

Femtosecond Laser vs. Conventional Phacoemulsification: Long-Term Posterior Capsule Opacification

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ABSTRACT

Background: Posterior capsule opacification (PCO) is the most common long-term complication after cataract surgery and may lead to decreased visual acuity requiring Nd:YAG laser capsulotomy. Advances in surgical techniques such as femtosecond laser-assisted cataract surgery aim to improve surgical precision and potentially reduce postoperative complications.

Objective: To compare the long-term incidence of posterior capsule opacification between femtosecond laser-assisted cataract surgery and conventional phacoemulsification.

Methodology: This was a hospital-based analytical cross-sectional study conducted at Swat Medical Complex Teaching Hospital from March 2021 to March 2022 including 235 patients undergoing cataract surgery.

Results: The mean age of patients was 63.8 ± 8.7 years with nearly equal gender distribution. Capsulotomy diameter was more consistent in the femtosecond group (5.01 ± 0.06 mm) compared with the conventional group (5.19 ± 0.21 mm). Ultrasound energy ($5.9 \pm 2.3\%$ vs $9.8 \pm 3.1\%$) and effective phaco time (27.4 ± 7.8 vs 39.6 ± 9.5 seconds) were significantly lower in the femtosecond group. Posterior capsule opacification occurred in 11.9% of patients in the femtosecond group compared with 23.9% in the conventional group. Nd:YAG capsulotomy was required in 7.6% of patients in the femtosecond group and 17.1% in the conventional group. Postoperative visual acuity was slightly better in the femtosecond group (0.07 ± 0.05 logMAR) compared with the conventional group (0.10 ± 0.07 logMAR).

Conclusion: Femtosecond laser-assisted cataract surgery demonstrated improved surgical precision, reduced ultrasound energy use, and lower incidence of posterior capsule opacification compared with conventional phacoemulsification.

Keywords: Cataract surgery, Femtosecond laser, Phacoemulsification, Posterior capsule opacification, Nd:YAG capsulotomy, Visual outcomes.

INTRODUCTION

One of the most widespread ophthalmic surgeries is cataract surgery, which is still the ultimate treatment for lens opacities of visual importance. Widespread issues with the surgical method may also occur, but the most common below-the-line complication specifically following cataract surgery is posterior capsule opacification (PCO), which may result in steady deterioration of visual performance necessitating Nd:YAG laser capsulotomy^{1,2}. PCO is caused by the proliferation and migration of residual lens epithelial cells onto the posterior capsule following surgery². Traditional phacoemulsification was regarded as the gold standard for cataract removal. The process consists of fragmentation of the crystalline lens by ultrasound, followed by aspiration and implantation of the intraocular lens into the capsular bag³. Despite its high effectiveness, incomplete cortical cleanup, damaged capsulotomy, and residual lens epithelial cells can lead to the development of PCO over time⁴.

The latest technology, femtosecond laser-assisted cataract surgery (FLACS), uses lasers to improve the precision and reproducibility of surgery. The femtosecond laser can perform vital surgical steps such as corneal incisions, anterior capsulotomy, and lens fragmentation with high precision^{5,6}. This leads to a more consistent capsulotomy size and improved centration of the intraocular lens⁶. PCO is a phenomenon caused by the growth and subsequent fibrotic or pearl-like transformation of residual epithelial cells into opacities that obstruct light transmission to the retina^{2,7}. Its development is influenced by multiple factors including surgical technique, intraocular lens type, patient-specific factors, and postoperative inflammation⁸. Proper interlocking of the anterior capsule with the intraocular lens optic reduces epithelial cell migration and PCO formation⁹.

The use of femtosecond laser technology can help reduce PCO rates by producing a circular and well-centered capsulotomy, ensuring uniform optic overlap^{5,9}. Additionally, laser-assisted lens fragmentation decreases ultrasound energy usage and intraocular trauma¹¹. Nevertheless, the long-term efficacy of femtosecond laser in preventing PCO remains debated. Some studies suggest that FLACS does not significantly reduce PCO incidence compared with conventional phacoemulsification^{4,12,13}. The design and material of the intraocular lens are also key determinants of

PCO development; modern square-edge IOLs provide a mechanical barrier preventing lens epithelial cell migration across the posterior capsule^{10,14,15}.

Objective: To compare the long-term incidence of posterior capsule opacification between femtosecond laser-assisted cataract surgery and conventional phacoemulsification.

METHODOLOGY

This was a hospital-based analytical cross-sectional study conducted at Swat Medical Complex Teaching Hospital from March 2021 to March 2022 including 235 patients undergoing cataract surgery^{1,4}.

Inclusion Criteria

- Patients aged ≥ 40 years diagnosed with age-related cataract and scheduled for cataract extraction with intraocular lens implantation^{7,16}.
- Patients undergoing either femtosecond laser-assisted cataract surgery or conventional phacoemulsification^{4,5}.
- Patients with clear visualization of the posterior capsule at the end of surgery^{2,3}.
- Patients willing to participate and able to attend long-term postoperative follow-up^{1,4}.

Exclusion Criteria

- Patients with previous ocular surgery or trauma¹⁴.
- Patients with pre-existing posterior capsule rupture or zonular instability¹⁵.
- Patients with advanced glaucoma, retinal disease, or corneal pathology affecting visual outcomes^{12,13}.
- Patients with systemic or ocular inflammatory conditions that could influence postoperative capsular changes^{8,11}.

Data Collection: After obtaining informed consent, demographic and clinical data were recorded using a structured proforma. All patients underwent detailed ophthalmic evaluation including visual acuity assessment, slit-lamp examination, intraocular pressure measurement, and dilated fundus examination^{9,11}. Preoperative biometric measurements including axial length, keratometry readings, and intraocular lens power calculation were obtained using optical biometry^{13,16}.

Patients were divided into two groups based on the surgical technique used: femtosecond laser-assisted cataract surgery (FLACS) group and conventional phacoemulsification group^{4,5}. In the FLACS group, key surgical steps such as corneal incision, anterior capsulotomy, and lens fragmentation were performed using a femtosecond laser system before lens removal^{4,5,10}. In the conventional group, standard manual phacoemulsification was performed using ultrasound energy^{3,4}. In both groups, intraocular lens implantation was performed within the capsular bag^{2,3}.

Patients were followed postoperatively at scheduled intervals to assess visual outcomes and the development of posterior capsule opacification^{1,2,4}. Slit-lamp examination was used to detect capsular opacification, and the need for Nd:YAG laser capsulotomy was recorded as an indicator of clinically significant PCO^{1,2,7}.

Statistical Analysis: Data were entered into Microsoft Excel and analyzed using SPSS version 26. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequency and percentage¹⁶. Comparisons between the femtosecond laser group and the conventional phacoemulsification group were performed using independent t-test for continuous variables and chi-square test for categorical variables¹⁶. The association between surgical technique and posterior capsule opacification incidence was also evaluated. A p-value <0.05 was considered statistically significant¹⁶.

RESULTS

A total of 235 patients were included with a mean age of 63.8 ± 8.7 years. Most patients were older than 65 years (89; 37.9%), followed by 56–65 years (84; 35.7%) and 40–55 years (62; 26.4%). Males accounted for 121 (51.5%) and females 114 (48.5%). Diabetes mellitus was present in 78 (33.2%) patients and hypertension in 92 (39.1%). The mean preoperative visual acuity was 0.82 ± 0.25 logMAR. Mean axial length and keratometry were 23.46 ± 0.91 mm and 43.7 ± 1.8 D respectively.

Among the patients, 118 underwent femtosecond laser surgery and 117 conventional phacoemulsification. Capsulotomy diameter was more consistent in the femtosecond group (5.01 ± 0.06 mm) compared with conventional surgery (5.19 ± 0.21 mm, p <0.001). Ultrasound energy (5.9 ± 2.3% vs 9.8 ± 3.1%) and effective phaco time (27.4 ± 7.8 vs 39.6 ± 9.5 seconds) were significantly lower in the femtosecond group (p <0.001). Complete cortical cleanup occurred in 113 (95.8%) vs 103 (88.0%) cases (p = 0.03). Intraoperative complications occurred in 4 (3.4%) and 7 (6.0%) cases respectively.

Table 1: Demographic and Baseline Clinical Characteristics of Patients (n = 235)

Variable	Category	Total (n = 235)
Age (years)	Mean ± SD	63.8 ± 8.7
Age Group	40–55 years	62 (26.4%)
	56–65 years	84 (35.7%)
	>65 years	89 (37.9%)
Gender	Male	121 (51.5%)
	Female	114 (48.5%)
Diabetes Mellitus	Yes	78 (33.2%)
	No	157 (66.8%)
Hypertension	Yes	92 (39.1%)
	No	143 (60.9%)
Preoperative Visual Acuity (logMAR)	Mean ± SD	0.82 ± 0.25
Axial Length (mm)	Mean ± SD	23.46 ± 0.91
Keratometry (D)	Mean ± SD	43.7 ± 1.8

Posterior capsule opacification developed in 14 patients (11.9%) in the femtosecond group compared with 28 (23.9%) in the conventional group (p = 0.018). The mean time to PCO detection was 19.6 ± 6.2 months in the femtosecond group and 17.4 ± 5.9 months in the conventional group (p = 0.04). Fibrotic PCO occurred in 6 (5.1%) vs 13 (11.1%) patients, while pearl-type PCO occurred in 8 (6.8%) vs 15 (12.8%) patients respectively.

Nd:YAG capsulotomy was required in 9 patients (7.6%) in the femtosecond group compared with 20 (17.1%) in the conventional group (p = 0.027). Postoperative visual acuity was slightly better in the femtosecond group (0.07 ± 0.05 logMAR) compared with 0.10 ± 0.07 in the conventional group (p = 0.002). Residual refractive error was lower (0.38 ± 0.26 D vs 0.49 ± 0.31 D, p = 0.01) and patient satisfaction scores were higher (8.9 ± 0.9 vs 8.3 ± 1.2).

Table 2: Distribution of Surgical Techniques and Intraoperative Parameters

Variable	Femtosecond Laser (n = 118)	Conventional Phaco (n = 117)	p-value
Capsulotomy Diameter (mm)	5.01 ± 0.06	5.19 ± 0.21	<0.001
Ultrasound Energy Used (%)	5.9 ± 2.3	9.8 ± 3.1	<0.001
Effective Phaco Time (seconds)	27.4 ± 7.8	39.6 ± 9.5	<0.001
Complete Cortical Cleanup	113 (95.8%)	103 (88.0%)	0.03
Intraoperative Complications	4 (3.4%)	7 (6.0%)	0.34

Table 3: Incidence of Posterior Capsule Opacification During Follow-Up

Variable	Femtosecond Laser (n = 118)	Conventional Phaco (n = 117)	p-value
Posterior Capsule Opacification	14 (11.9%)	28 (23.9%)	0.018
	104 (88.1%)	89 (76.1%)	
Time to PCO Detection (months)	19.6 ± 6.2	17.4 ± 5.9	0.04
Fibrotic Type PCO	6 (5.1%)	13 (11.1%)	0.09
Pearl Type PCO	8 (6.8%)	15 (12.8%)	0.11

Table 4: Nd:YAG Laser Capsulotomy Requirement and Postoperative Visual Outcomes

Variable	Femtosecond Laser (n = 118)	Conventional Phaco (n = 117)	p-value
Nd:YAG Capsulotomy Required	9 (7.6%)	20 (17.1%)	0.027
	109 (92.4%)	97 (82.9%)	
Postoperative Visual Acuity (logMAR)	0.07 ± 0.05	0.10 ± 0.07	0.002
Residual Refractive Error (D)	0.38 ± 0.26	0.49 ± 0.31	0.01
Patient Satisfaction Score (0–10)	8.9 ± 0.9	8.3 ± 1.2	0.003

DISCUSSION

The most prevalent long-term outcome after cataract surgery is posterior capsule opacification, which significantly affects visual outcomes. The mean age of patients in this study was 63.8 ± 8.7 years with an almost equal gender ratio, consistent with previous studies indicating that cataract surgery is primarily performed in older adults with similar gender distribution^{7,16}.

Our findings revealed that femtosecond laser surgery resulted in a more consistent capsulotomy diameter (5.01 ± 0.06 mm) compared with conventional phacoemulsification (5.19 ± 0.21 mm). Ultrasound energy (5.9 ± 2.3% vs 9.8 ± 3.1%) and effective phaco time (27.4 ± 7.8 s vs 39.6 ± 9.5 s) were also significantly lower in the FLACS group. Similar reductions in ultrasound energy and enhanced surgical accuracy have been reported in previous studies^{4,5,17}.

The postoperative rate of PCO was lower in the femtosecond group (11.9%) compared with conventional phacoemulsification (23.9%), and the mean time to PCO detection was slightly longer (19.6 ± 6.2 months vs 17.4 ± 5.9 months). This decrease in PCO incidence related to more accurate capsulotomy and improved IOL overlap has also been observed in other studies^{2,5,18}.

Morphologically, fibrotic PCO occurred in 5.1% vs 11.1% of patients, and pearl-type PCO in 6.8% vs 12.8% in the FLACS and conventional groups, respectively. Other studies have reported

similar trends of reduced epithelial cell proliferation after laser-assisted surgery^{2,18,19}. Nd:YAG capsulotomy was required in 7.6% of the FLACS group versus 17.1% of the conventional group, consistent with previous reports showing lower rates of secondary capsulotomy after femtosecond laser surgery^{1,2,20}.

Postoperative visual acuity was slightly better in the FLACS group (0.07 ± 0.05 logMAR vs 0.10 ± 0.07), residual refractive error was lower (0.38 ± 0.26 D vs 0.49 ± 0.31 D), and patient satisfaction was higher (8.9 ± 0.9 vs 8.3 ± 1.2). Similar improvements in refractive outcomes and patient satisfaction have been observed in previous studies^{5,6,21}.

Overall, the results indicate that femtosecond laser-assisted cataract surgery offers greater surgical precision and reduced long-term incidence of posterior capsule opacification compared with conventional phacoemulsification.

CONCLUSION

It is concluded that femtosecond laser-assisted cataract surgery demonstrated better surgical precision, lower ultrasound energy use, and reduced effective phaco time compared with conventional phacoemulsification. The incidence of posterior capsule opacification and the requirement for Nd:YAG capsulotomy were also lower in the femtosecond group. Additionally, slightly better postoperative visual acuity, lower residual refractive error, and higher patient satisfaction were observed, suggesting that femtosecond laser-assisted cataract surgery may provide improved long-term outcomes compared with conventional phacoemulsification.

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