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Meta-analysis

Safety of femtosecond laser-assisted cataract surgery versus conventional phacoemulsification for cataract: A meta-analysis and systematic review

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ABSTRACT

Purpose: To compare the complications of femtosecond laser-assisted cataract surgery (FLACS) with those of conventional phacoemulsification surgery (CPS) for age-related cataracts.
Methods: PubMed, Cochrane Library, and EMBASE were systematically searched for studies comparing FLACS and CPS. Outcomes were operative complications, including the intraoperative capsule tear, postoperative corneal edema, macular edema, uncontrolled IOP, etc. The effect measures were weighted with odds ratios with 95% CIs.
Results: Nineteen RCTs and 18 cohort studies, including 24,806 eyes (11,375 of the FLACS group and 13,431 of the CPS group), were identified. There were no significant differences between the two groups in anterior capsule tear, corneal edema, macular edema, uncontrolled IOP, vitreous loss, posterior vitreous detachment, etc. Posterior capsule tear rate showed a significantly lower in RCT subgroups ($P = 0.04$) and without differences in total ($P = 0.63$). Significant differences were observed in the incidence of descemet membrane tear/trauma ($P = 0.02$) and IFIS/iris trauma ($P = 0.04$. Additionally, The FLACS specific complications showed a significantly higher rate of miosis ($P < 0.0001$), corneal epithelial defect ($P = 0.001$), corneal haze ($P = 0.002$), and subconjunctival hemorrhage ($P = 0.01$).
Conclusions: FLACS maintains the same safety compared with CPS in terms of all intraoperative and postoperative complications. Although FLACS did show a statistically significant difference for several FLACS specific complications, it would not influence the visual outcome and heal itself.

1. Introduction

Cataract is the second leading cause of visual impairment and the first of blindness globally[1-,2] The prevalence of cataracts is around 47.8% among people who are over 50 years of age and cause more than 40% of blindness cases.[3–5] Currently, surgery is the most direct and effective treatment for cataracts. With the increased lifespan and elevated living standards, people pay more attention to visual outcomes. These demands promote cataract surgery from blindness prevention to refractive surgery.

With decades of exploration, phacoemulsification is considered the most successful surgical procedure for cataracts worldwide, performed with more excellent safety and shorter time than extracapsular cataract extraction (ECCE.).[6–9] Conventional phacoemulsification surgery (CPS) involves the creation of corneal incisions with a keratome blade, a continuous curvilinear capsulorrhexis using forceps, and manual splitting of the nucleus. In recent years, femtosecond laser (FSL) was approved by FDA in 2010 and introduced to replace these steps to gain better accuracy, safety, and refractive outcomes for cataract surgery.[10] Studies show that the femtosecond laser-assisted cataract surgery (FLACS) could create a high-quality capsulorhexis and get a better stabilizing of intraocular lens (IOL), thus gaining a better visual outcome.[11–13] The nuclear fragmentation with FSL could significantly reduce the phacoemulsification time and effective phacoemulsification time (EPT), thereby diminishing the corneal endothelial injury.

Although numerous benefits of FLACS have been reported, the safety of FLACS was still under dispute. Some studies found that FLACS might increase the risk of radial anterior capsular tears or posterior capsular tears, leading to a movement of IOL and a poor visual outcome.[4,14,15] However, no significant differences for capsule tear between the FLACS and CPS have also been reported.[16–18] Currently, nine meta-analyses have been conducted and focus on the efficiency and safety of FLACS and with disputation, especially the aspect of surgical safety. Additionally, lots of potential surgical complications were not included and discussed, and even several errors exist in some of the previous

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meta-analyses. Recently, several randomized controlled trials (RCTs) and clinical cohort studies have arisen, which would provide more information and evidence for surgical safety. Among them, most cohort studies only do not comply with random allocation when compared with RCTs, thus also with a high evidence level. In this study, we focus on the complications, review FLACS verse CPS from the incidence of various complications and assess the safety of the two techniques in a meta-analysis approach. Moreover, randomized controlled trials (RCTs) and high-quality clinical cohort studies were included in this meta-analysis to address a small sample size and provide more reliable and convincing evidence.

2. Methods

2.1. Search databases and strategy

Related English or Chinese publications until December 2021 were obtained from PubMed, EMBASE, and the Cochrane Controlled Trials Register. The publication list was built via searching with the following terms: femtosecond OR Femtolaser AND cataract. Reference lists of relevant reviews were also carefully scanned.

2.2. Inclusion and exclusion criteria

Studies included in this study should meet the following criteria: (1) randomized controlled trials, or prospective cohort studies; (2) comparative studies with FLACS versus CPS; (3) participants in the trials were diagnosed with cataracts without other eye disorders (e.g., amblyopia, glaucoma, diabetic retinopathy, or macular degeneration); (4) at least one of complications was reported. Abstracts, theses, case reports, opinion articles, correspondence articles were excluded.

2.3. Screening process

Two independent authors (JJ.X and HL.W) reviewed studies first by the titles and abstracts and then by full articles. Uncertainty articles were through careful discussion and affirmed by a third author (XY.C) finally. All studies that met our predefined criteria were included.

2.4. Data extraction and quality assessment

Three authors (JJ.X, HL.W, and XY.C) independently extracted relevant data from studies carefully. All data were collected into a standard form, including the authors, publication year, the type of study, sample size, complications, etc. All disagreements were resolved by discussion.

Cochrane Collaboration's tool for risk of bias was applied to evaluate the quality of included RCTs by two independent authors, which had random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting, and other biases.[66]

Newcastle-Ottawa Scale (NOS) was applied to assess the quality of cohort studies.[67,68] The NOS is an 8-stars scale based on patient selection (four stars), comparability (one star), and outcomes (three stars).

2.5. Statistical analysis

All statistical analyses were analyzed using RevMan software (version 5.4; Cochrane Collaboration, Oxford, United Kingdom). The odds ratio (OR) with a 95% CI was used to compare the complications (dichotomous variables) between FLACS and CPS. $P < 0.05$ was considered statistically significant for an overall effect. The chi-square and I^2 assessed statistical heterogeneity. $I^2 < 50\%$ was considered no significant evidence of heterogeneity, fixed-effects models were used to evaluate the differences between the two groups. Otherwise, the random-effects meta-analysis was applied. The sensitivity analysis was performed by omitting one study per time and assessing the alter of the results.

3. Results

3.1. Literature search

Fig. 1 shows a total of 3281 articles were initially identified. After removing duplications, the titles and abstracts of 1671 potential studies were reviewed, and 1139 articles were excluded. One hundred forty-five studies were eligible further identified with full texts. Nine of them were excluded because the data were not relevant to our outcomes of interest, and 3 of them were excluded because it was without effective data. Finally, 37 articles[19–57] were selected for this meta-analysis.

3.2. Characteristics of included studies

Nineteen random clinical trials (RCTs) and 18 prospective cohort studies were included in our meta-analysis. The overall characteristics of these studies are shown in Table 1. The quality assessment of RCTs was conducted by Revman and shown in S2 Figure. And the Newcastle-Ottawa Scale (NOS) was used to assess the quality of cohort studies (S3 Table). Overall, 24,806 eyes (11,375 of the FLACS group and 13,431 of the CPS group) were included. The duration of follow-up ranged from one week to twelve months.

4. Capsule related complications

4.1. a. Anterior capsule tear

Fifteen studies,[14,21,23,28,30–32,34,35,42,45,48,50–52] including 11,007 eyes, recorded the complication of anterior tear. The meta-analysis from all studies suggested there was no significant difference between FLACS and CPS (OR = 1.75, 95% CI 0.82 to 3.73, $P = 0.15$: Fig. 2A). However, time subgroup meta-analysis showed that the risk of anterior capsule tear was significantly high before 2015 years (OR = 4.58, 95% CI 1.42 to 14.77, $P = 0.01$; Fig. 2A) and without no significant difference after 2015(OR = 1.22, 95% CI 0.53 to 2.80, $P = 0.64$; Fig. 2A).

4.2. b. Posterior capsule tear

7 RCT[21,24,25,27,28,45,48] and 6 prospective studies[21,24,25,28,45,48] were included. Pooled data suggested no significant difference between the two groups in total (OR = 0.88, 95% CI 0.59 to 1.31, $P = 0.53$; Fig. 2B). Then two subgroups (non-RCT and RCT) were added to analyze as shown in (Fig. 3). FLACS revealed a significantly lower tear rate in the RCT subgroup and without differences in the non-RCT subgroup (subgroup of non-RCT: OR = 1.30, 95% CI 0.77 to 2.20, $P = 0.32$, subgroup of RCT OR = 0.49, 95% CI 0.26 to 0.95, $P = 0.04$).

5. FLACS specific complications

5.1. a. Corneal epithelial defect

Across two studies[14,51] by two different research teams, the risk ratio of the corneal epithelial defect was significantly higher for eyes receiving FLACS relative to CPS (OR = 4.94, 95% CI 1.91 to 12.80, $P = 0.001$; Fig. 3A).

5.2. b. Corneal haze

Two studies,[14,58] including 5956 eyes, assessed the ratio of postoperative corneal haze. The pooled data showed the risk of corneal haze was significantly higher in the FLACS group (OR = 13.51, 95% CI 2.55 to 71.47, $P = 0.002$; Fig. 3B).

5.3. c. Subconjunctival hemorrhage

Six studies[20,37,40,44,51,56] evaluated the occurrence of subconjunctival

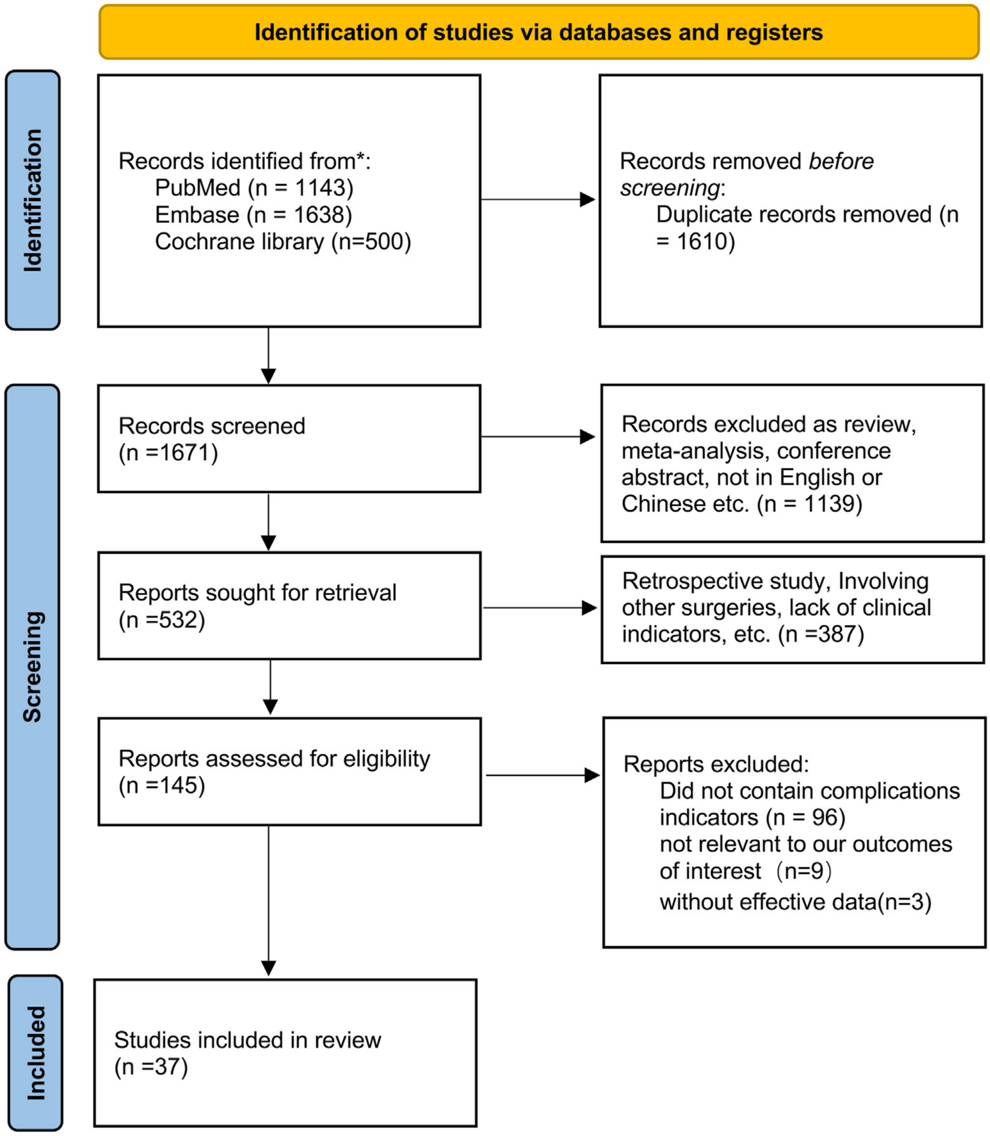

Fig. 1. PRISMA 2020 flow diagram for new systematic reviews which included searches of databases and registers only.

hemorrhage. Pooled data revealed that the risk of subconjunctival hemorrhage was higher in eyes receiving FLACS relative to CPS (OR = 6.42, 95% CI 1.48 to 27.86, $P = 0.01$; Fig. 3C).

5.4. d. Small pupil

Eight studies[24,28,29,33,34,37,40,56] assessed the pupil size during operation and recorded the events of the small pupil. The risk of small pupil in FLACS was significantly higher than that in the CPS group (OR = 3.05, 95% CI 1.83 to 5.07, $P < 0.0001$; Fig. 3D). However, pooled data shows no statistically significant differences between the group of FLACS and CPS for using iris hooks or malyugin ring (OR = 5.27, 95% CI 0.88 to 31.50, $P = 0.07$; Fig. S1K).

6. Other intraoperative and postoperative complications

6.1. a. Descemet membrane tear/trauma

The subgroup was divided by the incision approaches (corneal incision with laser or not). Although no significant difference was found in total (OR = 0.64, 95% CI 0.26 to 1.56, $P = 0.33$; Fig. 4A), a significantly lower incidence of Descemet membrane tear/trauma was revealed in laser-assisted group (OR = 0.16, 95% CI 0.03 to 0.79, $P = 0.02$; Fig. 4A).

6.2. b. IFIS/iris trauma

The meta-analysis from three studies[21,39,48] revealed that compared with the CPS group, IFIS/iris trauma incidence in the FLACS group was statistically significantly low (OR = 0.35, 95% CI 0.13 to 0.97, $P = 0.04$; Fig. 4B).

6.3. c. Macular edema

This part we included thirteen studies, including 9 RCT[24,27,28,30,35,44–46,48] and 4 perspective studies.[14,36,49,55] Although there was revealed a higher incidence of macular edema with FLACS in the subgroup of none-RCT (OR = 3.40 95% CI 1.12 to 10.33, $P = 0.03$; Fig. 4C), there was no significant differences were founded in the RCT subgroup and total (RCT subgroup: OR = 0.90, 95% CI 0.62 to 1.31, $P = 0.57$; Total: OR = 1.07, 95% CI 0.76 to 1.51, $P = 0.71$; Fig. 4C), which was more credible for less selection bias in RCT studies.

Besides, no significant difference was discovered with respect to the risk of suprachoroidal hemorrhage (OR = 3.35, 95% CI 0.35 to 32.34, $P = 0.30$; Fig. S1A), zonular dialysis/disinsertion (OR = 1.00, 95% CI 0.37

Table 1
Characteristics of included studies. FLACS, femtosecond laser-assisted cataract surgery; CPS, conventional phacoemulsification surgery; RCT, randomized controlled trial; None, not available.

Study ID	Country	Study design	Age of FLACS	Age of CPS(eyes)	No. of FLACS(eyes)	No. of CPS(eyes)	Follow up
Abell 2013	Australia	Cohort	72.8 ± 10.5	71.8 ± 10.8	200	200	1 month
Abell 2014	Australia	Cohort	72.4 ± 10.1	72.6 ± 9.8	804	822	2 months
Wang 2018	China	Cohort	57 ± 15	58 ± 14	58	34	3 months
Zhu, 2019	China	Cohort	69.39 ± 13.50	66.26 ± 12.58	66	66	6 months
Chlasta 2019	Poland	RCT	79.08 ± 5.51	74.59 ± 8.10	26	61	6 months
Conrad 2013	Germany	RCT	70.9	70.9	73	73	6 months
Dzhaber 2020a	USA	RCT	68 ± 9.6	68 ± 9.6	55	55	6 months
Day 2020	UK	RCT	68 ± 10		391	389	6 months
Day 2020a	UK	RCT	None	None	391	389	12 months
Day 2021	UK	RCT	68 ± 10		353	317	1 month
Schweitzer 2020	France	RCT	72·4 ± 8.6	72·1 ± 8.7	582	581	3 months
Dzhaber 2020	USA	RCT	68.3 ± 9.1		67	67	2 months
Reddy 2013	India	RCT	None	None	56	63	210 days
Daya 2014	UK	Cohort	None	None	108	108	3 months
Abell 2015	Australia	Cohort	73.5 ± 9.5	72.6 ± 9.6	1852	2228	3 months
Conrad 2015	Germany	RCT	71.6		100	100	3 months
Gao 2017	China	Cohort	66.32 ± 6.12	65.12 ± 7.15	59	47	3 months
Hansen 2020	USA	RCT	68.7 ± 8.5	69.0 ± 14.1	64	71	3 months
Liu 2016	China	Cohort	50.1 ± 3.3	49.6 ± 2.6	21	21	None
Ewe 2015	Australia	Cohort	71.7 ± 9.5	72.5 ± 10.8	833	458	3 months
Mursch 2017	Australia	RCT	72 ± 6		50	50	1 month
Oka 2021	USA	RCT	73.4 ± 6.5		53	53	None
Ewe 2016	Australia	Cohort	72.1 ± 9.3	73.6 ± 10.4	988	888	12 months
Manning 2016	Europe & Australia	Cohort	66.4 ± 10.2	67.5 ± 9.9	2814	4917	None
Ferreira 2018	Portugal	RCT	69 ± 8	71 ± 8	300	300	1 month
Roberts 2019	UK	RCT	69.9 ± 10.9	70.5 ± 9.8	200	200	1 month
Roberts 2018	UK	RCT	69.07 ± 11.55	69.78 ± 10.14	134	165	1 week
Titiyal 2018	India	Cohort	60.5 ± 10.8	59.5 ± 10.9	52	77	1 week
Roberts 2018a	UK	RCT	72.5 ± 10.5	69.7 ± 12.0	53	51	3 months
Vasavada 2019	USA	RCT	67.21 ± 11.11	63.70 ± 11.84	91	91	3 months
Chen 2019	China	Cohort	52.75 ± 3.18		47	47	None
Villavilla 2021	Spain	Cohort	68.92	69.1	63	57	None
Zhang 2016	China	Cohort	64.7 ± 16.7	66.6 ± 12.4	153	161	None
Yu 2015	China	Cohort	62.3 ± 11.6	56.5 ± 16.6	25	29	3 months
Yang 2019	China	Cohort	60.51 ± 3.41	61.43 ± 3.46	47	47	3 months
Zheng 2022	China	Cohort	68.53 ± 7.45	71.40 ± 8.50	30	30	1 month
Stanojcic 2021	UK	RCT	70.1 ± 9.4	69.8 ± 9.4	116	118	12 months

to 2.67, $P = 1.00$; Fig. S1B), lens drop (OR = 0.41, 95% CI 0.12 to 1.43, $P = 0.16$; Fig. S1C), vitreous loss (OR = 0.67, 95% CI 0.38 to 1.16, $P = 0.15$; Fig. S1D), posterior vitreous detachment (OR = 1.14, 95% CI 0.39 to 3.28, $P = 0.81$; Fig. S1E) and retinal detachment (OR = 1.60, 95% CI 0.52 to 4.91, $P = 0.41$; Fig. S1F). Additionally, the incidence of corneal edema (OR = 1.37, 95% CI 0.66 to 2.82, $P = 0.39$; Fig. S1G), uveitis (OR = 1.28, 95% CI 0.97 to 1.68, $P = 0.08$; Fig. S1H), PCO (OR = 0.89, 95% CI 0.17 to 4.67, $P = 0.89$; Fig. S1I) and uncontrolled high IOP (OR = 1.77, 95% CI 0.28 to 11.26 $P = 0.55$; Fig. S1J) also had no significantly differences between FLACS and CPS group.

7. Discussion

The femtosecond laser is a novel and advanced assistant technology for cataract surgery. Although several studies have evaluated the safety and efficacy of FLACS, the safety concerns with FLACS still exist. Previously, studies still did not get consistent results for sample size limitations. This meta-analysis added more RCTs and high-quality cohort studies to review the risk of inter/postoperative complications. Our meta-analysis considered the FLACS is as safe as CPS for cataracts. We found that FLACS does not increase the risk of intraoperative capsule tear, postoperative corneal edema, macular edema, uncontrolled IOP, etc. Additionally, applying FLACS would decrease intraoperative Descemet membrane tear/trauma, IFIS syndrome, and iris trauma. Although a high incidence of miosis, corneal epithelial defect, corneal haze, and subconjunctival hemorrhage irritated by FLACS, we still could control these efficiently without any influence on visual outcomes.

The quality of the capsular bag is known to be one of the most critical factors for the outcome of cataract surgery. Any complications of the capsule, including capsular tears and posterior capsular rupture, would cause vitreous loss and the IOL rotation, decentration, and, thus, the visual outcome.[59,60] Previously, several studies reported a higher incidence of anterior capsular tears in FLACS and suggested that anterior capsule tears more likely result from aberrant pulses and "postage-stamp" edge pattern perforated by femtosecond laser, as well as the unexpected eye movements.[16,61] Additionally, a learning curve also may be associated with the high anterior capsule tear rate in the femtosecond laser group. However, our meta-analysis demonstrated no difference between the FLACS and CPS groups in total. Our subgroup analysis found a high anterior capsule tear rate in FLACS eyes before 2015 and without significant differences between two groups after 2015 or analysis with whole studies. Although the meta-analysis of Kolb suggested higher rates of anterior capsule tear might account for the Catalys laser platform, we are more likely to believe that these interesting results might account for software upgrades and optimizing the capsulotomy setting.[15] Abell 2015 found a significant reduction in anterior capsulotomy tags after software upgrades, which might for a less capsulotomy time and lower chance of aberrant pulses.[32,58] Moreover, a greater vertical spot spacing (up to 20 μm) setting would significantly decrease the risk of anterior capsule tear.[55,56] These results might also account for a bias of different techniques and experiences that the two multicenter studies of Abell might induce. Moreover, the posterior capsule rupture rate in the FLACS group seemed the same as the CPS group, which is consistent with the Qian, Chen, and Popovic meta-analysis findings.[4,16,18] However, the more interesting point is the posterior capsule rupture rate seemed less with FLACS in the RCT subgroup and without differences in the none-RCT subgroup or total. These results might be caused by the selected bias induced by non-randomized allocation. Laser-assisted capsulotomy and

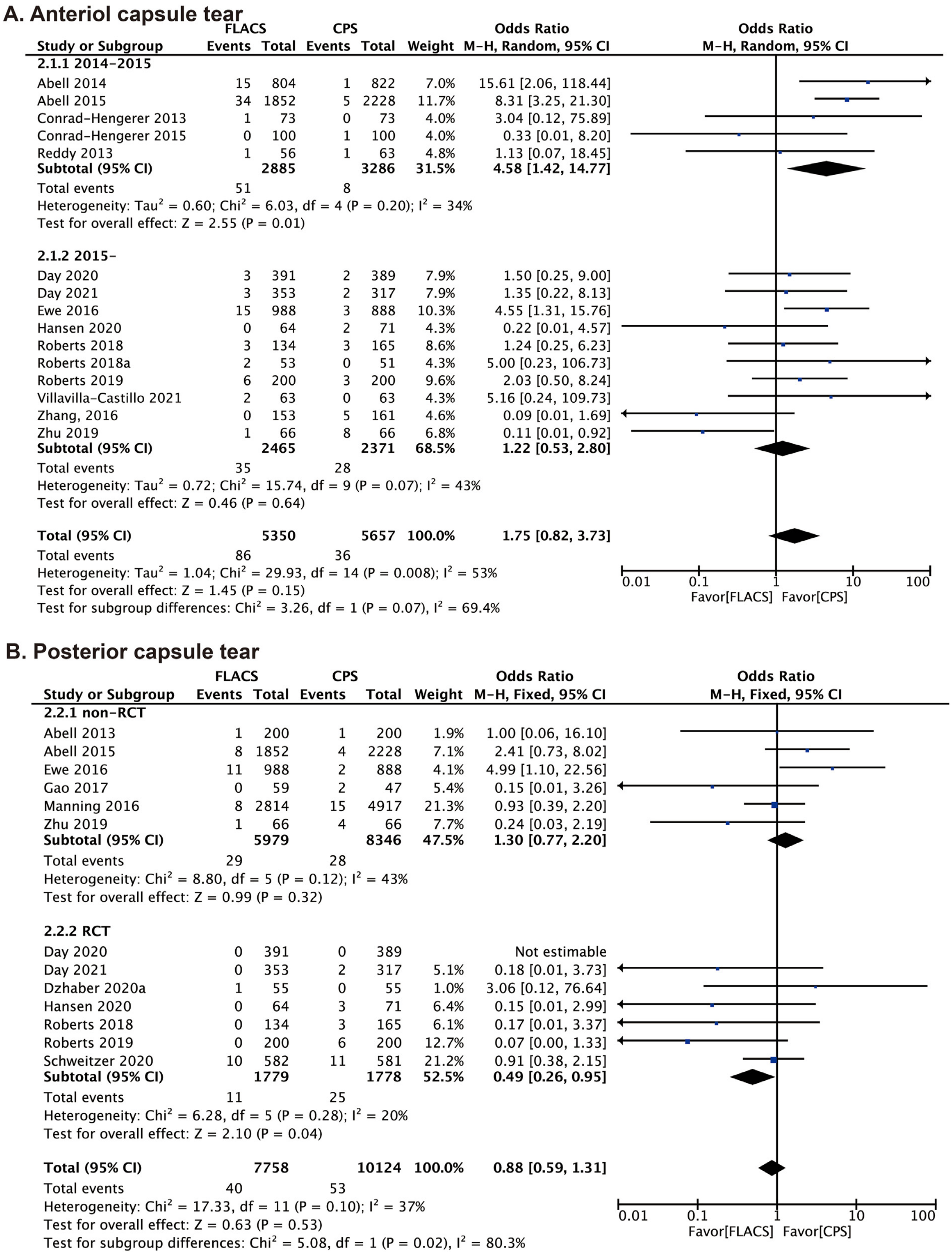

Fig. 2. Forest plot comparison of capsule tear rate after treatment with FLACS and CPS. A. Anterior capsule tear. B. Posterior capsule tear.

lens fragmentation with FLACS would greatly decrease the surgical difficulty. Patients would prefer to select FLACS and expect a better visual outcome. Meanwhile, a surgeon would choose laser-assisted pretreatment to down the surgical difficulty unconsciously. These possibilities might contribute to the selection bias and cover the potential benefit for FLACS.

Additionally, the more interesting point is the incidence of posterior capsule rupture in FLACS was potentially lower in the analysis of the RCT subgroup. We should also pay attention to these beneficial features, and more well-designed RCTs, especially well-blinded RCTs, are still

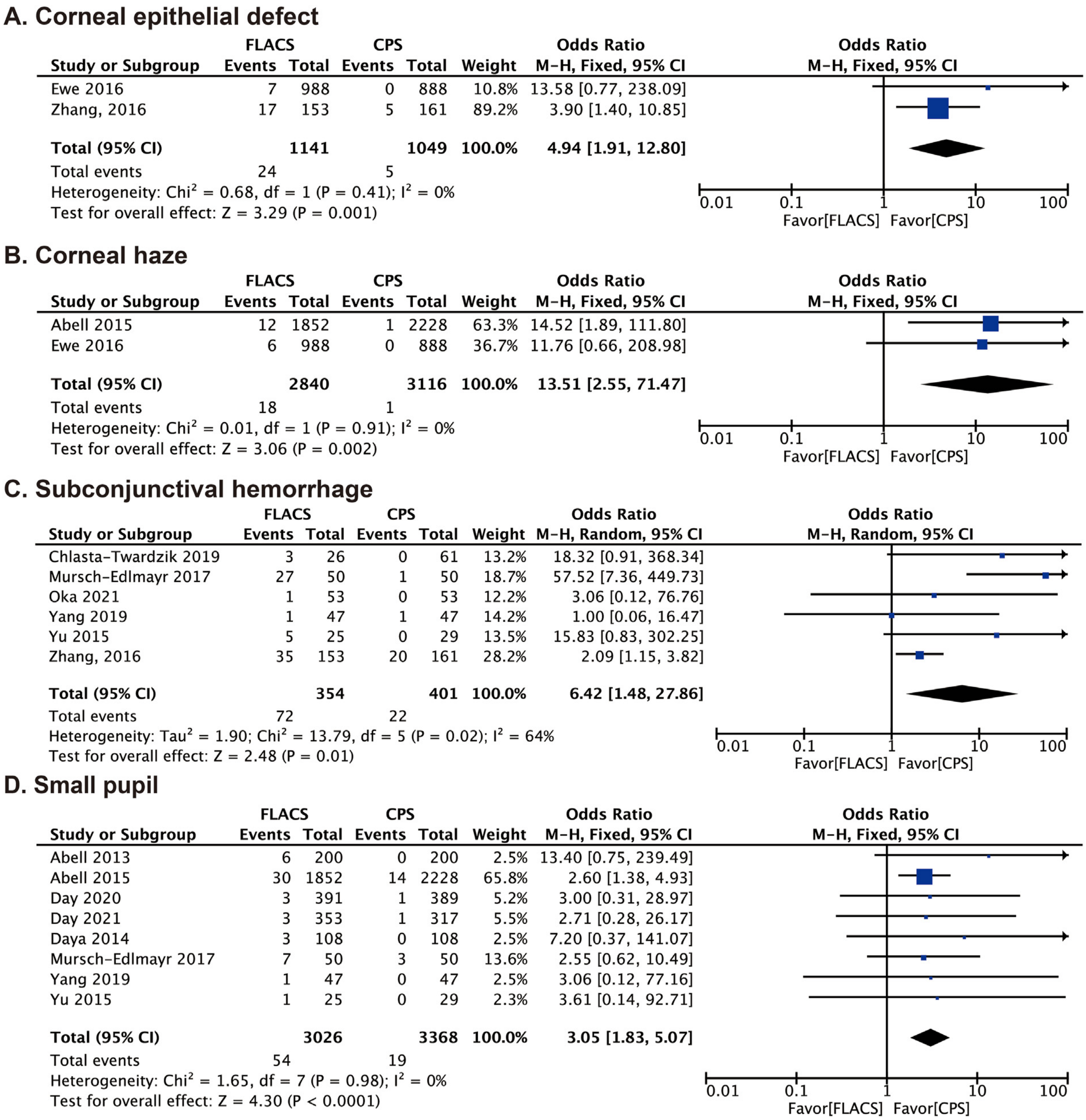

Fig. 3. Forest plot comparison of FLACS specific complications rates after treatment with FLACS and CPS. A. Corneal epithelial defect. B. Corneal haze. C. Subconjunctival hemorrhage. D. Small pupil.

necessary to provide more reliable evidence. Essentially, the clinical significance should be considered when discussing these results.

Using femtoseconds laser and direct contact with the ocular surface would bring out several FLACS specific complications.[62] In this meta-analysis, we first reviewed and showed that FSL pretreatment could significantly increase the incidence of unexpected miosis, subconjunctival hemorrhage, corneal epithelial defect, and corneal haze. Miosis after FSL mainly accounts for the increased concentration of PGE in aqueous humor.[63] Although intraoperative miosis always bothers the surgery, an experienced surgeon would pretreat with topical NSAID and efficiently decrease the possible risk for intraoperative miosis.[64] The ocular surface injuries might partially result from the learning curve, and the fluorescein staining of the corneal would heal within 1 week, not affecting the visual outcome.[65] Overall, with more experience, the FLACS specific complication could be prevented efficiently and not affect the visual outcome. Additionally, our meta-analysis revealed more benefits from making corneal incisions with FLACS for a lower incidence of Descemet membrane tear or trauma. Moreover, FLACS was superior in a lower rate of IFIS/iris trauma and with similar security on the incidence of macular edema. These data indicate that FLACS has the same safety as CPS.

However, several limitations are still presented in this study. Some of the limitations originate from the clinical trial. In some trials, it is difficult to blind the type of operation to participants and personnel, which might induce performance bias. The random sequence also lacked in some trials, which would result in a selection bias. Thus, we included high-quality cohort studies and reliable RCTs in our study. Additionally, the complication data were coming from different trials. It is hard to control the variances and heterogeneities from patients, surgeons, and even the type of femtosecond laser platform. Also, the follow time is different among the included studies, which might affect the incidence of part complications such as macular edema, uveitis, PCO,.etc. Moreover, each complication in our study was extracted from different trails, which only interested in a specific field.

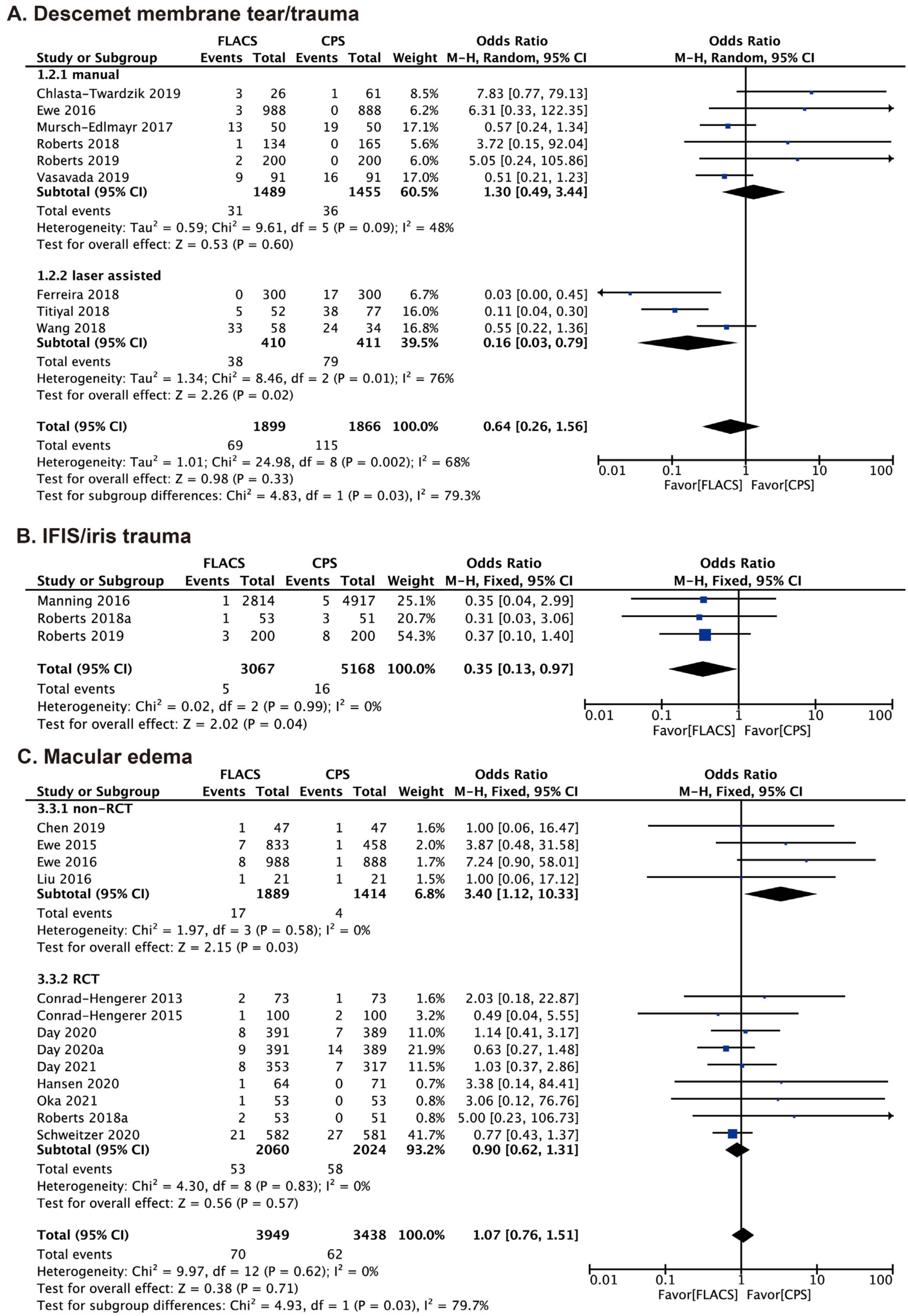

Fig. 4. Forest plot comparison of other intraoperative and postoperative complications rates after treatment with FLACS and CPS. A. Descemet membrane tear/trauma. B. IFIS/iris trauma. C. Macular edema.

8. Conclusion

In conclusion, our meta-analysis holds that FLACS maintain the same safety compared with CPS in terms of all intraoperative and post-operative complications. However, we expected more large patient populations and well-designed RCTs with longer follow-up periods to update the findings of this analysis.

Study Approval

Not Applicable.

Author Contributions

The authors confirm contribution to the paper as follows: Conception and design of study: KY, XYC; Data collection: JJX, HLW; Drafting the manuscript: JJX, XYC; All authors reviewed the results and approved the final version of the manuscript.

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Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Editorship Disclosure

Given his role as Editor-in-Chief, Ke Yao had no involvement in the peer-review of this article and has no access to information regarding its peer-review. Full responsibility for the editorial process for this article was delegated to Prof. Andrzej Grzybowski.

Abbreviations

FLACS	femtosecond laser-assisted cataract surgery
CPS	conventional phacoemulsification surgery
RCT	randomized controlled trial
ECCE	extracapsular cataract extraction
FSL	femtosecond laser
IOL	intraocular lens
EPT	effective phacoemulsification time
NOS	newcastle-Ottawa Scale

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.aopr.2022.100027.

References

1. Song P, Wang H, Theodoratou E, et al. The national and subnational prevalence of cataract and cataract blindness in China: a systematic review and meta-analysis. *J Glob Health*. 2018;8(1), 010804. https://doi.org/10.7189/jogh.08-010804.
2. Prokofyeva E, Wegener A, Zrenner E. Cataract prevalence and prevention in Europe: a literature review. *Acta Ophthalmol*. 2013;91(5):395–405.
3. Lee CM, Afshari NA. The global state of cataract blindness. *Curr Opin Ophthalmol*. 2017;28(1):98.
4. Popovic M, Campos-Möller X, Schlenker MB, et al. Efficacy and safety of femtosecond laser-assisted cataract surgery compared with manual cataract surgery: a meta-analysis of 14 567 eyes. *Ophthalmology*. 2016;123(10):2113–2126. https://doi.org/10.1016/j.ophtha.2016.07.005 10.1016/j.ophtha.2016.07.005. Epub . Accessed August 15, 2016.
5. Xu J, Fu Q, Chen X, et al. Advances in pharmacotherapy of cataracts. *Ann Transl Med*. 2020;8(22), 1552-1552.
6. Chen X, Chen K, He J, et al. Comparing the curative effects between femtosecond laser-assisted cataract surgery and conventional phacoemulsification surgery: a meta-analysis. *PLoS One*. 2016;11(3), e0152088. https://doi.org/10.1371/journal.pone.0152088 10.1371/journal.pone.0152088. eCollection 2016.
7. Roberts TV, Lawless M, Chan CC, et al. *Femtosecond Laser Cataract Surgery: Technology and Clinical Practice*. Clinical & Experimental Ophthalmology; 2012.
8. Tabin G, Chen M, Espandar L. Cataract surgery for the developing world. *Curr Opin Ophthalmol*. 2008;19(1):55–59.
9. Uy HS, Edwards K, Curtis N. Femtosecond phacoemulsification: the business and the medicine. *Curr Opin Ophthalmol*. 2012;23(1):33–39.
10. Baig NB, Cheng GP, Lam JK, et al. Intraocular pressure profiles during femtosecond laser–assisted cataract surgery. *J Cataract Refract Surg*. 2014;40(11):1784–1789.
11. Kránitz K, Takacs A, Miháltz K, et al. Femtosecond laser capsulotomy and manual continuous curvilinear capsulorrhexis parameters and their effects on intraocular lens centration. *J Refract Surg*. 2011;27(8):558–563.
12. Bahler CK, Hann CR, Fjield T, et al. Second-generation trabecular meshwork bypass stent (iStent inject) increases outflow facility in cultured human anterior segments. *Am J Ophthalmol*. 2012;153(6):1206–1213.
13. Kránitz K, Miháltz K, Sándor GL, et al. Intraocular lens tilt and decentration measured by Scheimpflug camera following manual or femtosecond laser–created continuous circular capsulotomy. *J Refract Surg*. 2012;28(4):259–263.
14. Ewe SY, Abell RG, Oakley CL, et al. A comparative cohort study of visual outcomes in femtosecond laser-assisted versus phacoemulsification cataract surgery. *Ophthalmology*. 2016;123(1):178–182.
15. Kolb CM, Shajari M, Mathys L, et al. Comparison of femtosecond laser–assisted cataract surgery and conventional cataract surgery: a meta-analysis and systematic review. *J Cataract Refract Surg*. 2020;46(8):1075–1085.
16. Chen X, Xiao W, Ye S, et al. Efficacy and safety of femtosecond laser-assisted cataract surgery versus conventional phacoemulsification for cataract: a meta-analysis of randomized controlled trials. *Sci Rep*. 2015;5:13123. https://doi.org/10.1038/srep13123 10.1038/srep13123.
17. Ali MH, Ullah S, Javaid U, et al. Comparison of characteristics of femtosecond laser-assisted anterior capsulotomy versus manual continuous curvilinear capsulorrhexis: a meta-analysis of 5-year results. *J Pakistan Med Assoc*. 2017;67(10):1574–1579. Published 2017/09/29.
18. Qian DW, Guo HK, Jin SL, et al. Femtosecond laser capsulotomy versus manual capsulotomy: a Meta-analysis. *Int J Ophthalmol*. 2016;9(3):453–458. https://doi.org/10.18240/ijo.2016.03.23 10.18240/ijo.2016.03.23. eCollection 2016.
19. Wang X, Zhang Z, Li X, et al. Evaluation of femtosecond laser versus manual clear corneal incisions in cataract surgery using spectral-domain optical coherence tomography. *J Refract Surg*. 2018;34(1):17–22. https://doi.org/10.3928/1081597X-20171109-01.
20. Chlasta-Twardzik E, Nowinska A, Wylegala E. Comparison of the selected parameters of the anterior segment of the eye between femtosecond laser-assisted cataract surgery, microincision cataract surgery, and conventional phacoemulsification: a case-control study. *Medicine (Baltim)*. 2019;98(52), e18340. https://doi.org/10.1097/MD.0000000000018340.
21. Roberts HW, Wagh VK, Sullivan DL, et al. A randomized controlled trial comparing femtosecond laser-assisted cataract surgery versus conventional phacoemulsification surgery. *J Cataract Refract Surg*. 2019;45(1):11–20. https://doi.org/10.1016/j.jcrs.2018.08.033.
22. Vasavada VA, Vasavada S, Vasavada AR, et al. Comparative evaluation of femtosecond laser-assisted cataract surgery and conventional phacoemulsification in eyes with a shallow anterior chamber. *J Cataract Refract Surg*. 2019;45(5):547–552. https://doi.org/10.1016/j.jcrs.2018.11.037.
23. Zhu Y, Chen X, Chen P, et al. Lens capsule-related complications of femtosecond laser-assisted capsulotomy versus manual capsulorhexis for white cataracts. *J Cataract Refract Surg*. 2019;45(3):337–342. https://doi.org/10.1016/j.jcrs.2018.10.037.
24. Day AC, Burr JM, Bennett K, et al. Femtosecond laser-assisted cataract surgery versus phacoemulsification cataract surgery (fact): a randomized noninferiority trial. *Ophthalmology*. 2020;127(8):1012–1019. https://doi.org/10.1016/j.ophtha.2020.02.028.
25. Dzhaber D, Mustafa O, Alsaleh F, et al. Comparison of changes in corneal endothelial cell density and central corneal thickness between conventional and femtosecond laser-assisted cataract surgery: a randomised, controlled clinical trial. *Br J Ophthalmol*. 2020;104(2):225–229. https://doi.org/10.1136/bjophthalmol-2018-313723 10.1136/bjophthalmol-2018-313723. Epub 2019 May 16.
26. Dzhaber D, Mustafa OM, Alsaleh F, et al. Visual and refractive outcomes and complications in femtosecond laser-assisted versus conventional phacoemulsification cataract surgery: findings from a randomised, controlled clinical trial. *Br J Ophthalmol*. 2020;104(11):1596–1600. https://doi.org/10.1136/bjophthalmol-2019-314548.
27. Schweitzer C, Brezin A, Cochener B, et al. Femtosecond laser-assisted versus phacoemulsification cataract surgery (FEMCAT): a multicentre participant-masked randomised superiority and cost-effectiveness trial. *Lancet*. 2020;395(10219):212–224. https://doi.org/10.1016/S0140-6736(19)32481-X.

28. Day AC, Burr JM, Bennett K, et al. Femtosecond laser-assisted cataract surgery compared with phacoemulsification: the FACT non-inferiority RCT. *Health Technol Assess*. 2021;25(6):1–68. https://doi.org/10.3310/hta25060.
29. Abell RG, Kerr NM, Vote BJ. Femtosecond laser-assisted cataract surgery compared with conventional cataract surgery. *Clin Exp Ophthalmol*. 2013;41(5):455–462. https://doi.org/10.1111/ceo.12025.
30. Conrad-Hengerer I, Al Juburi M, Schultz T, et al. Corneal endothelial cell loss and corneal thickness in conventional compared with femtosecond laser-assisted cataract surgery: three-month follow-up. *J Cataract Refract Surg*. 2013;39(9):1307–1313. https://doi.org/10.1016/j.jcrs.2013.05.033.
31. Reddy KP, Kandulla J, Auffarth GU. Effectiveness and safety of femtosecond laser-assisted lens fragmentation and anterior capsulotomy versus the manual technique in cataract surgery. *J Cataract Refract Surg*. 2013;39(9):129. https://doi.org/10.1016/j.jcrs.2013.05.035 {Reddy, 2013 #2170}2017-2306.
32. Abell RG, Davies PEJ, Phelan D, et al. Anterior capsulotomy integrity after femtosecond laser-assisted cataract surgery. *Ophthalmology*. 2014;121(1):17–24. https://doi.org/10.1016/j.ophtha.2013.08.013.
33. Daya SM, Nanavaty MA, Espinosa-Lagana MM. Translenticular hydrodissection, lens fragmentation, and influence on ultrasound power in femtosecond laser-assisted cataract surgery and refractive lens exchange. *J Cataract Refract Surg*. 2014;40(1):37–43. https://doi.org/10.1016/j.jcrs.2013.07.040.
34. Abell RG, Darian-Smith E, Kan JB, et al. Femtosecond laser-assisted cataract surgery versus standard phacoemulsification cataract surgery: outcomes and safety in more than 4000 cases at a single center. *J Cataract Refract Surg*. 2015;41(1):47–52. https://doi.org/10.1016/j.jcrs.2014.06.025 10.1016/j.jcrs.2014.06.025. Epub 2014 Nov 11.
35. Conrad-Hengerer I, Al Sheikh M, Hengerer FH, et al. Comparison of visual recovery and refractive stability between femtosecond laser-assisted cataract surgery and standard phacoemulsification: six-month follow-up. *J Cataract Refract Surg*. 2015;41(7):1356–1364. https://doi.org/10.1016/j.jcrs.2014.10.044.
36. Ewe SY, Oakley CL, Abell RG, et al. Cystoid macular edema after femtosecond laser-assisted versus phacoemulsification cataract surgery. *J Cataract Refract Surg*. 2015;41(11):2373–2378. https://doi.org/10.1016/j.jcrs.2015.04.031.
37. Yu AY, Ni LY, Wang QM, et al. Preliminary clinical investigation of cataract surgery with a noncontact femtosecond laser system. *Laser Surg Med*. 2015;47(9):698–703. https://doi.org/10.1002/lsm.22405.
38. Ewe SY, Abell RG, Oakley CL, et al. A comparative cohort study of visual outcomes in femtosecond laser-assisted versus phacoemulsification cataract surgery. *Ophthalmology*. 2016;123(1):178–182. https://doi.org/10.1016/j.ophtha.2015.09.026.
39. Manning S, Barry P, Henry Y, et al. Femtosecond laser-assisted cataract surgery versus standard phacoemulsification cataract surgery: study from the European Registry of quality outcomes for cataract and refractive surgery. *J Cataract Refract Surg*. 2016;42(12):1779–1790. https://doi.org/10.1016/j.jcrs.2016.10.013.
40. Mursch-Edlmayr AS, Bolz M, Luft N, et al. Intraindividual comparison between femtosecond laser-assisted and conventional cataract surgery. *J Cataract Refract Surg*. 2017;43(2):215–222. https://doi.org/10.1016/j.jcrs.2016.11.046.
41. Ferreira TB, Ribeiro FJ, Pinheiro J, et al. Comparison of surgically induced astigmatism and morphologic features resulting from femtosecond laser and manual clear corneal incisions for cataract surgery. *J Refract Surg*. 2018;34(5):322–329. https://doi.org/10.3928/1081597X-20180301-01.
42. Roberts HW, Wagh VK, Mullens IJM, et al. Evaluation of a hub-and-spoke model for the delivery of femtosecond laser-assisted cataract surgery within the context of a large randomised controlled trial. *Br J Ophthalmol*. 2018;102(11):1556–1563. https://doi.org/10.1136/bjophthalmol-2017-311319 10.1136/bjophthalmol-2017-311319. Epub 2018 Feb 7.
43. Stanojcic N, Roberts HW, Wagh VK, et al. A randomised controlled trial comparing femtosecond laser-assisted cataract surgery versus conventional phacoemulsification surgery: 12-month results. *Br J Ophthalmol*. 2021;105(5):631–638. https://doi.org/10.1136/bjophthalmol-2020-316311.
44. Oka Y, Sasaki N, Injev VP. Comparison of femtosecond laser-assisted cataract surgery and conventional phacoemulsification on endothelial cell density when using torsional modality. *Clin Ophthalmol*. 2021;15:4227–4237. https://doi.org/10.2147/OPTH.S329935.
45. Hansen B, Blomquist PH, Ririe P, et al. Outcomes of resident-performed laser-assisted vs traditional phacoemulsification. *J Cataract Refract Surg*. 2020;46(9):1273–1277. https://doi.org/10.1097/j.jcrs.0000000000000253.
46. Day AC, Burr JM, Bennett K, et al. Femtosecond laser-assisted cataract surgery compared with phacoemulsification cataract surgery: randomized noninferiority trial with 1-year outcomes. *J Cataract Refract Surg*. 2020;46(10):1360–1367. https://doi.org/10.1097/j.jcrs.0000000000000257.
47. Titiyal JS, Kaur M, Ramesh P, et al. Impact of clear corneal incision morphology on incision-site descemet membrane detachment in conventional and femtosecond laser-assisted phacoemulsification. *Curr Eye Res*. 2018;43(3):293–299. https://doi.org/10.1080/02713683.2017.1396616.
48. Roberts HW, Wagh VK, Sullivan DL, et al. Refractive outcomes after limbal relaxing incisions or femtosecond laser arcuate keratotomy to manage corneal astigmatism at the time of cataract surgery. *J Cataract Refract Surg*. 2018;44(8):955–963. https://doi.org/10.1016/j.jcrs.2018.05.027.
49. Chen J, Wang D, Zheng J, et al. Efficacy of femtosecond laser-assisted phacoemulsification for cataract patients and its influence on serum levels of inflammatory factors. *J Coll Physicians Surg Pak*. 2019;29(2):123–127. https://doi.org/10.29271/jcpsp.2019.02.123.
50. Villavilla-Castillo J, Perez-Casaseca C, Espejo-de-Los-Riscos E, et al. Study of the efficiency and workflow of femtosecond laser-assisted cataract surgery in a Spanish public hospital. *J Fr Ophtalmol*. 2021;44(8):1190–1201. https://doi.org/10.1016/j.jfo.2021.01.030.
51. Zhang GB, Ye XY, Chen W, et al. Clinic analysis of femtosecond laser-assisted cataract surgery. *Zhonghua Yan Ke Za Zhi*. 2016;52(2):93–98. https://doi.org/10.3760/cma.j.issn.0412-4081.2016.02.004.
52. Day AC, Burr JM, Bennett K, et al. Femtosecond laser-assisted cataract surgery compared with phacoemulsification cataract surgery: randomized noninferiority trial with 1-year outcomes. *J Cataract Refract Surg*. 2020;46(10):1360–1367. https://doi.org/10.1097/j.jcrs.0000000000000257.
53. Stanojcic N, Roberts HW, Wagh VK, et al. A randomised controlled trial comparing femtosecond laser-assisted cataract surgery versus conventional phacoemulsification surgery: 12-month results. *Br J Ophthalmol*. 2021;105(5):631–638. https://doi.org/10.1136/bjophthalmol-2020-316311.
54. Gao QS, Di X, He W. Clinical application of femtosecond laser assisted cataract surgery combined with triple-focus intraocular lens implantation in the treatment of cataract. *Int Eye Sci*. 2018;18(3):491–494. https://doi.org/10.3980/j.issn.1672-5123.2018.3.20.
55. Liu M, Zeng G, Cheng ZX. Effects of femtosecond laser assisted cataract surgery and the prognosis of patients. *Int Eye Sci*. 2016;16(8):1557–1560. https://doi.org/10.3980/j.issn.1672-5123.2016.8.42.
56. Yang B, Yuan FL, Sun Y, et al. Femtosecond laser-assisted phacoemulsification combined with multifocal intraocular lens implantation in the treatment of cataract. *Int Eye Sci*. 2019;19(9):1528–1531. https://doi.org/10.3980/j.issn.1672-5123.2019.9.19.
57. Zheng YJ, Zhao CM, Liu XY, et al. Clinical evaluation of femtosecond laser-assisted phacoemulsification in the treatment of cataract with shallow anterior chamber. *Int Eye Sci*. 2022;22(1):87–90. https://doi.org/10.3980/j.issn.1672-5123.2022.1.18.
58. Abell RG, Darian-Smith E, Kan JB, et al. Femtosecond laser–assisted cataract surgery versus standard phacoemulsification cataract surgery: outcomes and safety in more than 4000 cases at a single center. *J Cataract Refract Surg*. 2015;41(1):47–52.
59. Kolb CM, Shajari M, Mathys L, et al. Comparison of femtosecond laser-assisted cataract surgery and conventional cataract surgery: a meta-analysis and systematic review. *J Cataract Refract Surg*. 2020. Publish Ahead of Print(8):1.
60. Oakley Carmen L, Ewe SY, Allen PL, et al. Visual outcomes with femtosecond laser-assisted cataract surgery versus conventional cataract surgery in toric IOL insertion. *Clin Exp Ophthalmol*. 2016;44:570–573.
61. Wang J, Su F, Wang Y, et al. Intra and post-operative complications observed with femtosecond laser-assisted cataract surgery versus conventional phacoemulsification surgery: a systematic review and meta-analysis. *BMC Ophthalmol*. 2019;19.
62. Latz C, Asshauer T, Rathjen C, et al. Femtosecond-laser assisted surgery of the eye: overview and impact of the low-energy concept. *Micromachines*. 2021;12(2):122. https://doi.org/10.3390/mi12020122.
63. Schultz T, Joachim SC, Stellbogen M, et al. Prostaglandin release during femtosecond laser-assisted cataract surgery: main inducer. *J Refract Surg*. 2015;31(2):78–81. https://doi.org/10.3928/1081597x-20150122-01.
64. Schultz T, Joachim SC, Szuler M, et al. NSAID pretreatment inhibits prostaglandin release in femtosecond laser-assisted cataract surgery. *J Refract Surg*. 2015;31(12):791–794. https://doi.org/10.3928/1081597X-20151111-01.
65. Yu Y, Hua H, Wu M, et al. Evaluation of dry eye after femtosecond laser-assisted cataract surgery. *J Cataract Refract Surg*. 2015;41(12):2614–2623. https://doi.org/10.1016/j.jcrs.2015.06.036.
66. Higgins JPT, Savović J, Page MJ, et al. Assessing risk of bias in a randomized trial. In: Higgins JPTTJ, Chandler J, Cumpston M, Li T, Page MJ, Welch VA, eds. *Cochrane Handbook for Systematic Reviews of Interventions Version 6.2*. 2021 (updated February 2021), Cochrane.
67. Peterson J, Welch V, Losos M, et al. *The Newcastle-Ottawa Scale (NOS) for Assessing the Quality of Nonrandomised Studies in Meta-Analyses*. Ottawa: Ottawa Hospital Research Institute; 2011:1–12.
68. Wells GA, Shea B, O'Connell D, et al. The Newcastle-Ottawa Scale (NOS) for assessing the quality of nonrandomised. *Stud meta-analyses*. 2000. Oxford.