Femtosecond Laser-Assisted Cataract Surgery After Corneal Refractive Surgery

Hyunmin Ahn
Yonsei University College of Medicine
Ikhyun Jun
Yonsei University College of Medicine
Kyoung Yul Seo
Yonsei University College of Medicine
Eung Kweon Kim
Saevit Eye Hospital
Tae-im Kim (TIKim@yuhs.ac)
Yonsei University College of Medicine

Research Article

Keywords: Femtosecond Laser-Assisted, Surgery, FLACS, CRS

Posted Date: September 7th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-871249/v1

Version of Record: A version of this preprint was published at Scientific Reports on March 11th, 2022. See the published version at https://doi.org/10.1038/s41598-022-08297-8.

Abstract

Cataract is the leading cause of blindness worldwide, and advanced cataract techniques such as femtosecond laser-assisted cataract surgery (FLACS) have been commercially available. Corneal refractive surgery (CRS) is one of the most popular surgeries for the correction of refractive errors. CRS changes the cornea not only anatomically but also pathophysiologically. However, there has been no clinical research analyzing the refractive and safety outcomes of FLACS after CRS. The aim of this study is to evaluate whether FLACS after CRS is more effective and safe than conventional PCS. Participants with a previous CRS history who underwent FLACS or conventional PCS were included in this study. The visual outcomes and the refractive outcomes including refractive, corneal, and ocular residual astigmatism were compared. The safety outcomes were then studied intraoperatively and postoperatively. A total of 102 patients with age-related cataract were enrolled. At 3 months postoperatively, UCVA, BCVA, and predictive error were not significantly different between the FLACS and conventional PCS groups. Reduction of refractive astigmatism was higher in FLACS. Postoperative ORA was significant lower in FLACS. Reduction of ORA was higher in FLACS. The intraoperative and postoperative complications were also not significantly different between the two groups. FLACS was found to be effective in patients with a previous history of CRS in terms of vision and refractive outcomes and was free from adverse effects. The competitive edge of FLACS in postoperative ORA, with the reduction of refractive astigmatism and ORA, may provide better visual quality than conventional PCS.

Introduction

Cataract is the leading cause of blindness worldwide,[1] and cataract surgery is one of the most commonly performed operations, with more than 30 million operations performed per year in the United States.[2] Phacoemulsification cataract surgery (PCS) became the standard method of cataract treatment.[1] Advanced cataract techniques such as multifocal intraocular lens (IOL), toric IOL, and femtosecond laser-assisted cataract surgery (FLACS) have been commercially available for over 10 years.[3–5] FLACS enables a well-centered and predetermined capsulotomy when compared to the conventional method. This machine-controlled capsulorhexis can minimize IOL tiltation,[6, 7] resulting in fewer higher-order aberrations.[8]

Corneal refractive surgery (CRS) is one of the most popular surgeries for the correction of refractive errors, especially myopia.[9] In the United states, approximately 800,000 laser in situ keratomileusis (LASIK) procedures were performed annually.

Accurate IOL calculation for cataract surgery after CRS is a major challenge.[10] CRS alters the anterior corneal curvature and anterior to posterior corneal relationships, causing difficulty in predicting the effective lens position.[11] CRS also affects corneal thickness, integrity, and irregularity.[12] Because these changes cause an unpredictable deterioration of visual quality, accurate prediction and intended outcome are important in patients with a previous history of CRS and must be confirmed.

To date, there has been no clinical research analyzing the refractive and safety outcomes of FLACS after CRS. Only a few case reports suggested the benefit of FLACS in patients with a previous history of CRS.[13, 14] The aim of this study is to evaluate whether FLACS after CRS is more effective and safe than conventional PCS.

Results

A total of 102 eyes of 102 consecutive patients with age-related cataract and a previous history of CRS were included in this study. Table 1 shows the baseline characteristics of the study population according to FLACS and conventional PCS. The baseline characteristics of FLACS and conventional PCS were not significantly different.

Table 1
Baseline Characteristics between FLACS and conventional PCS

Parameter	**FLACS (n = 51)**	**Convention (n = 51)**	**P-value**
Age, Mean ± SD	61.58 ± 9.00	62.58 ± 10.21	0.601
Sex (M/F), n	25/26	23/28	0.692
Laterality (R/L), n	29/22	27/24	0.691
Corneal refractive surgery, n (%)			0.376
PRK	10 (19.6)	5 (9.8)	-
LASIK	34 (66.7)	38 (74.5)	-
LASEK	7 (13.7)	8 (15.7)	-
Period between cataract surgery and corneal refractive surgery (years)	16.11 ± 6.80	14.76 ± 5.11	0.260
UCVA (Decimal), Mean ± SD	0.26 ± 0.19	0.24 ± 0.20	0.606
BCVA (Decimal), Mean ± SD	0.45 ± 0.30	0.43 ± 0.25	0.715
Preoperative spherical equivalent (D), Mean ± SD	-5.85 ± 4.39	-5.53 ± 3.38	0.681
Preoperative refractive astigmatism (D), Mean ± SD	1.12 ± 0.56	1.10 ± 0.79	0.883
≤ 0.50 D, n (%)	10 (19.6)	9 (17.6)	0.799
≤ 1.00 D, n (%)	25 (49.0)	27 (52.9)	0.692
Preoperative corneal power (D), Mean ± SD	39.15 ± 2.07	39.29 ± 2.27	0.746
Preoperative corneal astigmatism (D), Mean ± SD	0.79 ± 0.53	0.84 ± 0.49	0.622
≤ 0.50 D, n (%)	21 (41.2)	20 (39.2)	0.540
≤ 1.00 D, n (%)	43 (84.3)	39 (72.5)	0.318
Preoperative ocular residual astigmatism (D), Mean ± SD	1.29 ± 0.77	1.20 ± 0.88	0.584

BCVA, best corrected visual acuity; D, diopter; FLACS, femtosecond laser assisted cataract surgery; PCS, phacoemulsification cataract surgery; SD, standard deviation; UCVA, uncorrected visual acuity

Parameter	FLACS (n = 51)	Convention (n = 51)	P-value
Axial length (mm), Mean ± SD	27.23 ± 2.51	27.19 ± 2.34	0.934
Anterior chamber depth (mm), Mean ± SD	3.60 ± 0.41	3.65 ± 0.36	0.514
BCVA, best corrected visual acuity; D, diopter; FLACS, femtosecond laser assisted cataract surgery; PCS, phacoemulsification cataract surgery; SD, standard deviation; UCVA, uncorrected visual acuity			

Table 2 shows the 3-month postoperative outcomes with indices of the Alpins method. There were no significant differences between FLACS and conventional PCS in terms of UCVA, BCVA and predictive error ($p = 1.000$, 1.000 and 0.796, respectively). The proportions of preoperative and postoperative refractive astigmatism ≤ 0.50 D were changed from 20–49% in FLACS and 18–49% in conventional PCS, and the changes in proportion were not significantly different between the two groups ($p = 0.787$). In the Alpins method, none of the indices were different between the two groups after adjustment for TIA. Postoperative ORA was 0.20 D [95% CI: 0.05–0.35] lower in FLACS than in conventional PCS ($p = 0.018$).

Table 2
Postoperative results at 3 months between FLACS and conventional PCS

Parameter	FLACS (n = 51)	Convention (n = 51)	P-value
UCVA (Decimal), Mean ± SD	0.73 ± 0.28	0.73 ± 0.27	1.000
BCVA (Decimal), Mean ± SD	0.96 ± 0.07	0.96 ± 0.08	1.000
Postoperative spherical equivalent (D), Mean ± SD	-1.12 ± 1.25	-1.14 ± 1.21	0.935
Prediction error (D), Mean ± SD	-0.30 ± 0.86	-0.25 ± 1.08	0.796
Postoperative refractive astigmatism (D), Mean ± SD	0.73 ± 0.60	0.76 ± 0.59	0.800
≤ 0.50 D, n (%)	25 (49.0)	25 (49.0)	1.000
≤ 1.00 D, n (%)	42 (82.4)	41 (80.4)	0.799
Postoperative corneal power (D), Mean ± SD	39.60 ± 2.01	39.23 ± 2.20	0.377
Postoperative corneal astigmatism (D), Mean ± SD	0.86 ± 0.46	0.89 ± 0.51	0.756
≤ 0.50 D, n (%)	18 (35.3)	19 (37.3)	0.837
≤ 1.00 D, n (%)	42 (82.4)	43 (84.3)	0.790
Alpins method*			
Target induced astigmatism	0.86 ± 0.46	0.89 ± 0.51	0.756
Surgically induced astigmatism	0.50 ± 0.31	0.53 ± 0.40	0.673
Difference vector	0.89 ± 0.50	0.87 ± 0.51	0.842
Magnitude of error	0.32 ± 0.56	0.29 ± 0.57	0.789
Angle of error	0.2 ± 33.5	-0.7 ± 32.9	0.891
Absolute angle of error	26.0 ± 18.5	27.6 ± 20.5	0.680
Correction index	0.88 ± 1.01	0.82 ± 0.94	0.757
Index of success	1.28 ± 1.03	1.16 ± 0.98	0.548
Postoperative ocular residual astigmatism (D), Mean ± SD	0.63 ± 0.38	0.83 ± 0.46	0.018†

BCVA, best corrected visual acuity; D, diopter; FLACS, femtosecond laser assisted cataract surgery; PCS, phacoemulsification cataract surgery; SD, standard deviation; UCVA, uncorrected visual acuity

* Adjustment for TIA

† P < 0.05

Figure 1 shows the changes in preoperative and postoperative refractive astigmatism and ORA. In both FLACS and conventional PCS, postoperative refractive astigmatism was significantly reduced from 1.12 ± 0.56 to 0.86 ± 0.46 ($p = 0.010$) and 1.10 ± 0.79 to 0.76 ± 0.59 ($p = 0.018$), respectively. The reduction of refractive astigmatism was significantly higher in FLACS than in conventional PCS ($p = 0.036$). Postoperative ORA was significantly lower in FLACS than in conventional PCS ($p = 0.018$). The reduction of ORA was significantly higher in FLACS than in conventional PCS ($p = 0.012$).

Table 3 shows the intraoperative and postoperative complications according to the groups; no significant differences were observed between the groups ($p = 0.872$ and 0.858, respectively).

Table 3
Intraoperative and postoperative complications of FLACS and conventional PCS

The complications, n (%)	FLACS (n = 51)	Conventional (n = 51)
≥ 1 intraoperative complications*	5 (9.8)	4 (5.9)
Intraoperative flap complications	0 (0)	0 (0)
Anterior capsule tear	0 (0)	0 (0)
Posterior capsule tear	0 (0)	1 (2.0)
Zonular dialysis	2 (3.9)	2 (2.0)
Intraoperative pupil constriction	2 (3.9)	1 (2.0)
Dropped lens fragments	0 (0)	0 (0)
Suprachoroidal hemorrhage	0 (0)	0 (0)
Incomplete capsulotomy / capsulorrhexis	2 (5.9)	0 (0)
≥ 1 postoperative complications†	7 (13.7)	9 (21.6)
Postoperative anterior uveitis	0 (0)	0 (0)
Posterior capsular opacity	5 (9.8)	6 (11.8)
Endophthalmitis	0 (0)	0 (0)
Macular edema	1 (2.0)	3 (5.9)
Retinal tear or detachment	1 (2.0)	1 (2.0)
Increased intraocular pressure	0 (0)	1 (2.0)
Vitreous prolapse	0 (0)	0 (0)

FLACS, femtosecond laser assisted cataract surgery; PCS, phacoemulsification cataract surgery

* $P = 0.727$

† $P = 0.586$

Discussion

The results of this study suggest that FLACS for patients with a previous history of CRS was more effective and safe than conventional PCS in terms of vision, refractive outcomes, and safety outcomes at 3 months' follow-up. Postoperative ORA was significantly lower and the reduction of refractive astigmatism and ORA was significantly higher in FLACS than in conventional PCS.

Because the target IOL (D) had been set not only for far vision or emmetropia but also for near vision, uncorrected visual acuity (UCVA), BCVA, and prediction error were analyzed. UCVA, BCVA, and prediction error were not significantly different between FLACS and conventional PCS. The Barrett True-K formula is one of the most accurate IOL calculation formulas for patients with a previous history of CRS,[17] and the prediction error of Barrett True-K formula was − 0.24, which was similar to those of our study (-0.30 in FLACS and − 0.25 in conventional PCS).

Postoperative ORA was lower, and reduction of refractive astigmatism and ORA were significantly higher in FLACS than in conventional PCS. A multicenter, randomized study showed that FLACS had no advantage in corneal astigmatism, as in our study,[18] but it did not analyze the effect of FLACS on refractive astigmatism and ORA. ORA is composed of posterior corneal astigmatism, lens astigmatism, and retinal astigmatism.[19] The preoperative and postoperative posterior corneal astigmatism was not significantly different in our study (0.80 ± 0.40 and 0.88 ± 0.45 in FLACS; 0.84 ± 0.49 and 0.88 ± 0.51 in conventional PCS; $p = 0.653$ and 1.000, respectively). In a previous report, ORA, which also included a part of retinal astigmatism, was found to be inversely correlated with axial length and positively correlated with SE and corneal astigmatism.[20] In our study, axial length, SE, and both anterior and posterior corneal astigmatism, were not significantly different between the two groups. Therefore, the difference in ORA between the two groups may be explained by lens astigmatism due to lens tilt and decentration caused by the different capsulotomy methods between FLACS and conventional PCS.[6, 7] Previous studies have reported that horizontal and vertical IOL tilt and decentration were significantly higher in manual capsulotomy and that the results showed a correlation with changes in refraction values between 1 month and 1 year after surgery. IOL tilt and decentration influence visual acuity, dysphotopsia, and coma-like aberrations.[21–24] Moreover, CRS also induced aberrations in a previous study[25]: the root-mean-square wavefront error increased 1.9-fold in a 6.5 mm pupil and significantly in a 3.0 mm pupil, and positive spherical aberration was increased 4-fold after myopic LASIK. Oblate corneas that underwent myopic correction benefited from aspheric IOLs with negative spherical aberration which compensates the positive corneal spherical aberration,[26] and aspheric IOLs are shown to produce more optical quality degradation if tilted or decentered.[27] Considering the visual impacts of capsulotomy method and CRS, femtosecond laser may provide a higher quality of vision and have a greater impact on patients after CRS.

Trauma vulnerability is a concern in patients with a history of CRS.[28, 29] The physical and thermal energy in the process of FLACS could damage the previous CRS-operated tissue.[30–32] However, the complication rates between FLACS and conventional PCS for patients with a history of CRS were not different intraoperatively and postoperatively in our study. The overall intraoperative and postoperative complication rates were 2.8% and 12.5% in FLACS in a previous study,[5] which was similar to that of our study. Specifically, posterior capsule tear rates were 0% for FLACS, as in the previous UK reports.[5, 33] An intraoperative pupil contracture of 3.9% and incomplete laser capsulotomy of 5.9% were the challenges of FLACS.[5, 34, 35] In the UK reports, 9.7% of the FLACS group and 8.2% of the PCS group experienced postoperative anterior uveitis.[5] In this study, only 1 out of 204 participants developed postoperative anterior uveitis. The intense anti-inflammatory treatment for a month in our hospital may decrease the complication.

There are certain limitations in our study. First, the results of this study did not involve the patients' subjective symptoms. In a Chinese report, FLACS resulted in dry eye at postoperative day 1, week 1, and month 1.[36] However, in the UK reports, the health-related quality of life and vision questionnaires did not show a significant difference between FLACS and conventional PCS.[5, 37] After CRS, there was a possibility of visual disturbance and other subjective dissatisfaction,[38] and the additional laser treatment could affect the subjective outcomes. Second, our study showed that FLACS had an advantage on ORA and that refractive astigmatism in FLACS was lower than that in conventional PCS. The influence of IOL-induced astigmatism on ORA and aberration was estimated and not directly measured, although posterior corneal astigmatism and the factors affecting retinal astigmatism were well-controlled and showed no differences. Further assessment of the patients’ subjective outcomes and analyses for ORA and aberration are required to investigate the effectiveness of FLACS after CRS.

In conclusion, at 3 months’ follow-up, FLACS was effective in terms of vision and refractive outcomes and was free from adverse effects. The competitive edge of FLACS in postoperative ORA, with reduction of refractive astigmatism and ORA, may provide better visual quality than conventional PCS. Considering the results and other previously known advantages, FLACS is effective and safe in patients with a previous history of CRS.

Methods

The Severance Hospital Clinical Research Ethics Committee approved the study protocol (YUHS-SH-IRB-4-2021-0774). The study was conducted in accordance with the tenets of the Declaration of Helsinki, and informed consent was obtained from the subjects after explanation of the nature and possible consequences of the study.

Study Design and Patients

This retrospective comparative study was performed at the Severance Hospital, Yonsei University College of Medicine, between June 2018 and December 2020. The participants had the history of the CRS (LASIK, laser epithelial keratomileusis (LASEK), and photorefractive keratectomy (PRK)) and classified into two groups of 51 patients each: FLACS and conventional PCS. The participants in the conventional PCS group were selected by the computerized random sorting using Python version 3.8.

Procedures

All participants underwent a detailed preoperative ophthalmological evaluation, including slit-lamp and fundus examinations. IOL power calculation was performed using optical biometry (IOLMaster 700, Carl Zeiss Meditec AG). Corneal measurement was based on Scheimpflug tomography (Pentacam, Oculus

Inc.) simulated K performed within 2 weeks before the surgery. All participants underwent FLACS or conventional PCS with the femtosecond system (LenSx, Alcon Laboratories, Inc.) under topical anesthesia.

The surgical procedures of FLACS and conventional PCS after the femtosecond laser procedure were similar. The clear corneal incision on the temporal side was created using a 2.65–2.80 mm keratome, and the anterior capsule button was removed. In the conventional PCS group, capsulotomy was performed using a capsulotomy needle or forceps. Phacoemulsification was performed using the Centurion vision system (Alcon Laboratories, Inc.). All operations were performed by experienced surgeons (I.J., K.Y.S., and T.I.K). Postoperative care, including empirical antibiotics and anti-inflammatory medications, was administered as per standard unit practice for cataract surgery for a month.

Outcomes

The primary outcomes were best corrected visual acuity (BCVA, decimal scaled), and the refractive outcomes were postoperative spherical equivalent (SE), prediction error, refractive astigmatism, corneal power, corneal astigmatism with vector analysis by the Alpins method in the ACRS website, and ocular residual astigmatism (ORA) at the 3-month follow-up.[15] Prediction error was calculated as the difference of target IOL [diopters (D)] using the Barrett True-K formula and postoperative SE. The vector analysis includes eight indices: target-induced astigmatism vector (TIA), defined as the astigmatic change that the surgery was intended to induce or preoperative astigmatism; surgically induced astigmatism vector (SIA), defined as the astigmatic change that the surgery actually induced; and difference vector (DV), defined as the induced astigmatic change that would enable the initial surgery to achieve its intended target or postoperative astigmatism, magnitude of error (SIA minus TIA), angle of error (AE, angle between TIA vector and SIA vector), absolute value of AE, correction index (SIA divided by TIA), and index of success (DV divided by TIA). ORA was calculated using refractive astigmatism and corneal anterior astigmatism values. The secondary outcomes were the safety outcomes of intra- and postoperative complications.[5]

Statistical Analysis

The study was framed as a comparative design focusing on BCVA, predictive error, refractive outcomes, and safety outcomes. Because TIA is known to affect SIA and other indices of the Alpins method,[16] a comparative analyses was performed using the Alpins method with the adjustment of TIA. Comparisons of preoperative and postoperative values in each group were analyzed using the paired t-test. Comparative analyses for change of continuous and categorical values between the two groups were analyzed using the repeated measures ANOVA and generalized linear model with logistic regression. A P-value of <0.05 was considered statistically significant, and 95% confidence interval (CI) was calculated.

Declarations

Author contributions

H.A. conception or design of the work, data collection, data analysis and interpretation, writing the manuscript; I.J., K.Y.S., E.K.K. critically revised the manuscript ;T.K. conception or design of the work, data analysis and interpretation, critical revision of the article. All authors have approved the final version of to be published. All persons designated as authors qualify for authorship.

Conflict of Interest

No conflicting relationship exists for any author.

Financial Support

None

References

1. Bourne, R. R. *et al.* Causes of vision loss worldwide, 1990–2010: a systematic analysis. *The lancet global health*, **1** (6), e339–e349 (2013).
2. Centers for Medicare & Medicaid Services. CY 2019 Top 200 Level II HCPCS Codes Ranked by Charges (PDF). Accessed May 3, 2021. https://www.cms.gov/files/document/cy-2019-top-200-level-ii-hcpcs-codes-ranked-charges.pdf
3. Khandelwal, S. S., Jun, J. J., Mak, S., Booth, M. S. & Shekelle, P. G. Effectiveness of multifocal and monofocal intraocular lenses for cataract surgery and lens replacement: a systematic review and meta-analysis. *Graefe's Archive for Clinical and Experimental Ophthalmology*, **257** (5), 863–875 (2019).
4. Kessel, L. *et al.* Toric intraocular lenses in the correction of astigmatism during cataract surgery: a systematic review and meta-analysis., **123** (2), 275–286 (2016).
5. Day, A. C. *et al.* Femtosecond laser-assisted cataract surgery versus phacoemulsification cataract surgery (FACT): a randomized noninferiority trial., **127** (8), 1012–1019 (2020).
6. Nagy, Z. Z. *et al.* Comparison of intraocular lens decentration parameters after femtosecond and manual capsulotomies. *Journal of refractive surgery*, **27** (8), 564–569 (2011).
7. Kránitz, K. *et al.* Intraocular lens tilt and decentration measured by Scheimpflug camera following manual or femtosecond laser–created continuous circular capsulotomy. *Journal of Refractive Surgery*, **28** (4), 259–263 (2012).
8. Miháltz, K. *et al.* Internal aberrations and optical quality after femtosecond laser anterior capsulotomy in cataract surgery. *Journal of Refractive Surgery*, **27** (10), 711–716 (2011).
9. Jabbour, S. & Bower, K. S. Refractive Surgery in the US in 2021. *JAMA*, **326** (1), 77–78 (2021).
10. Savini, G. & Hoffer, K. J. Intraocular lens power calculation in eyes with previous corneal refractive surgery. *Eye and Vision*, **5** (1), 1–10 (2018).
11. Gimbel, H., Sun, R. & Kaye, G. B. Refractive error in cataract surgery after previous refractive surgery. *Journal of Cataract & Refractive Surgery*, **26** (1), 142–144 (2000).

12. Pinheiro, M. N. Jr *et al.* Corneal integrity after refractive surgery: effects of radial keratotomy and mini-radial keratotomy., **102** (2), 297–301 (1995).
13. Huang, P-W., Huang, W-H., Tai, Y-C. & Sun, C-C. Femtosecond laser-assisted cataract surgery in a patient with traumatic cataract and corneal opacity after LASIK: a case report. *BMC ophthalmology*, **20** (1), 1–4 (2020).
14. Wang, W. *et al.* Femtosecond laser-assisted cataract surgery with implantation of a diffractive trifocal intraocular lens after laser in situ keratomileusis: a case report. *BMC ophthalmology*, **18** (1), 1–5 (2018).
15. Reinstein, D. Z., Archer, T. J. & Randleman, J. B. *JRS standard for reporting astigmatism outcomes of refractive surgery* (SLACK Incorporated Thorofare, NJ, 2014).
16. Chan, T. C. *et al.* Vector analysis of corneal astigmatism after combined femtosecond-assisted phacoemulsification and arcuate keratotomy. *American journal of ophthalmology*, **160** (2), 250–255 e2. (2015).
17. Yeo, T. K., Heng, W. J., Pek, D., Wong, J. & Fam, H. B. Accuracy of intraocular lens formulas using total keratometry in eyes with previous myopic laser refractive surgery. *Eye*, **35** (6), 1705–1711 (2021).
18. Schweitzer, C. *et al.* Femtosecond laser-assisted versus phacoemulsification cataract surgery (FEMCAT): a multicentre participant-masked randomised superiority and cost-effectiveness trial. *The Lancet*, **395** (10219), 212–224 (2020).
19. Alpins, N., Ong, J. K. & Stamatelatos, G. New method of quantifying corneal topographic astigmatism that corresponds with manifest refractive cylinder. *Journal of Cataract & Refractive Surgery*, **38** (11), 1978–1988 (2012).
20. Liu, Y. *et al.* Evaluating internal and ocular residual astigmatism in Chinese myopic children. *Japanese journal of ophthalmology*, **61** (6), 494–504 (2017).
21. Madrid-Costa, D. *et al.* Visual simulation through different intraocular lenses using adaptive optics: effect of tilt and decentration. *Journal of Cataract & Refractive Surgery*, **38** (6), 947–958 (2012).
22. Hayashi, K., Yoshida, M. & Hayashi, H. All-distance visual acuity and contrast visual acuity in eyes with a refractive multifocal intraocular lens with minimal added power., **116** (3), 401–408 (2009).
23. Tester, R., Pace, N. L., Samore, M. & Olson, R. J. Dysphotopsia in phakic and pseudophakic patients: incidence and relation to intraocular lens type. *Journal of Cataract & Refractive Surgery*, **26** (6), 810–816 (2000).
24. Taketani, F., Matuura, T., Yukawa, E. & Hara, Y. Influence of intraocular lens tilt and decentration on wavefront aberrations. *Journal of Cataract & Refractive Surgery*, **30** (10), 2158–2162 (2004).
25. Moreno-Barriuso, E. *et al.* Ocular aberrations before and after myopic corneal refractive surgery: LASIK-induced changes measured with laser ray tracing. *Investig. Ophthalmol. Vis. Sci*, **42** (6), 1396–1403 (2001).
26. Kohnen, T., Mahmoud, K. & Bühren, J. Comparison of corneal higher-order aberrations induced by myopic and hyperopic LASIK., **112** (10), 1692 e1-1692. e11. (2005).

27. Lawu, T., Mukai, K., Matsushima, H. & Senoo, T. Effects of decentration and tilt on the optical performance of 6 aspheric intraocular lens designs in a model eye. *Journal of Cataract & Refractive Surgery*, **45** (5), 662–668 (2019).
28. Jabbur, N. S., Sakatani, K. & O'Brien, T. P. Survey of complications and recommendations for management in dissatisfied patients seeking a consultation after refractive surgery. *Journal of Cataract & Refractive Surgery*, **30** (9), 1867–1874 (2004).
29. Dudenhoefer, E. J., Vinger, P. F. & Azar, D. T. Trauma after refractive surgery. *International ophthalmology clinics*, **42** (3), 33–45 (2002).
30. De Medeiros, F. W. *et al.* Effect of femtosecond laser energy level on corneal stromal cell death and inflammation. *Journal of Refractive Surgery*, **25** (10), 869–874 (2009).
31. Shimmura, S. *et al.* Excimer laser-induced hydroxyl radical formation and keratocyte death in vitro. *Investigative ophthalmology & visual science*, **40** (6), 1245–1249 (1999).
32. Maatz, G. *et al.* Chemical and physical side effects at application of ultrashort laser pulses for intrastromal refractive surgery. *Journal of Optics A: Pure and Applied Optics*, **2** (1), 59 (2000).
33. Roberts, H. W. *et al.* A randomized controlled trial comparing femtosecond laser–assisted cataract surgery versus conventional phacoemulsification surgery. *Journal of Cataract & Refractive Surgery*, **45** (1), 11–20 (2019).
34. Abell, R. G. *et al.* Femtosecond laser–assisted cataract surgery versus standard phacoemulsification cataract surgery: outcomes and safety in more than 4000 cases at a single center. *Journal of Cataract & Refractive Surgery*, **41** (1), 47–52 (2015).
35. Diakonis, V. F. *et al.* Effects of femtosecond laser-assisted cataract pretreatment on pupil diameter: a comparison between three laser platforms. *Journal of Refractive Surgery*, **32** (2), 84–88 (2016).
36. Yu, Y. *et al.* Evaluation of dry eye after femtosecond laser–assisted cataract surgery. *Journal of Cataract & Refractive Surgery*, **41** (12), 2614–2623 (2015).
37. Lundström, M. *et al.* Risk factors for refractive error after cataract surgery: analysis of 282 811 cataract extractions reported to the European Registry of Quality Outcomes for cataract and refractive surgery. *Journal of Cataract & Refractive Surgery*, **44** (4), 447–452 (2018).
38. Fan-Paul, N. I., Li, J., Miller, J. S. & Florakis, G. J. Night vision disturbances after corneal refractive surgery. *Survey of ophthalmology*, **47** (6), 533–546 (2002).

Figures

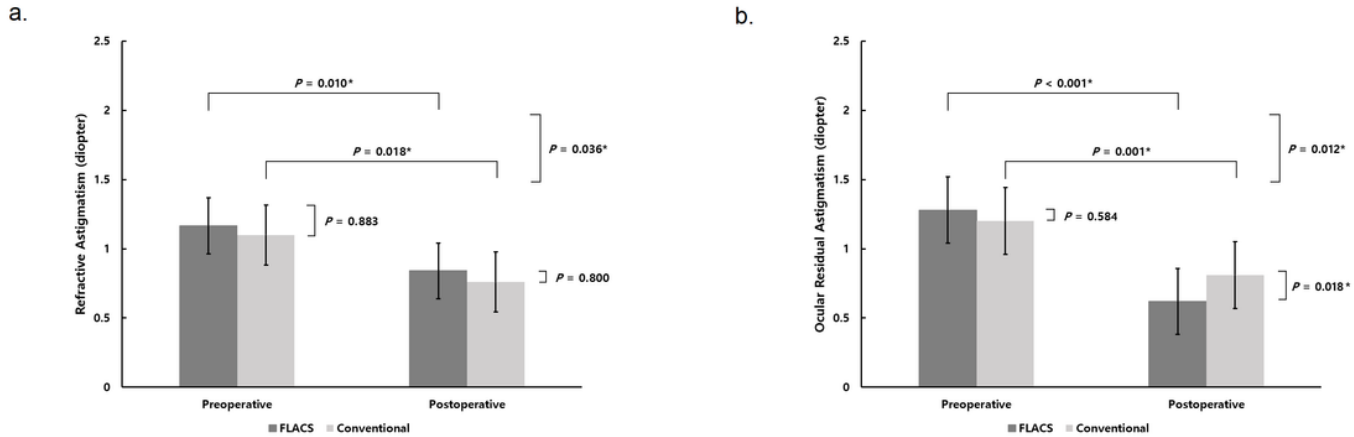

Figure 1

Preoperative and postoperative refractive astigmatism (1-a) and ocular residual astigmatism (1-b) in FLACS and conventional phacoemulsification cataract surgery. FLACS, Femtosecond laser-assisted cataract surgery. * P<0.05