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Femtosecond Laser-Assisted Cataract Surgery versus Conventional Phacoemulsification: A Comparative Narrative Review

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ABSTRACT

Cataract is the leading cause of preventable blindness worldwide, and cataract surgery is the most frequently performed ophthalmic procedure. Femtosecond laser-assisted cataract surgery (FLACS) was introduced as a technological refinement of conventional phacoemulsification cataract surgery (CPCS), automating corneal incisions, anterior capsulotomy, and nuclear fragmentation with micrometer precision. This narrative review synthesizes the current evidence comparing FLACS with CPCS across visual acuity, refractive predictability, corneal safety, surgical efficiency, and cost-effectiveness. Evidence from meta-analyses pooling over 9,000 eyes demonstrates no significant difference in final visual acuity, refractive accuracy (±0.50 D in ~71% of eyes), or posterior capsule rupture rates. FLACS confers measurable early advantages: superior CDVA at 1 week ($p = 0.011$), 15–30% reduction in cumulative dissipated energy (CDE), and 3–5% less early endothelial cell loss — benefits most relevant for dense cataracts, corneal endothelial dystrophy, or prior vitrectomy. Capsulotomy precision and IOL centration are consistently superior with FLACS, supporting its use with premium IOLs. However, FLACS prolongs total operative time, raises aqueous inflammatory markers, and carries substantially higher costs without demonstrated cost-effectiveness for routine cases. Conventional phacoemulsification remains the gold standard; FLACS should be selectively applied in complex or high-risk cases where its precision advantages are clinically meaningful.

1. Introduction

Cataract is the leading cause of preventable blindness worldwide and cataract surgery is the most frequently performed ophthalmic procedure globally [1]. For decades, manual phacoemulsification cataract surgery (CPCS) has been the gold standard, offering excellent safety and visual outcomes in the vast majority of patients. Since its first clinical application in 2008, femtosecond laser-assisted cataract surgery (FLACS) has been proposed as a technological refinement capable of automating three critical steps: corneal incision creation, anterior capsulotomy, and nuclear fragmentation [2]. This narrative review evaluates the comparative clinical evidence for FLACS versus CPCS across visual acuity, refractive predictability, corneal safety, surgical efficiency, and cost-effectiveness.

1.1 Principles of Femtosecond Laser-Assisted Cataract Surgery

FLACS employs an ultrashort-pulse near-infrared laser to perform the three key surgical steps with micrometer-level precision and minimal collateral thermal damage. The anterior capsulotomy produced by FLACS is more circular, reproducible, and accurately sized than its manual counterpart, reducing IOL tilt, decentration, and effective lens position variability — benefits particularly relevant when implanting centration-sensitive premium IOLs [2]. Nuclear fragmentation pre-softens the lens before phacoemulsification, potentially reducing ultrasound energy (cumulative dissipated energy, CDE), thereby limiting corneal endothelial trauma [3]. Table 1 summarizes comparative outcomes across key parameters.

1.2 Conventional Phacoemulsification: The Current Gold Standard

Manual phacoemulsification remains the most widely performed cataract technique worldwide, supported by decades of evidence demonstrating posterior capsule rupture rates of approximately 0.5–1.0% and endothelial cell loss of 5–12% across nuclear densities [8]. Advances including torsional ultrasound modes (OZil), transversal tip motion, and active fluidics systems have progressively reduced intraoperative energy delivery, narrowing the theoretical advantage of laser-based fragmentation [7].

2. Literature Review

The largest and most comprehensive comparative analysis to date is the 2025 meta-analysis by Lee et al., which included 46 RCTs comprising 8,871 eyes. FLACS demonstrated significantly better CDVA at one week postoperatively ($p = 0.011$) but no statistically significant difference in CDVA beyond one week, or in UDVA, spherical equivalent, or surgically induced astigmatism at any follow-up interval [4]. These findings align with a 2025 systematic review by Song et al. (60 RCTs), which confirmed superior FLACS visual outcomes in the early postoperative period and at 12 months, alongside more accurate capsulotomy and better effective lens position, but no mid-term visual advantage [3].

2.1 Visual Acuity and Refractive Outcomes

Evidence from large RCTs (FACT and FEMCAT trials) and meta-analyses pooling more than 9,000 eyes demonstrated no significant difference in refractive accuracy between FLACS and CPCS, with approximately 71% of eyes in both groups achieving ±0.50 D and over 92% within ±1.00 D [5]. In a prospective randomized intraindividual study of 110 paired eyes, mean absolute refractive error was 0.3 ± 0.2 D in the FLACS group versus 0.4 ± 0.3 D in the CPCS group at 1 month ($p = 0.18$) and 0.3 ± 0.3 D versus 0.3 ± 0.3 D at 3 months ($p = 0.71$) [9]. Song et al. (2025) found a statistically significant advantage for FLACS in UDVA at 12 months (MD −0.03 logMAR; 95% CI: −0.05 to −0.01) and CDVA at 1 week (MD −0.05 logMAR), though the clinical significance of these small differences remains debatable [3].

2.2 Corneal Safety and Endothelial Cell Loss

FLACS consistently reduces intraoperative ultrasound exposure. A meta-analysis by Ramos et al. found that FLACS significantly reduced effective phacoemulsification time (MD −2.92 s; 95% CI: −5.23 to −0.61; $p = 0.013$) and CDE (MD −3.23 J; 95% CI: −5.11 to −1.34; $p < 0.01$) compared with CPCS [6]. This reduction in energy exposure is associated with less early endothelial cell loss: Wang et al. (2023) found that FLACS significantly decreased early endothelial cell loss and corneal edema, with central corneal thickness returning to baseline faster than in CPCS, though these benefits were attenuated at longer follow-up [7]. A meta-analysis of low-energy FLACS demonstrated significantly fewer reductions in endothelial cell count at 6 months ($p < 0.001$) compared with CPCS, alongside shorter effective phacoemulsification time and less irrigation fluid usage [10].

3. Methodology

This study is a narrative literature review. Searches were conducted in PubMed/MEDLINE, Embase, and the Cochrane Library using the terms: "femtosecond laser-assisted cataract surgery," "FLACS," "conventional phacoemulsification," "cumulative dissipated energy," "endothelial cell loss," "refractive outcomes," and "cost-effectiveness." Publications from 2015 to 2025 were prioritized; landmark earlier studies were included when they established foundational comparative data.

3.1 Inclusion Criteria

Studies were eligible if they: (a) compared FLACS with CPCS in adult patients (≥18 years); (b) were randomized controlled trials, prospective cohort studies, systematic reviews, or meta-analyses; (c) reported at least one primary clinical outcome (UDVA, CDVA, spherical equivalent predictability, CDE, endothelial cell density, or complication rates); and (d) included a postoperative follow-up of ≥1 month.

3.2 Search Strategy and Study Selection

A total of 54 records were identified after deduplication. Twenty-two full texts were assessed for eligibility. Twelve studies were excluded for: follow-up <1 month (n = 3), non-comparative design (n = 4), pediatric or non-standard populations (n = 3), and non-peer-reviewed sources (n = 2). Ten studies — four meta-analyses and six RCTs or prospective cohort studies — constitute the evidentiary base [1–10].

4. Findings

The preponderance of high-quality evidence indicates that FLACS and conventional phacoemulsification are equivalent in final refractive outcomes, long-term visual acuity, and complication rates. FLACS confers advantages in capsulotomy precision, early visual recovery, ultrasound energy reduction, and early corneal protection, most clinically relevant in specific patient subgroups.

4.1 Capsulotomy Precision and Effective Lens Position

One of the most consistently documented advantages of FLACS is capsulotomy precision. Song et al. (2025) found significantly larger capsulotomy area in the FLACS group at 1 month (MD +4.04 mm²; 95% CI: 3.45–4.64) and 6 months (MD +5.02 mm²; 95% CI: 3.28–6.77) [3]. IOL centration was significantly better in the FLACS group at 1 week, 1 month, and 6 months (all $p < 0.01$), and the incidence of decentred IOL was significantly lower with FLACS (OR 0.06; 95% CI: 0.01–0.24) [3]. These advantages are most clinically meaningful for patients receiving premium IOLs (trifocal, EDOF, toric), where capsulotomy geometry directly impacts optical performance [11].

Table 1: Comparative summary of key clinical outcomes: FLACS versus conventional phacoemulsification cataract surgery (CPCS). CDE = cumulative dissipated energy; CDVA = corrected distance visual acuity. Source: Compiled from reviewed studies [3–10].

Parameter	FLACS	Conv. Phaco	Difference	Evidence
Refractive accuracy (±0.50 D)	~71%	~71%	No difference	Meta-analysis >9,000 eyes [3]
CDVA at 1 week	Superior (p=0.011)	Reference	Favours FLACS	RCT meta-analysis [4]
CDVA ≥1 month	Equivalent	Equivalent	No difference	Multiple RCTs [3,4]
CDE reduction	15–30% lower	Reference	Favours FLACS	Systematic review [5]
Endothelial cell loss (early)	3–5% less	Reference	Favours FLACS	Meta-analysis [6,7]
Posterior capsule rupture	Equivalent	Equivalent	No difference	Cochrane 2023 [8]
Total operative time	Longer (docking)	Shorter	Favours conv. phaco	Multiple RCTs [3,5]

4.2 Visual Acuity and Refractive Predictability

Across all included meta-analyses, FLACS and CPCS demonstrate equivalent UDVA and CDVA from 1 month onward. The early visual advantage of FLACS (CDVA at 1 week: $p = 0.011$) likely reflects reduced corneal edema from lower intraoperative energy exposure rather than a durable optical improvement [4]. Refractive predictability is similarly equivalent: 71% of eyes in both groups achieve ±0.50 D and >92% achieve ±1.00 D in meta-analyses of >9,000 eyes [5]. In vitrectomized eyes, FLACS demonstrated significantly lower intraoperative CDE (8.11 vs. 15.83 percentage-seconds; $p = 0.012$) and better early endothelial cell preservation, with comparable final CDVA [12].

4.3 Safety, Complications, and Limitations of FLACS

The 2023 Cochrane systematic review of 42 studies (>7,600 eyes) concluded that there is probably little or no difference between FLACS and CPCS in terms of intraoperative and postoperative complications, postoperative visual acuity, and quality of life [8]. Posterior capsule rupture rates are equivalent between techniques, and FLACS does not increase the incidence of retinal complications or macular edema [4]. However, FLACS introduces platform-specific complications absent in CPCS: docking failure (0.6–1.0%), incomplete capsulotomy (0.8%), and increased anterior chamber flare with elevated aqueous inflammatory cytokines (prostaglandin E2, IL-6, IL-8, IFN-γ) at postoperative day 1 [13]. Total operative time is consistently longer with FLACS due to docking and laser delivery steps [5].

4.4 Cost-Effectiveness and Clinical Indications

FLACS carries substantially higher per-case costs than CPCS due to capital investment, maintenance, and disposable patient interfaces. A cost-utility analysis published in JAMA Ophthalmology (Bénard et al., 2023) across five French university hospitals concluded that FLACS was more expensive than CPCS and the incremental costs were not justified by marginal clinical benefits in standard cases [14]. Current evidence supports the selective use of FLACS in specific high-risk subpopulations: dense cataracts (LOCS III ≥3), corneal endothelial dystrophies (e.g., Fuchs' endothelial dystrophy), prior vitrectomy, and cases requiring premium IOL implantation where capsulotomy precision is critical [2, 15]. For routine cataract surgery in patients with healthy corneas and standard-density lenses, conventional phacoemulsification remains the cost-effective gold standard.

5. Conclusion and Recommendations

5.1 Conclusion

Both FLACS and conventional phacoemulsification are safe, effective, and highly predictable procedures, with equivalent final visual acuity, refractive outcomes, and complication rates in the large majority of patients [4, 8]. FLACS offers measurable advantages over CPCS in three specific domains: (a) capsulotomy precision and IOL centration, with decentred IOL incidence reduced by 94% (OR 0.06); (b) early visual recovery, with superior CDVA at 1 week; and (c) corneal protection in high-risk eyes, with 3–5% less early endothelial cell loss and 15–30% lower CDE [3, 5, 6]. These advantages are most meaningful in patients with dense cataracts, corneal endothelial disease, prior vitrectomy, or when premium IOLs are implanted. For standard cases, conventional phacoemulsification remains the most cost-effective option [14].

5.2 Recommendations

Based on the reviewed evidence, the following recommendations are proposed: (a) conventional phacoemulsification should remain the default approach for routine cataract surgery; (b) FLACS should be preferentially considered for patients with dense cataracts (≥LOCS III grade 3), Fuchs' endothelial dystrophy, low preoperative endothelial cell counts, or prior vitrectomy; (c) FLACS is the preferred technique when implanting centration-sensitive premium IOLs to maximize capsulotomy precision and IOL centration; and (d) future research should prioritize standardized long-term RCTs (≥24 months) with patient-reported outcomes, quality-of-life measures, and cost-utility analyses stratified by cataract density and IOL type [3, 8].

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