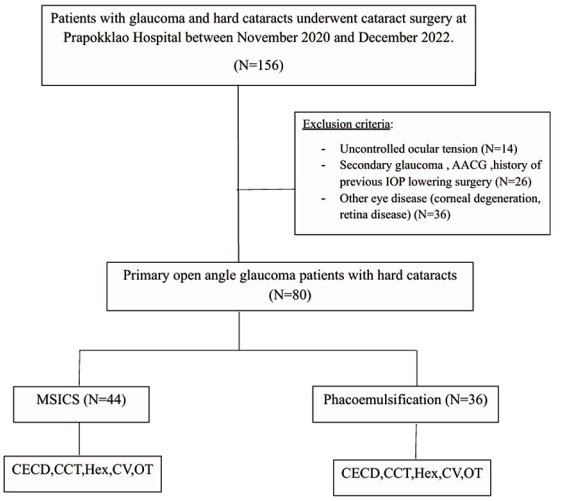

Figure 1. The CONSORT flow diagram.

CCT, central corneal thickness; CECD, central endothelium cells density; OT, ocular tension; Hex, hexagonality; CV, coefficient variation of endothelial cell size

Materials and Methods

The present study was a retrospective cohort study enrolled and compared POAG patients with hard cataracts who underwent cataract surgery using the MSICS or PE methods at Prapokklao Hospital in Chanthaburi Province, Thailand between November 2020 and December 2022. Data was collected from the medical records of 71 patients, which included 80 eyes. All surgical procedures were performed by a single surgeon, and the study was reviewed and approved by the Research Ethics Committee of the Chanthaburi Research Ethics Committee/Region 6, Thailand (number 052/67).

The inclusion criteria were POAG patients with hard cataracts classified as N3, C3, or higher according to the Lens Opacities Classification System III (LOCS III)[13], without evidence of zonular dialysis prior to cataract surgery. Exclusion criteria included preoperative IOP of more than 25 mmHg despite anti-glaucoma medical treatment, acute angle-closure glaucoma (AACG), glaucoma secondary to trauma, postoperative iritis, congenital glaucoma, or glaucoma with comorbidities such as corneal dystrophy, retinal detachment, or diabetic retinopathy. In addition, patients that had a history of previous IOP-lowering surgery, such as trabeculectomy or glaucoma drainage device implantation were excluded (Figure 1).

Surgical methods

Patients in both groups received retrobulbar anesthesia. In the MSICS group, surgery was performed using a modified Blumenthal technique[14], with a superior scleral tunnel incision. The anterior capsule was opened by either capsulorhexis or capsulotomy. The lens was luxated into the anterior chamber and removed. A foldable intraocular lens (CT ASPHINA 404, ZEISS, Germany) was implanted, and a scleral suture was placed.

The PE technique was performed using the Stellaris machine (Bausch & Lomb, ultrasound power 40%, vacuum 300 mmHg). Following a clear corneal incision, the anterior capsule was opened using capsulorhexis. The lens was fragmented and aspirated via PE. A foldable intraocular lens (CT ASPHINA 404, ZEISS, Germany) was subsequently implanted.

Postoperative care

Both groups received standard postoperative care. During the first postoperative week, both groups were prescribed dexamethasone eye drops every two hours and moxifloxacin eye drops four times daily. As the inflammation in the anterior chamber decreased during follow-up visits, the dexamethasone eye drops were reduced to four times daily, while moxifloxacin eye drops continued at the same frequency until completion. At the one-month postoperative follow-up, if there was no residual inflammation in the anterior chamber and the eyes appeared clear, all eye drops were discontinued. IOP was measured and glaucoma medications were adjusted as needed for each patient.

Table 1. Demographic data

	Total (n=80)	MSICS (n=44)	Phacoemulsification (n=36)	p-value
Sex; n (%)				0.134[a]
Male	34 (42.5)	22 (50.0)	12 (33.3)	
Female	46 (57.5)	22 (50.0)	24 (66.7)	
Age (years); mean±SD	66.7±9.1	66.8±9.2	66.6±9.1	0.911[b]
Visual acuity*: pre-op.; n (%)				0.927[a]
20/200 to 20/400	13 (16.3)	7 (15.9)	6 (16.7)	
<20/400	67 (83.7)	37 (84.1)	30 (83.3)	
Lens; n (%)				0.061[a]
Brown cataract	74 (92.5)	38 (86.4)	36 (100)	
White cataract	6 (7.5)	6 (13.6)	0 (0.0)	

MSICS=manual small-incision cataract surgery; SD=standard deviation

* WHO classification of visual impairment (VI): no/mild VI visual acuity >20/70, moderate VI visual acuity 20/70 to 20/200, severe VI visual acuity 20/200 to 20/400, blindness visual acuity <20/400

The p-value by (a) Pearson chi-square test or Fisher's exact test, (b) independent t-test, significant level at p<0.05

Observations and measurements

Measurements included CCT, CECD, ocular tension, hexagonality, and coefficient of variation of endothelial cell size obtained by an ophthalmic nurse using a specular microscope. Measurements were taken one day preoperatively and subsequently on day-1 and 7 and month-1, 3, 6, 12, and 18 postoperatively. VA was measured by an ophthalmic nurse using Snellen's chart at each visit, pre- and postoperatively. IOP was measured using a Goldmann applanation tonometer at each visit, pre- and post-operatively, by an ophthalmologist. Postoperative complications, such as posterior capsule tears, vitreous loss, hyphema, iritis, lens drop, increased IOP, and corneal edema, were recorded.

Data collection

Data collected from the medical records included age, gender, type of glaucoma, number of current glaucoma medications, VA, IOP, CCT, CECD, hexagonality, coefficient of variation of endothelial cell size, and postoperative complications.

Statistical analysis

The sample size was calculated through comparison of the MSICS and PE techniques in patients with moderate hard cataracts[4]. One day postoperatively, CCT increased by 73 and 138 microns in the MSICS and PE groups, respectively. The sample size was calculated using Stata version 14, with an 80% power at the 5% significance level (two-sided), resulting in a required sample size of 22 individuals per group. To prevent loss of samples during data collection, an additional 20% was added, yielding 27 people per group. Baseline demographic data and eye drop medication quantities were analyzed using the chi-square or Fisher's exact tests. CCT and CECD were compared using the paired t-test. A p-value of less than 0.05 was considered statistically significant.

Results

Eighty eyes from 71 patients with POAG with hard cataracts underwent cataract surgery. Forty-four eyes underwent surgery using the MSICS method, and 36 eyes underwent PE. The mean age in both groups was similar, with an overall mean age of 66.7±9.1 years (range of 47 to 92). The patient cohort included 46 females, accounting for 57.5% of all participants. In the MSICS group, 38 patients (86.4%) had brown cataracts and six (13.6%) had white cataracts. In the PE group, all 36 patients had brown cataracts. Most patients had a worse preoperative VA than 20/400, including 37 patients (84.1%) in the MSICS group and 30 (83.3%) in the PE group (Table 1).

All patients in both groups received intraocular lens implantation after surgery. Intraoperative complications were observed, one case in the MSICS group, where a posterior capsule rupture occurred, however, there was no vitreous loss. The patient successfully received the intraocular lens implanted in the sulcus.

Three months postoperative, most patients had a VA better than 20/70 in both groups, including 20 patients (45.5%) in the MSICS group and 17 (47.2%) in the PE group (Table 2).

The preoperative CCT in the MSICS group was 513.3±35.8 microns, increasing to 553.5±44.6 microns one day postoperatively. Conversely, in the PE group, preoperative CCT was 519.4±28.9 microns,

Table 2. Vision levels before and after cataract surgery

Visual acuity (VA)	Total (n=80); n (%)	MSICS (n=44); n (%)	Phacoemulsification (n=36); n (%)	p-value
Pre-operative				0.927
20/200 to 20/400	13 (16.3)	7 (15.9)	6 (16.7)	
<20/400	67 (83.7)	37 (84.1)	30 (83.3)	
POD-1				0.884
>20/70	6 (7.5)	3 (6.8)	3 (8.3)	
20/70 to 20/200	15 (18.7)	7 (15.9)	8 (22.2)	
20/200 to 20/400	35 (43.8)	20 (45.5)	15 (41.7)	
<20/400	24 (30.0)	14 (31.8)	10 (27.8)	
POD-7				0.741
>20/70	20 (25.0)	10 (22.7)	10 (27.8)	
20/70 to 20/200	33 (41.3)	20 (45.5)	13 (36.1)	
20/200 to 20/400	19 (23.7)	9 (20.5)	10 (27.8)	
<20/400	8 (10.0)	5 (11.3)	3 (8.3)	
POM-1				0.997
>20/70	31 (38.8)	17 (38.7)	14 (38.9)	
20/70 to 20/200	33 (41.3)	18 (40.9)	15 (41.7)	
20/200 to 20/400	11 (13.7)	6 (13.6)	5 (13.9)	
<20/400	5 (6.2)	3 (6.8)	2 (5.5)	
POM-3				0.969
>20/70	37 (46.2)	20 (45.5)	17 (47.2)	
20/70 to 20/200	31 (38.8)	18 (40.9)	13 (36.1)	
20/200 to 20/400	8 (10.0)	4 (9.1)	4 (11.1)	
<20/400	4 (5.0)	2 (4.5)	2 (5.6)	

MSICS=manual small-incision cataract surgery; POD-1=first postoperative day; POD-7=seventh postoperative day; POM-1=first postoperative month; POM-3=third postoperative month

The p-value by Pearson chi-square test or Fisher's exact test, significant level at $p<0.05$

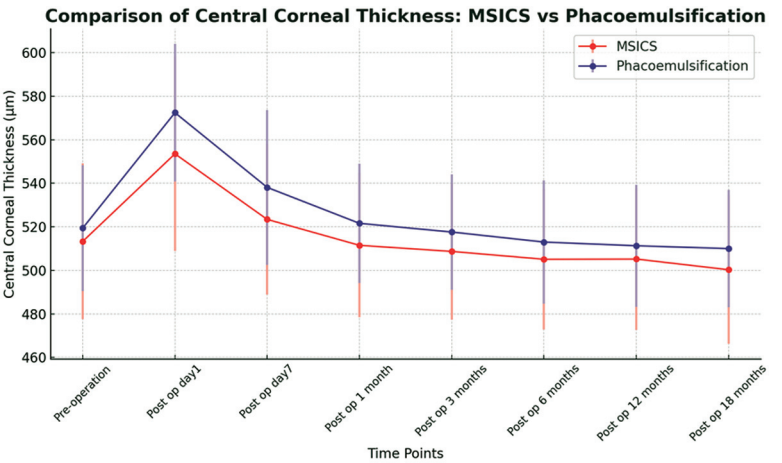

Figure 2. Comparison of the central corneal thickness between the MSICS and Phacoemulsification techniques.

increasing to 572.4±31.7 microns postoperatively. The percentage increase in CCT one day after surgery was 7.11% for MSICS and 9.20% for PE (p=0.022). In both groups, CCT returned close to the preoperative levels one-month postoperatively, measuring 511.5±33.1 and 521.6±27.4 microns for the MSICS and PE groups, respectively (Figure 2).

Preoperative IOP levels were 16.6±3.01 mmHg and 15.5±2.38 mmHg in the MSICS and PE groups, respectively. Both groups showed a significant

Table 3. Number of eyes drop medications used to lower intraocular pressure before and after cataract surgery

Number of anti-glaucoma medication	Pre-operative; n (%)		POM-6; n (%)		POM-18; n (%)	
	MSICS	PE	MSICS	PE	MSICS	PE
0	0 (0.0)	0 (0.0)	10 (22.7)	2 (5.6)	10 (22.7)	2 (5.56)
1	12 (27.3)	9 (25.0)	21 (47.7)	13 (36.1)	21 (47.7)	13 (36.1)
2	15 (34.1)	18 (50.0)	11 (25.0)	21 (58.3)	13 (29.6)	21 (58.3)
3	15 (34.1)	8 (22.2)	2 (4.55)	0 (0.0)	0 (0.0)	0 (0.0)
4	2 (4.5)	1 (2.78)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
p-value	0.496		0.009		0.015	

MSICS=manual small-incision cataract surgery; PE=phacoemulsification; POM-6=sixth postoperative month; POM-18=eighteenth postoperative month
The p-value by Pearson chi-square test or Fisher' s exact test, significant level at p<0.05

Table 4. The corneal endothelial cell density before and after cataract surgery in both groups

CECD (cell/mm^2)	MSICS	Phacoemulsification	p-value
Pre-operative	2,556.6±308.8	2,514.7±223.5	0.498
POD-1	2,520±277.1	2,474.6±273.6	0.466
POD-7	2,476.8±316.3	2,444.8±271.8	0.634
POM-1	2,489±302.1	2,421.9±272.9	0.299
POM-3	2,502.6±261.4	2,418.8±235.2	0.140
POM-6	2,469.3±282.8	2,352.4±254.8	0.058
POM-12	2,466.3±291.2	2,365.5±261.6	0.111
POM-18	2,459.3±270.4	2,346.8±251.2	0.060

CECD=central endothelium cells density; MSICS=manual small-incision cataract surgery; POD-1=first postoperative day; POD-7=seventh post-operative day; POM-1=first postoperative month; POM-3=third post-operative month; POM-6=sixth postoperative month; POM-12=twelfth postoperative month; POM-18=eighteenth postoperative month
The p-value by independent t-test, significant level at p<0.05

IOP reduction postoperatively. At the one-month follow-up, IOP was 14.1±2.15 mmHg for MSICS and 15.7±1.88 mmHg for PE (p=0.008). At three months, IOPs were 14.8±2.08 mmHg for MSICS and 15.8±1.66 mmHg for PE (p=0.032). At 12 months, mean IOP was 14.2±2.24 mmHg in MSICS and 15.7±1.96 mmHg in PE (p=0.002). After one month, the MSICS group showed a decrease of 2.5±2.74 mmHg, while the PE groups showed a decrease of 0.22±2.69 mmHg, which was statistically significant (p<0.001).

Before surgery, patients in both groups averaged two glaucoma medications, with a range of one to four. In the MSICS group, 15 patients (34.1%) used two medications, while 18 (50%) in the PE group did the same. At 6 months' follow-up, medication use decreased for both groups and 21 patients (47.7%) in the MSICS group primarily used one medication, compared to 21 patients (58.3%) in the PE group who primarily used two medication, showing a significant difference (p=0.009). After 18 months, both groups reduced their use to 0 to 2 medications, with 21 (47.7%) and 21 (58.3%) patients in the MSICS and PE groups using one and two medications, respectively, with a significant difference (p=0.015) (Table 3).

During the 18-month follow-up, the MSICS and PE groups showed a decrease in CECD, but this difference was not statistically significant. The reduction appeared to stabilize after six months, with the MSICS group reaching a level of 2,469.3±282.8 cells/mm² (3.72%) and the PE group of 2,352.4±254.8 cells/mm² (7.75%) (p=0.058) (Table 4). There was no statistically significant difference in the coefficient of variation of endothelial cell size between the groups at the 18-months follow-up.

Discussion

Overall, the results of this study indicated that POAG patients with hard cataracts had poor VA before surgery. Three months postoperatively, most patients improved to better than 20/70 in both groups. Similar to findings in non-glaucoma patients, after six months, both groups achieved a VA of 20/60 or better[10,15]. Furthermore, one study showed that there was no significant difference in postoperative VA between the two methods for patients with hard cataracts[16]. The variability in VA improvement in the present study, compared to others, may be due to the present study focus on glaucoma patients who may have experienced optic nerve damage from the disease.

The CCT measurement one day postoperatively showed an increase of 40.25±24.88 microns in the MSICS group and 53.08±24.23 microns in the PE group, yielding a statistically significant difference (p=0.022). Both groups returned to a normal CCT comparable to preoperative levels at the one-month follow-up, which aligns with the findings of Kongsap[4], who compared both surgical methods in patients with white cataracts. Their study further

observed increases of 67.4±72.7 and 138.0±103.1 microns in the MSICS and PE groups, respectively, one day post-surgery, with a statistically significant difference ($p<0.008$). Similarly, two comparative studies of hard lens cataracts[17,18] showed that CCT increased by 28 to 34 microns (5% to 6.5%) in the MSICS group and 53 to 63 microns (10% to 11.8%) in the PE group one day following cataract surgery. The CCT of both groups returned to baseline values comparable to pre-surgery levels when followed up six weeks after surgery, with a statistically significant difference ($p<0.001$). This contrasts with one study[16], who assessed CCT increases six weeks postoperatively for hard cataracts using both methods. They further found no statistically significant difference ($p=0.28$), with the MSICS group showing an increase of 16.2±14.2 microns and the PE group an increase of 21.7±20.9 microns.

In the present study, CECD was reported following cataract surgery in POAG patients with an 18-month follow-up. The CECD decreased in both groups, but the difference was not statistically significant ($p=0.058$). CECD reduction began to stabilize six months post-surgery, with the MSICS group showing a 3.81% decrease and the PE group showing a 6.68% decrease. Similarly, another study[4,17] showed that CECD decreased postoperatively in both groups, with no statistically significant difference. This contrast with a prior study[16] that compared both surgical methods for hard cataracts, finding significant reduction in CECD after six weeks, with decreased of 7.1% in the MSICS group and 12.0% in the PE group ($p=0.0071$). Additionally, they reported that the decrease in CECD correlated directly with increasing age ($p=0.01$) and greater hardness of the cataract lens ($p=0.0183$) in the PE group. In this prior study[19], CECD decreased by 13.49% in the MSICS group and 3.27% in the PE group six weeks postoperatively. A statistically significant difference in CECD was identified between one and six weeks postoperatively ($p=0.016$). The greater reduction in CECD in the MSICS group may be due to positioning of the surgical instruments in the anterior chamber close to the corneal endothelium, potentially causing injury. During the extraction of the cataract lens, some parts of the lens may contact the corneal endothelial cells. Various MSICS techniques, such as the use of viscoelastic substances and an anterior chamber maintainer during surgery, can help to reduce corneal endothelial cell damage.

Following cataract surgery, IOP decreased in both groups. One-month postoperatively, the MSICS group showed a reduction of –2.5±2.74 mmHg, compared to 0.22±2.69 mmHg in the PE group, which was statistically significant ($p<0.001$). The study also observed a reduction of one to two eye drops in both groups at six months ($p=0.009$) and 18 months ($p=0.015$). This aligns with studies on non-glaucoma patients[20], which reported significant IOP reductions ($p<0.001$) six weeks postoperatively. Reports indicate a correlation between IOP values before and after cataract surgery[21-23], suggesting that a higher preoperative IOP leads to a greater reduction post-surgery. The decrease in IOP is due to an increase in the anterior chamber depth (ACD), expanded anterior chamber angle, and reduced resistance at the trabecular meshwork, which enhances aqueous humor outflow. Several prior studies have shown that replacing the thick cataract lens with a thinner posterior chamber intraocular lens increases ACD[20,24,25]. Another prior study[26] found that energy from PE surgery triggers the release of interleukin 1 in response to stress, resulting in decreased IOP post-surgery. Another study[27] also explained the mechanical pump theory, where the removal of the cataract lens and placement of the IOL causes the anterior lens capsule to move backward, resulting in posterior rotation of the ciliary body. Post-surgery, the pump expands and resumes function, thereby enhancing aqueous humor outflow and further reducing IOP.

In contrast with other studies on non-glaucoma patients[28,29], the present study found postoperative IOP reductions in both surgical methods were not statistically significant compared to preoperative levels. Additionally, it was noted that one day after cataract surgery, patients in the MSICS group experienced a slight increase in IOP, due to residual viscoelastic material in the anterior chamber, affecting early postoperative IOP. The surgical technique used to close the surgical wound can affect aqueous outflow through the trabecular meshwork, thereby influencing the IOP.

Limitation

As this study was a retrospective analysis based on medical records, it has inherent limitations, including a lack of randomization in the division of surgical groups, which may introduce sampling bias in the sample. However, there were no significant differences between the two groups. Additionally, there was no clear documentation regarding the severity of glaucoma, such as visual field tests and optic disc assessments, before and after cataract

surgery. These assessments would be necessary to understand disease progression and prognosis of glaucoma.

Conclusion

Overall, the present study found that POAG patients with hard cataracts underwent PE had significantly greater CCT values for one day post-surgery compared to those who underwent MSICS. In the long-term follow-up after cataract surgery, the decrease in CECD was not significantly different between the two groups. Additionally, both groups showed a reduction in IOP one month following cataract surgery, with the MSICS group demonstrating a significantly greater decrease in IOP than the PE group.

What is already known about this topic?

PE showed greater increase CCT compared to MSICS method. After cataract surgery, a reduction in CECD was observed for both methods.

What does this study add?

MSICS may be the preferred method for cataract surgery in POAG patients with hard cataracts, as it appears to offer better IOP control and less corneal endothelial damage over time compared to PE.

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Conflicts of interest

The authors declare that they have no commercial interests related to the company or products mentioned in this study.

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