Original Article

Clinical outcomes of femtosecond laser–assisted cataract surgery versus conventional phacoemulsification: A retrospective study in a tertiary eye care center in South India

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Purpose: To compare the clinical outcomes of femtosecond laser–assisted cataract surgery (FLACS) versus conventional phacoemulsification (CP) in terms of refractive outcomes, cumulative dissipated energy, and intraoperative complications. **Methods:** In this retrospective study performed in a tertiary care ophthalmic hospital, we reviewed 2124 eyes that underwent FLACS or CP. Uncorrected distance visual acuity (UDVA), corrected distance visual acuity (CDVA), cumulative dissipated energy (CDE), and intraoperative complications were analyzed in the study. **Results:** Out of 2124 eyes, 873 underwent FLACS and 1251 underwent CP. The postoperative mean UCVA after one month was 0.05 ± 0.11 logMAR and 0.14 ± 0.23 logMAR for FLACS and CP, respectively ($P < 0.00001$). Mean CDVA one month post operation was 0.02 ± 0.07 logMAR and 0.06 ± 0.19 logMAR for FLACS and CP, respectively ($P < 0.0001$). The CDE for the FLACS group was 6.17 ± 3.86 ($P < 0.00001$) and it was 9.74 ± 6.02 for the CP group. The intraoperative complication for the FLACS group was 1.60% and the CP group was 2.39% ($P < 0.00001$). **Conclusion:** The visual outcomes were better in FLACS compared to CP. The CDE was lower for the FLACS group and FLACS had significantly less intraoperative complications.

Key words: Cataract, cumulative dissipated energy, femtosecond laser, intraoperative complications, phacoemulsification, posterior capsular rent

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Cataract surgery is one of the most common procedures performed worldwide. It has evolved tremendously from its first procedure of couching to its latest technology. Femtosecond (femto) laser–assisted cataract surgery (FLACS) is an innovative technology that plays a major role in achieving an excellent outcome in the world of cataract surgery. Though it was introduced years ago, several studies have debated the advantages and necessity of such a technology.[1] Despite its high precision for several stages of cataract surgery, the associated significant financial cost causes inconvenience among patients.[2] The femtosecond laser delivers ultra-short (10^{-15} seconds) pulses of energy at near-infrared wavelengths that can be precisely focused at various depths in the anterior segment of the eye.[3] The absorption of the photon energy ionizes the tissue and generates plasma. Rapidly expanding and contracting bubbles of tissue vapor can disrupt adjacent tissue and cleave precise planes within the tissues.[4–8] Femto laser corrects the pre-existing cylinder in a patient's eye using its astigmatic correction module, thereby resulting in a better outcome compared to conventional phacoemulsification (CP). Femtosecond laser–assisted astigmatic keratotomy (FS-AK) precisely incises the corneal stroma to a given depth and length and thus helps in flattening the steepest meridian of corneal astigmatism. It is found to be efficacious in the management of low-to-moderate astigmatism (<1.5 D).[9] Indeed, it is possible to create intrastromal (IS) FS-AKs that avoid breaching the overlying epithelium and thus prevent postoperative pain and discomfort.[10,11] However in manual, limbal, relaxing incisions there are certain drawbacks like lack of reproducibility of incision length and depth, increased postoperative discomfort, infection within the incisions, corneal melt, and perforation, often leading to unpredictable results.[12,13] Intraocular lens (IOL)–power calculation errors are mostly due to inaccuracy of effective lens position (ELP) calculation.[14,15] It is seen that femtosecond laser capsulotomies are more precise, consistent, and better-centered compared to manual capsulorhexis,[2,15,16] thus causing less tilt and decrease in posterior capsule opacification (PCO).[17–20] During manual capsulorhexis in CP, an extended rhexis, decentered rhexis, or problems in sizing of the rhexis diameter may lead to decentration or tilt of the IOL and consequently result in unsatisfactory visual outcomes. Femto laser–assisted nuclear fragmentation also requires less ultrasound energy (cumulative dissipated energy or CDE) and thus reduces ocular complications like endothelial cell

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loss.[21,22] In addition, there is some evidence that recovery of visual acuity is faster with FLACS than CP.[23] Various studies have shown that intraoperative complications are less in FLACS compared to CP.[24] Some of the disadvantages of FLACS are failure to dock, globe tilt or decentration, corneal folds or suction loss, incomplete capsulotomies, laser-induced miosis, requirement of sufficient pupillary dilatation and also its limitations in white cataracts.

In this study, we tried to compare the visual outcomes, energy consumption, and intraoperative complications related to FLACS and CP procedures.

Methods

A comparative, retrospective study of FLACS versus CP was carried out in a tertiary eye care center in South India from January 2017 to December 2019. A total of 2124 eyes were included in the study, of which 873 cases underwent FLACS and 1251 cases underwent CP. All patients that underwent FLACS and phacoemulsification with an astigmatism of < 1.25 and cases where foldable aspheric hydrophobic acrylic IOL was implanted were included in the study. Data of these patients were collected from the electronic medical record and reviewed retrospectively. Both FLACS and phacoemulsification surgeries done by four experienced surgeons (experienced in both FLACS and CP) were compared in the study. Each patient underwent a complete ophthalmologic evaluation of the anterior segment and the posterior segment. Preoperative uncorrected distance visual acuity (UDVA) was assessed by a logMAR chart. The grade of the cataract was documented by the (Lens Opacities Classification System) LOCS III system. IOL master 700 was used for biometry. CDE and any intraoperative complications were recorded. Postoperative UDVA and corrected distance visual acuity (CDVA) were recorded at postoperative day 30. Eyes with pathologies like corneal scarring, keratoconus, amblyopia, glaucoma, retinal pathology, optic nerve pathology, and patients with preexisting astigmatism more than 1.25 D were excluded from the study. Premium lenses like toric IOL, multifocal IOL, and procedures other than FLACS and CP were excluded from the study.

Statistical analysis

Descriptive statistics were presented with frequency and percentage for categorical data. Mean and standard deviations (SD) were used for continuous parametric data while median and interquartile ranges (IQR) were used for non-parametric data. Parametric tests were used if the data were distributed normally, and for skewed data non- parametric tests were performed. The normality of the data was checked using the Shapiro–Wilk test. The Mann–Whitney *U* test was used to find out the significant difference between the two independent groups. A proportion test was used to find out the significant difference between the two proportions. All the statistical tests were two-sided at the 5% level and were performed using Stata 14. Statistical significance was considered at $P < 0.05$.

Surgical technique

FLACS

The FLACS procedure was performed using the LenSx Femtosecond Laser System (Alcon Inc., Fort Worth, TX) and was performed under topical anesthesia. The capsulotomy was planned for 4.9-mm diameter and lensectomy of 5-mm diameter, with a corneal primary incision of 2.2 mm and with the paracentesis of 1.0 mm and an arcuate incision with respect to preexisting astigmatism. Hard cataracts with nuclear sclerosis grades III–IV were dealt with grid pattern or chop pattern or with the hybrid (chop with cylinder) pattern. Soft cataracts with nuclear sclerosis grades I–II were planned with the chop pattern or cylinder pattern. Once the laser procedure was done, the patient was shifted to the cataract operation theater (OT). The surgeon used the LenSx Spatula (designed by Dr. Steven Slade) to open the incision by identifying the silver streak on the cornea where the incision was created. Dispersive or cohesive viscoelastic was injected into the anterior chamber and the free-floating rhexis flap was then removed using the McPherson forceps. A gentle hydrodissection was performed. Since the nucleus was already cracked by the laser, the surgeon removed the nucleus with minimal ultrasound energy with Alcon Centurion Vision System. The second hydro wave was used to loosen the cortex, and then the cortex wash was done using the coaxial or bimanual irrigation-aspiration probe. A foldable aspheric hydrophobic acrylic IOL was then implanted into the bag.

Conventional phacoemulsification

Phacoemulsification was done using the Alcon centurion system. A 0.9 mm, balanced tip phaco probe was used in the procedure. A 2.2 mm, temporal, clear, corneal incision was created with a keratome and a 1.1 mm side port was used to create a paracentesis incision at the 2 o' clock position away from the main incision. A 5.0–5.5-mm diameter continuous curvilinear capsulorhexis was performed manually using a cystitome or capsulorhexis forceps. Phacoemulsification was performed by direct chop technique with Alcon's Centurion Vision System. Then the cortex wash was done using a coaxial irrigation-aspiration probe. A foldable aspheric hydrophobic acrylic IOL was implanted in the bag.

Results

We evaluated 2124 eyes in our study, with 873 in the FLACS group and 1251 in the CP group. The mean age in the FLACS group was 55.21 ± 11.48 years and in the CP group was 55.65 ± 11.49 years. In the FLACS group out of the operated cases, 421 cases (48.22%) involved the right eye and 452 cases (51.77%) involved the left eye, and in the CP group 602 cases (48.12%) involved the right eye and 649 cases (51.88%) involved the left eye [Table 1].

Table 1: Demographic profile

Parameter	FLACS *n*=873 *n* (%)	CP *n*=1251 *n* (%)
Age		
Mean±SD	55.21±11.48	55.65±11.49
Min.-Max.	30-86	31-87
Gender		
Male	238 (27.26)	781 (62.43)
Female	635 (72.74)	470 (37.57)
Operated Eye		
Right	421 (48.22)	602 (48.12)
Left	452 (51.77)	649 (51.88)

n: Number of eyes; SD: Standard deviation; FLACS: Femtosecond laser-assisted cataract surgery; CP: Conventional phacoemulsification

Mean postoperative UDVA on day 30 was 0.05 ± 0.11 logMAR in FLACS cases and 0.14 ± 0.23 logMAR in CP cases with a *P* value of < 0.00001. Mean postoperative CDVA on day 30 was 0.02 ± 0.07 logMAR with FLACS and 0.06 ± 0.19 logMAR with CP with a *P* value of < 0.0001. The visual acuity analyzed was statistically significant for FLACS versus CP [Table 2]. In the postoperative one month, emmetropia was 93.7% for FLACS and 90.6% for CP (*P* < 0.005).

Intraoperative parameters that were unique to FLACS were analyzed. Docking is very crucial for perfect laser delivery and the outcome. Docking failure was seen in five (0.57%) cases due to deep-set eyes, small palpebral aperture, prominent nose, eye movement post docking, mismatch in contact lens, and keratometry reading of the patient which was overcome by application of custom-made contact lens. Incomplete capsulotomies were seen in seven (0.8%) cases. While docking, there were corneal folds in two cases and two cases had debris on the contact lens which led to incomplete laser delivery and incomplete capsulotomy; thus capsulotomy had to be done manually in that case. Out of the intumescent mature cataracts, in three of them during laser delivery, the laser field was obscured by the liquefied cortex, and the cases ended up in incomplete capsulotomy along with a capsular tag. This was identified using tryphan blue and the remaining 1–2 o'clock capsulotomy was done manually. Out of the hard cataracts, intraoperative capsulorhexis extension was seen in six eyes (0.68%). Around 20 cases (2.29%) had tilted and posterior incision that led to difficulty during instrumentation and also caused difficulty in opening the incision. Intraoperative miosis of pupil size less than 4 mm was seen in eight cases (0.91%) [Fig. 1]. Iris hooks were required in six patients (0.68%). Postoperative complications like mild subconjunctival hemorrhage occurred in five eyes (0.57%) after FLACS. In one patient (0.11%), there was retained Anterior Lens Capsule (ALC) flap which was missed intraoperatively, and it was managed by the removal of the flap on the second postoperative day.

Intraoperative complications were analyzed between the two groups, and it was seen that CP had a significantly higher number of complications compared to FLACS. Posterior capsular rent (PCR) was seen to be higher in the CP group (2.39%). In FLACS, out of the 715 immature cataracts, six cases (0.83%) had PCR during irrigation aspiration and in two cases (0.27%) PCR was noticed during emulsification. Among the 90 cases with nuclear sclerosis grade IV, PCR occurred in four cases (4.44%) due to a split in the anterior capsule during emulsification, and two (2.22%) of the cases had to be converted to manual small incision cataract surgery (MSICS). In one case (0.13%), zonular dialysis was noted during irrigation aspiration. In the posterior polar cataracts out of the 68 cases, PCR occurred in one case (1.25%) during the last piece emulsification. In the CP group, out of the 881 immature cataracts, PCR occurred in six cases (0.68%) during emulsification, and in one case (0.11%) PCR was noted during irrigation aspiration. Three (0.34%) immature cataracts had cortex drop during irrigation aspiration, and one case (0.11%) had a nucleus drop during phacoemulsification. In cataracts with nuclear sclerosis grade IV, out of the 85 cases, a breach in the posterior capsule was noted in four cases (4.70%) during emulsification and in one case (1.17%) during irrigation aspiration. Out of the 164 mature cataracts in the CP group, one (0.60%) ended up in PCR during posterior capsule polish. Descemet membrane detachment was seen in one case (0.07%) in the CP group. In the CP group, out of the 120 posterior polar cataracts PCR was seen in six cases (5%) during irrigation aspiration and in one case (0.83%) during emulsification of nucleus. Two cases (0.15%) had nucleus drop and cortex drop during emulsification of nucleus [Table 3].

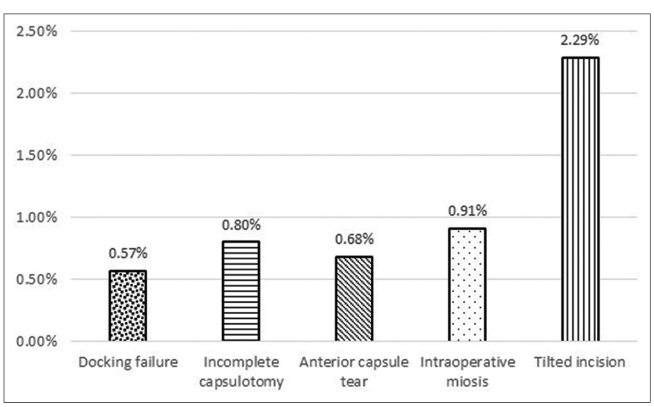

Figure 1: Intraoperative complications in FLACS during laser delivery

The mean values of CDE were analyzed. CDE for the FLACS group was lower in all cataract grades compared to the CP group. The CDE for the FLACS group was 6.17 ± 3.86 and CP group was 9.74 ± 6.02 and it was statistically significant with *P* < 0.00001 [Table 4].

Discussion

In our study, we retrospectively analyzed the surgical data of 2124 eyes that underwent FLACS or CP. Visual outcomes, CDE,

Table 2: Visual acuity

Parameter	FLACS Mean±SD	CP Mean±SD	*P*
UDVA (logMAR)			
Preoperative	0.76±0.408	0.99±0.635	<0.00001*
Postoperative 1 month	0.05±0.11	0.14±0.23	<0.00001*
CDVA (logMAR)			
Postoperative 1 month	0.02±0.07	0.06±0.19	<0.00001*

VA: Visual acuity; UDVA: Uncorrected visual acuity; CDVA: Corrected distance visual acuity; SD: Standard deviation; FLACS: Femtosecond laser-assisted cataract surgery; CP: Conventional phacoemulsification; *: Statistical significance

Table 3: Intraoperative complications

Intraoperative complication	FLACS	CP	*P*
Posterior capsular rent	13 (1.48%)	20 (1.59%)	<0.0001*
Zonular dialysis	1 (0.11%)	1 (0.07%)	
Cortex drop	0	5 (0.39%)	
Descemet membrane detachment	0	1 (0.07%)	
Nucleus drop	0	3 (0.23%)	
Total	14 (1.60%)	30 (2.39%)	

FLACS: Femtosecond laser-assisted cataract surgery; CP: Conventional phacoemulsification; *: Statistical significance

Table 4: Cumulative dissipated energy (CDE)

CDE	Mean (SD)	*P*
FLACS	6.17±3.86	<0.00001ᴹ
CP	9.74±6.02	

CDE: Cumulative dissipated energy; SD: Standard deviation; FLACS: Femtosecond laser-assisted cataract surgery; CP: Conventional phacoemulsification; M: Mann-Whitney *U* test

and intraoperative complications were analyzed in both the groups on postoperative day 30. Our study showed significant differences in visual acuity and refractive outcomes between femtosecond laser and phacoemulsification techniques for cataract surgery. In the postoperative one month, emmetropia was 93.7% for FLACS and 90.6% for CP ($P < 0.005$). The postoperative mean UCVA after one month was 0.05 ± 0.11 logMAR and 0.14 ± 0.23 logMAR for FLACS and CP, respectively ($P < 0.00001$). Postoperative mean CDVA after one month was 0.02 ± 0.07 logMAR and 0.06 ± 0.19 logMAR for FLACS and CP, respectively ($P < 0.0001$). The reason for statistical significance in CDVA could not be ascertained. However, the difference was clinically meager.

Visual outcomes of our study can be compared with the meta-analysis done by Ye *et al.*,[25] where they found that cataract refractive outcomes were significantly improved after FLACS. Few other reports have also concurred similar results in different ethnic groups,[14,26] but these findings were contradicted by a study done by Berk *et al.* and Edward *et al.*, where they found no statistical significance for FLACS versus CP for visual acuity.[15,27] Several other authors have also reported that there is no difference in refractive outcomes between FLACS and CP.[28–31]

In our study, we found that the CDE for FLACS was less compared to CP. The CDE for the CP group was 9.74 ± 6.02 and for FLACS it was 6.17 ± 3.86 ($P < 0.00001$). Several published literature articles have demonstrated that FLACS is superior to CP for reduction in mean phaco energy and effective phaco time.[31–33]

Our study found that FLACS resulted in a statistically significant decrease in intraoperative complications when compared to CP. It was seen that the PCR rate was less in FLACS compared to CP for both hard cataracts and posterior polar cataracts (PPC). PCR rate in hard cataract was 4.44% in FLACS group and it was 5.88% in the CP group. PCR in PPC was 1.47% in FLACS and 5.83% in the CP group.

In the FLACS group, PCR in hard cataracts was commonly seen during emulsification. In FLACS, a safety offset of at least 500 μm from the posterior capsule is kept which might lead to incomplete separation of the nucleus. In dense cataracts, a nuclear plate is left behind at the end of nucleus management, which poses an increased risk of posterior capsule rupture.[34] PCR in soft cataracts during FLACS occurred most often during cortical aspiration. During anterior capsulotomy—cylindrical cuts starting from below the surface of the anterior capsule and continuing through the capsule a few microns into the anterior chamber[35]—the laser not only cuts the capsule but also cuts the cortex. This creates a flush edge of the cortex fused to the capsule. Since there is no anterior lip of the cortex, the aspiration tip has to be placed up under the edge of the anterior capsule to grasp the cortex, which might explain the occurrence of PCR during cortex aspiration. A second wave of hydrodissection is helpful in such cases to loosen the adherent cortex. PCR in soft cataracts was also seen during emulsification as it is harder to separate and grip the soft nucleus.[34]

In PPC, the posterior offset can be increased above the polar opacity identified on the intraoperative optical coherence tomography (OCT) and avoid deep nucleus segmentation, as bubbles produced may rupture through the deficient posterior capsule. Abhay R. Vasavada described a technique of femto delineation for PPC. Laser energy is preset depending on the density of the nucleus. The width of the cylinders can be modified manually, and an offset of at least 500 μm from the posterior capsule is preset based on the OCT view. In case of preexisting posterior capsule defect, an offset of 700–800 μm can be preset. This helps to safeguard the potentially fragile posterior capsule from injury. Because of its sharp demarcation, the last epinuclear layer can be easily stripped using a combination of the phaco probe and bimanual irrigation-aspiration, thus eliminating the need for any type of hydro procedure in PPC. It enhances safety and reduces posterior capsule rupture rates in these cataracts.[36]

Intraoperative complications that is unique to FLACS like incomplete capsulotomy were seen in 0.8% of cases. It manifests as areas of uncut capsule, tags and bridges. Studies using high definition electron microscopy and finite element modeling based on three-dimensional atomic force microscopy have shown that laser capsulotomy integrity may be compromised by postage stamp perforations and additional aberrant pulses, which can lead to a higher incidence of anterior capsule tears.[37] Several studies conducted by Abell *et al.*, Roberts *et al.*, and Bali *et al.* found a higher rate of anterior capsule tears in the FLACS group.[37–39] However, Chang *et al.*[40] in their study found that anterior capsular tears were not due to the tags but due to the spinning nuclear fragments and contact with either the phacoemulsification probe and irrigation aspiration tip or the second instrument. Similarly, in our cases, it was seen that anterior capsular tears were not caused by the tags but occurred during the separation of chopped/fragmented nuclear pieces with a leathery posterior plate in harder cataract. Intraoperative miosis was seen in 0.91% of cases. Though anterior capsulotomy can be performed in a 5.0-mm pupil, laser application in such cases can cause pupillary miosis and iris trauma, and lenticular fragmentation may become more difficult.[41,42] Pretreatment with topical Non-steroidal anti-inflammatory drug (NSAID) eye drops may be done to decrease prostaglandin-induced miosis.[43,44] In FLACS cases, preoperatively Verion image-guided system (Alcon Inc., Fort Worth, TX) was used to measure the pupillary diameter. A pupil larger than 4.5 mm diameter was selected for FLACS. Preoperative NSAID was prescribed for two days before surgery. In patients with mid-dilated pupil, the capsulotomy size and femto laser energy were reduced. Iris hooks were required in six cases (0.68%) of intraoperative miosis.

Various studies have found FLACS to have many advantages over traditional phacoemulsification, supporting the results of our current study. Chen *et al.*,[45] while comparing the intraoperative complication rate of FLACS to traditional phacoemulsification, found that the overall complication rate for FLACS was 1.8%, whereas that of the traditional procedure was 5.8%. Choi *et al.*[46] found that there were complications during FLACS, such as subconjunctival hemorrhage, miosis, early entry corneal incision, and incomplete corneal incision. Abell *et al.*[47] studied the outcomes in more than 4000 eyes at a single center and found that the two techniques were equally safe.

Our study has certain limitations that include the relatively smaller sample size and the retrospective nature of our study. Moreover, four surgeons were included in the study which would lead to some amount of variations in the result. Though the surgeons were experienced in both FLACS and phacoemulsification surgeries, one cannot avoid the fact that each one of them will have their separate skills and techniques while performing the surgeries. We also did not compare the cost factor which can influence the patient's choice between FLACS and CP. We used the *post hoc* analysis, and it was found that our study was underpowered to find the differences in refractive outcomes between the two procedures. In future, studies with longer follow-up and equal sample sizes can throw more light on these surgical techniques.

Conclusion

Femtosecond laser–assisted cataract surgery is a viable alternative to conventional phacoemulsification. FLACS had reduced ultrasound energy, fewer intraoperative complications, and better visual outcomes as compared to CP.

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Conflicts of interest

There are no conflicts of interest.

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