Comparison of choroidal thickness after standard phacoemulsification versus femtosecond laser assisted surgery: A systematic review and meta-analysis.

Barry Moses Quan Ren Koh[1, 2,3], Wei Kiong Ngo[1,3,4], Rupesh Agrawal [1,3,4], Bryan Chin Hou Ang[1,3,4,5]

[1]Department of Ophthalmology, National Healthcare Group Eye Institute, Tan Tock Seng Hospital, Singapore
[2]Duke NUS Medical School, Singapore
[3]Singapore Eye Research Institute, Singapore
[4]Lee Kong Chian School of Medicine, Nanyang Technological University, Singapore
[5]Mayo Clinic, Department of Ophthalmology, Jacksonville, Florida, USA

Abstract

Purpose: To investigate changes in choroidal thickness post-cataract surgery at 1-week, 1-month, and 3-months following phacoemulsification versus femtosecond laser assisted cataract surgery (FLACS).

Methods: The PubMed and EMBASE databases were searched from inception until March 2024. All relevant studies comparing choroidal thickness (CT) before and after cataract surgery were retrieved and filtered.

Results: A total of 29 studies including 2084 eyes were included. There was no significant change in CT at 1-week (*P*=.29), 1-month (*P*=.54), and 3-months (*P*=.91) after phacoemulsification, nor following FLACS at 1-week (*P*=.80), 1-month (*P*=.77), and 3-months (*P*=.71). In subgroup analysis, the CT of patients with diabetes mellitus (DM) at 3-months (but not at 1-week (*P*=.22) or 1-month (*P*=.31)) was significantly thicker than before surgery (MD=8.90, 95% CI: 1.55-16.25, *P*=.02). Patients of Caucasian ethnicity had significantly thicker CT (*P*<.001) at 1-week and 1-month (both *P*<.001) post-operatively but not at 3-months (*P*=.49). No difference in CT compared to baseline was observed in Asians 1-week (*P*=.97), 1-month (*P*=.87) and 3-months (*P*=.83) post-operatively. Reduction of topical anti-inflammatory medication 1-week post-operatively resulted in thicker CT in DM patients at 3-months (MD=8.90, CI=1.55-16.25, *P*=.008), and in non-DM patients at 1-month (MD=0.73, CI=-1.61-3.06, P<.001) and 3-months (MD=-0.13, CI=-2.22-1.97, P<.001).

Conclusion: CT did not significantly increase in eyes 1-week, 1-month, and 3-months after either phacoemulsification or FLACS. Patients with DM and of Caucasian ethnicity were more likely to have thicker CT post-operatively. Reduction of topical anti-inflammatory post-operatively was associated with an increase in CT.

Keywords: Choroidal thickness, Cataract, Flacs, Cataract surgery.

Introduction

Cataract is the leading cause of reversible blindness and visual impairment globally, affecting 3.9% of those aged 55 to 65 years old and 92.6% of those older than 80 years old. Currently, the two most commonly performed surgical treatments for cataract include phacoemulsification and femtosecond laser assisted cataract surgery (FLACS) [1].

Pseudophakic cystoid macular edema (CME) remains one of the most common complication following cataract surgery, occurring in 20-30% of all cases at 1-2 months after phacoemulsification due to increased ocular inflammation after surgery resulting in edema and choroidal thickness increase [2, 3]. A few studies have shown choroidal thickness (CT) to be directly related to CME, varying with its severity with the

***Correspondence to:** Bryan Chin Hou ANG, National Healthcare Group Eye Institute, Tan Tock Seng Hospital, Singapore. E-mail: drbryanang@gmail.com

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choroid being thicker in instances of macular edema [4, 5, 6] thus serving as a good measurement of CME. Clinically, CME affects visual acuity and patients are treated with topical or intravitreal anti-inflammatory agents [3].

The main difference between FLACS and phacoemulsification is that FLACS which uses lasers to create corneal incisions, perform capsulorhexis, and fragment the nucleus, has led to a reduction in ultrasound energy and time needed for phacoemulsification, thus resulting in less collateral damage to the surrounding ocular tissue and less inflammation and release of prostaglandins reducing the postoperative risk of CME. Several cohort studies have reported lesser changes in CT post-surgery for FLACS compared to phacoemulsification [7, 8, 9, 10].

The exact timing of edema onset, the extent of choroidal thickness increase it causes, and when it subsides remain subjects of considerable debate. Several studies have shown that CT increases after conventional phacoemulsification cataract surgery at 1-week and 1-month time points [11, 12, 13]. On the other hand, other studies reported no significant changes in CT [14, 15, 16]. To date only one meta-analysis was done to investigate the effect of conventional phacoemulsification on subfoveal CT [5]. However, since the publication of this meta-analysis in 2018, there has been an emergence of multiple cohort studies. Furthermore, the effects of diabetes mellitus (DM), a significant risk factor for CME, [17, 18] and the type of cataract surgery (FLACS or phacoemulsification) has not been investigated in a meta-analysis yet.

The primary aim of this meta-analysis was to investigate if there are significant changes in choroidal thickness post-surgery at 1-week, 1-month, and 3-months. Furthermore if CT is affected by the type of cataract surgery. The secondary aim was to investigate if the presence of DM, use of post-operative anti-inflammatory medication, and ethnicity of patients was associated with a change in CT post-cataract surgery.

Methods

Literature search

The study followed the methodological expectations for Cochrane Intervention Reviews when conducting the review and the Preferred Reporting Items of Systematic reviews and Meta-Analyses (PRISMA) 2020 for the reporting [17]. The PubMed and Embase databases were searched from inception until March 2024 without language restrictions for all relevant studies using search terms “choroidal thickness” and “cataract” or “phacoemulsification” or “FLACS”. An additional manual search was done to identify any studies not included.

Data collection

Two investigators (BK and BA) performed the literature search independently and the senior author (BA) was consulted if there were disagreements between screeners. After screening titles and abstracts, full-text articles evaluation was performed using the inclusion and exclusion criteria (Figure 1).

Inclusion criteria included: (1) studies with patients who underwent cataract surgery (2) choroidal thickness measured

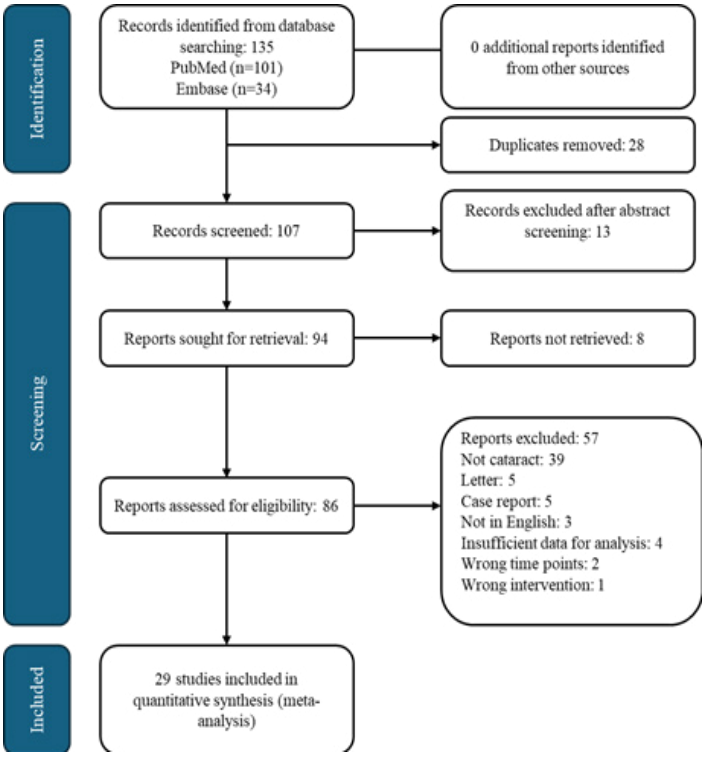

Figure 1. *PRISMA flow diagram of the selection process.*

before and after surgery; (3) macular thickness values represented as mean difference with 95% CI; (5) cohort studies, case-controls, and randomised control trials.

Exclusion criteria included: (1) cataract patients who underwent corrective surgeries other than phacoemulsification or FLACS; (2) conference abstracts, case reports; (3) papers without full texts or data available for retrieval; (4) duplicates.

Quality assessment and risk of bias:

The quality of the 29 included studies were assessed using the Risk of Bias Assessment Tool for Nonrandomised Studies (RoBANS 2.0) method comprising eight domains: comparability of the target group, target group selection, confounders, measurement of intervention, blinding, outcome assessment, incomplete conduce data, and selective outcome reporting. The risk of bias was categorised as low, unclear, and high risk.

Outcome measures:

Two study arms were created: phacoemulsification and FLACS. We grouped outcomes into three timepoints – 1-week post-intervention to detect any short-term change in CT, 1-month post-intervention to detect sustained changes in CT and 3-months post-intervention as a measure of medium to long term changes in CT. The control group consisted of pre-operative CT measurements.

Statistical analysis

The study compared the mean difference in CT between the specified timepoint (1-week, 1-month, or 3-months) and pre-operative baseline (control). We used Cochrane Review Manager version 5.4 to analyse the data. I^2 statistic was applied to assess heterogeneity between studies. Subgroup analysis by ethnicity, presence of DM, as well as use of topical anti-inflammatory. All statistical analyses used *P*-values with a cut-off of 0.05 and 95% confidence intervals (CI).

Results

Description of studies:

The electronic search identified 135 studies. Figure 1 depicts the PRISMA flow diagram of included and excluded studies. 28 studies were duplicates and further 13 studies were excluded based on abstract screening. Full-text reading was performed on 94 studies, of which we excluded 39 studies that did not examine cataract surgery, 5 letters, 5 case reports, 4 studies deemed to have insufficient data, 3 studies not in English, 2 studies not examining CT at 1-week, 1-month or 3-months, and 1 study not examining FLACS or phacoemulsification. A total of 29 studies including 2084 eyes were enrolled for final analysis. The characteristics of the studies are shown in Table 1 [33, 46].

Table 1. *Overview of included studies and synthesis table illustrating key study characteristics.*

Author	Year	No. of eyes	Type of surgery	Time points (time span)	Ethnicity	DM	NSAIDs
Abdellatif [33]	2018	66	Phacoemulsification	1 wk, 1 mth, 3 mths	Asian	No	Yes
Ahmed [34]	2023	100	Phacoemulsification	1 wk, 1 mth, 3 mths	Asian	No	No
Akcam [35]	2022	20	Phacoemulsification	1 wk, 1 mth	Asian	No	No
Appolloni [7]	2022	52	FLACS and Phaco	1 wk, 1 mth	Caucasian	No	No
Asena [8]	2017	25	FLACS and Phaco	1 wk, 1 mth	Asian	No	Yes
Bayhan [36]	2016	38	Phacoemulsification	1 mth	Asian	No	Yes
Brito [14]	2015	31	Phacoemulsification	1 mth	Caucasian	Yes	No
Celik [37]	2016	30	Phacoemulsification	1 mth	Asian	No	Yes
Cevher [38]	2021	22	Phacoemulsification	1 wk, 1 mth	Asian	No	Yes
Chen [39]	2018	36	Phacoemulsification	1 wk, 1 mth, 3 mths	Asian	No	No
Chen [9]	2022	26	FLACS	1 wk, 1 mth, 3 mths	Asian	No	No
Falcão [15]	2014	14	Phacoemulsification	1 wk, 1 mth	Caucasian	No	No
Gama	2016	20	Phacoemulsification	1 wk, 1 mth	Caucasian	No	Yes
Ghiasian [40]	2021	32	Phacoemulsification	1 mth	Asian	No	Yes
Gudauskiene [41]	2019	30	Phacoemulsification	1 mth, 3 mths	Caucasian	No	No
Ibrahim [42]	2018	53	Phacoemulsification	1 wk, 1 mth, 3 mths	Caucasian	No	No
İçöz [13]	2023	50	Phacoemulsification	1 mth, 3 mths	Asian	No	Yes
Ikegami [22]	2020	33	Phacoemulsification	1 wk, 1 mth, 3 mths	Asian	Yes	No
Jiang [43]	2018	100	Phacoemulsification	1 wk, 1 mth, 3 mths	Asian	No	No
Ma [44]	2017	23	Phacoemulsification	1 wk, 1 mth	Asian	Yes	No
Ma [10]	2021	47	FLACS and Phaco	1 wk, 1 mth, 3 mths	Asian	Yes	No
Pierru [45]	2014	32	Phacoemulsification	1 wk, 1 mth, 3 mths	Caucasian	Yes	No
Shahzad [46]	2018	101	Phacoemulsification	1 wk, 1 mth	Asian	No	Yes
Torabi [28]	2019	21	Phacoemulsification	1 wk, 1 mth, 3 mths	Asian	Yes	No
Tranos [12]	2023	46	Phacoemulsification	1 wk, 1 mth, 3 mths	Caucasian	No	Yes
Yao [26]	2020	23	Phacoemulsification	1 wk, 1 mth, 3 mths	Asian	Yes	Yes
Yao [11]	2023	22	Phacoemulsification	1 wk, 1 mth, 3 mths	Asian	Yes	Yes
Yip [24]	2019	18	Phacoemulsification	1 mth, 3 mths	Asian	Yes	Yes
Yilmaz [16]	2016	65	Phacoemulsification	1 wk, 1 mth, 3 mths	Asian	Yes	No

DM: diabetes mellitus. FLACS: femtosecond laser-assisted cataract surgery.

The publication dates ranged from January 2014 to September 2023. 21 of 29 studies were performed in Asian eyes and the remaining 8 were performed in Caucasian eyes. 10 studies were conducted on patients with DM and 13 studies using post-operative non-steroidal anti-inflammatory drugs (NSAIDs). Eyes in 4 studies underwent FLACS while eyes in the rest of the 25 studies underwent phacoemulsification surgery.

Risk of bias in included studies:

The Cochrane Reviewer's Handbook evaluation chart was created to determine the overall quality of the literature. The results are depicted in Figure 2. Random sequence generation (selection bias), allocation concealment (selection bias), blinding of participants and personnel (performance bias), attrition bias, reporting bias, and other bias were "low risk" in most studies.

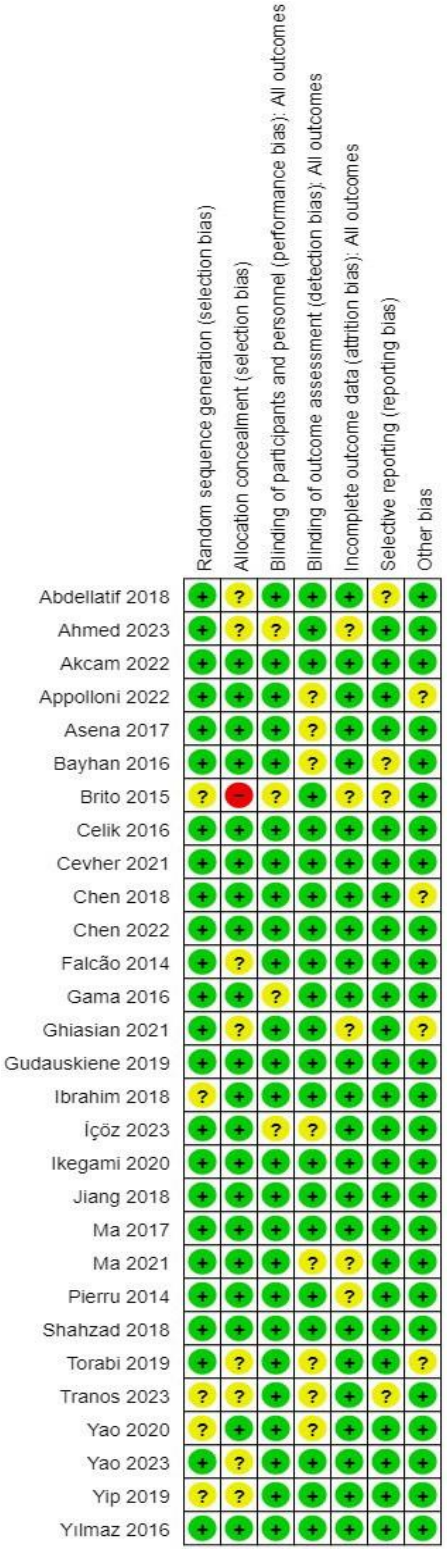

Figure 2: *Risk of bias using Cochrane risk of bias tool (RoB 2).*

Random sequence generation (selection bias) was "unclear risk" for five studies, and "low risk" for the rest. Allocation concealment (selection bias) was "high risk" for one study, "unclear risk" in eight studies but "low risk" in others. Incomplete outcome data (attrition bias) posed "uncertain risk" for five studies, and "low risk" for the remaining studies. There were four "uncertain risk" articles with selective reporting (reporting bias), and the rest were "low risk" articles. Another bias was classified as "uncertain risk" in three studies and "low risk" in the remaining studies.

Primary outcomes:

Difference in CT between pre-operative baseline and 1-week after surgery

For phacoemulsification, a total 18 studies including 1786 eyes provided detailed information on CT 1 week post-operatively. There was no significant difference in CT found (MD=1.19, 95% CI:-1.02-3.40, *P*=0.29, I^2=57%) (Figure 3a).

For FLACS, a total of 4 studies including 294 eyes similarly showed no significant differences in CT pre-operatively compared to 1-week post-operatively (MD=1.16, 95% CI: -7.71-10.03, *P*=0.80, I^2=0%) (Figure 3b). A summary of the data is presented in Table 2.

Difference in CT between pre-operative baseline and 1-month after surgery

For phacoemulsification, a total 24 studies including 2084 eyes provided detailed information on CT 1-month post-operatively. There was no significant difference in CT found (MD=0.73, 95% CI:-1.61-3.06, *P*=0.54, I^2=59%) (Figure 3c).

For FLACS, a total of 4 studies including 294 eyes similarly showed no significant difference in CT pre-operatively compared to 1-month post-operatively (MD=1.29, 95% CI: -7.46-10.05, *P*=0.77, I^2=0%) (Figure 3d).

Difference in CT between pre-operative baseline and 3-months after surgery

For phacoemulsification, a total 16 studies including 1534 eyes provided detailed information on CT 3-months post-operatively. There was no significant difference in CT found (MD=-0.13, 95% CI:-2.22-1.97, *P*=0.91, I^2=70%) (Figure 3e).

For FLACS, a total of 2 studies including 140 eyes similarly showed no significant differences in CT pre-operatively compared to 3-months post-operatively (MD=2.28, 95% CI: -9.63-14.19, *P*=0.71, I^2=0%) (Figure 3f).

Secondary outcomes:

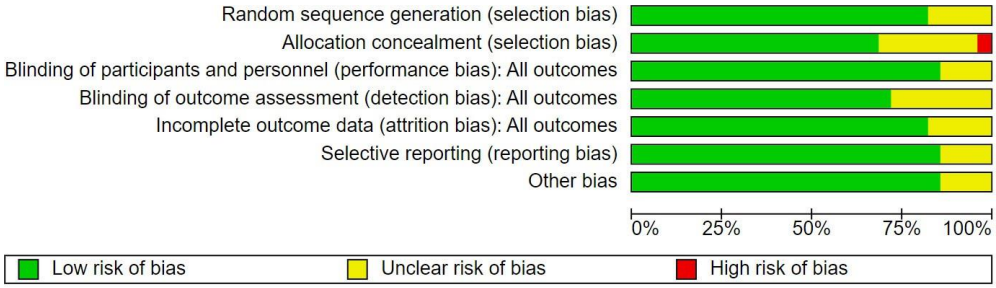

Figure 3a: *Phacoemulsification choroidal thickness difference between control and 1-week after surgery.*

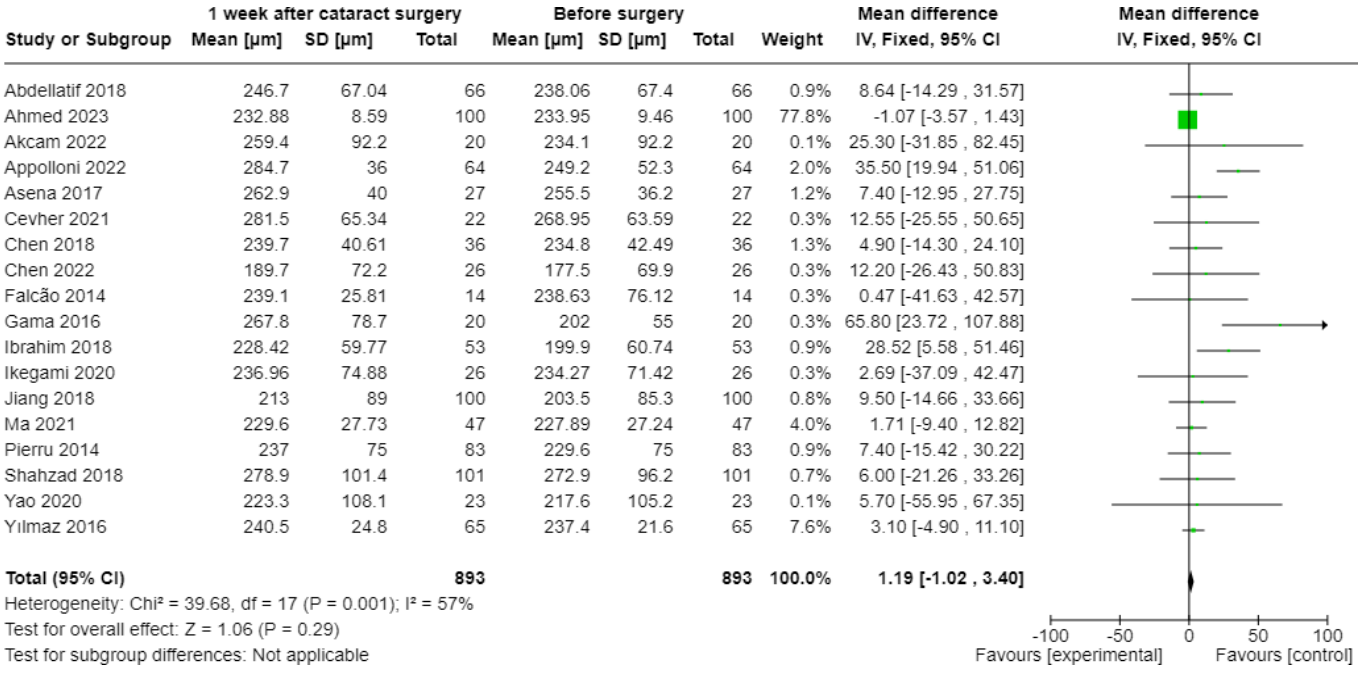

Figure 3b: *FLACS choroidal thickness difference between control and 1-week after surgery.*

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Table 2. *Summary of I² Values for Differences in Choroidal Thickness.*

Timepoint	Group	Mean Difference (MD)	95% CI	P-value	I² (%)
1-week post-op vs. pre-op	Phacoemulsification	1.19	-1.02 to 3.40	0.29	57
	Femtosecond	1.16	-7.71 to 10.03	0.80	0
1-month post-op vs. pre-op	Phacoemulsification	0.73	-1.61 to 3.06	0.54	59
	Femtosecond	1.29	-7.46 to 10.05	0.77	0
3-months post-op vs. pre-op	Phacoemulsification	-0.13	-2.22 to 1.97	0.91	70
	Femtosecond	2.28	-9.63 to 14.19	0.71	0
3-months post-op vs. pre-op (DM only)	All surgical types (DM only)	8.9	1.55 to 16.25	0.02	37

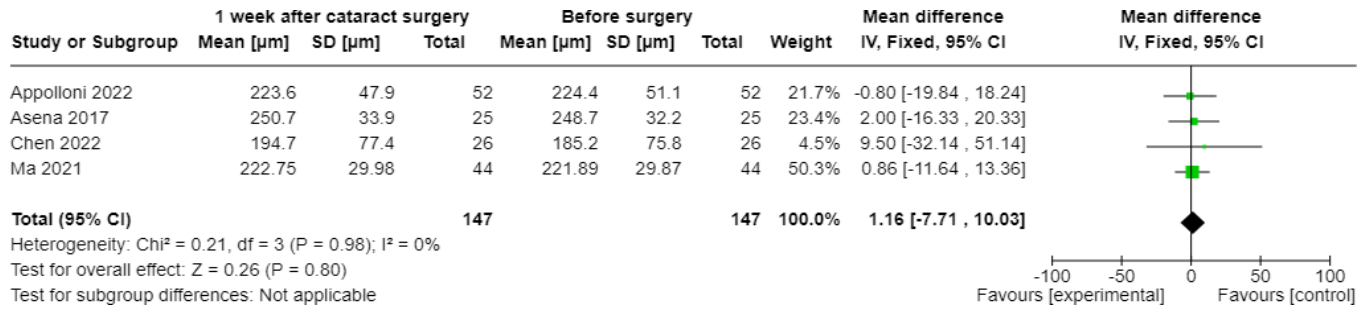

Figure 3c: *Phacoemulsification choroidal thickness difference between control and 1-month after surgery.*

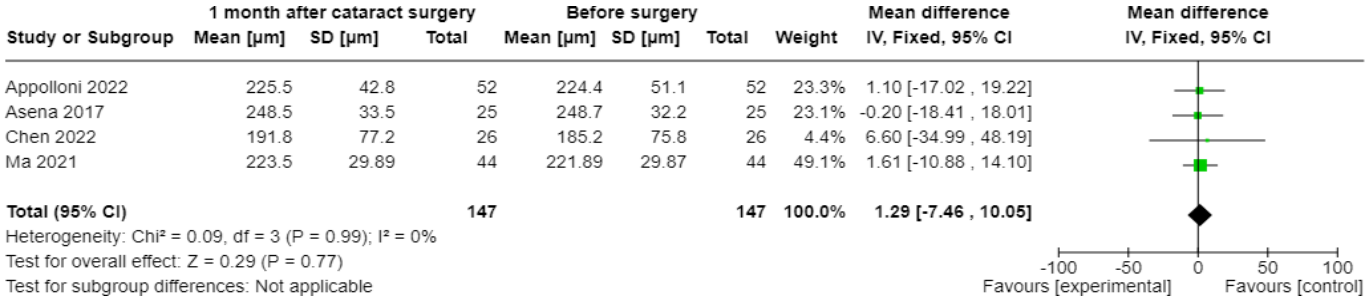

Figure 3d: *FLACS choroidal thickness difference between control and 1-month after surgery.*

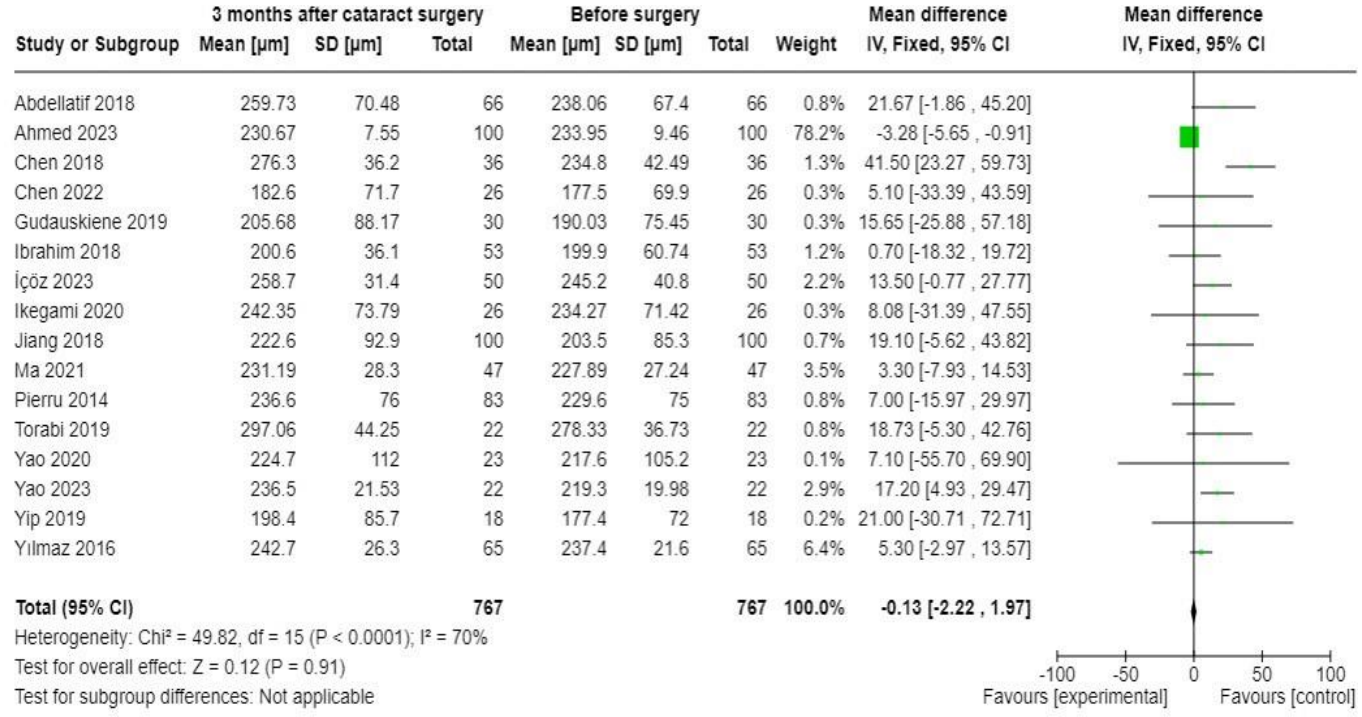

Figure 3e: *Phacoemulsification choroidal thickness difference between control and 3-months after surgery.*

Difference in CT in DM patients between pre-operative baseline and 1-week, 1-month, and 3-months

The analysis for participants with DM showed a statistically significant increase in CT 3-months post-operatively versus pre-operatively (MD=8.90, 95% CI: 1.55-16.25, *P*=0.02, I^2=37%) from 7 studies (Figure 4a). There were no statistically significant differences for results at 1-week (*P*=0.22) and 1-month (*P*=0.31).

Choroidal thickness comparison of DM patients on NSAIDs

In a subgroup analysis comparing CT at 1-week, 1-month, and 3-months post-operatively versus pre-operatively in participants with DM, CT for those on NSAIDs were statistically thicker at 3-months post-operatively (MD=8.90, CI=1.55-16.25, *P*=0.008) **(figure 4b)** and at 1-week (MD=4.13, CI=-2.48-10.74, *P*=0.04) (Figure 4c). No significant increase was noted at 1-month (*P*=0.29).

Choroidal thickness comparison by ethnicity

Subgroup analysis by ethnicity showed that Caucasian ethnicity had a significant increase in CT at 1-week post-surgery (MD=1.19, CI=-1.02-3.40, *P*<0.00001) (Figure 5a) and 1-month post-surgery (MD=0.73, CI=-1.61-3.06, *P*=0.0003) (Figure 5b), compared to preoperative baseline. No significant increase from baseline was noted at 3-months (*P*=0.49).

Choroidal thickness comparison for non-DM patients on anti-inflammatory medications

Patients who were on NSAIDs had a significant increase in CT at 1-month compared to pre-operative baseline (MD=0.73, CI=-1.61-3.06, *P*<0.0001) (Figure 6a). At 3-months, patients who were on NSAIDs had significantly increase in CT compared to pre-operative baseline (MD=-0.13, CI=-2.22-1.97, *P*<0.0001) (figure 6b).

Discussion

Our systematic review and meta-analysis of 29 studies with a pooled total of 2084 eyes showed firstly, that there were no significant changes in CT at 1 week, 1 month, and 3 months after either standard phacoemulsification or FLACS compared to preoperative baseline, with also no significant difference in the change in CT between FLACS and phacoemulsification. Secondly, in diabetic patients who underwent phacoemulsification, CT was significantly greater than before surgery at 3 months, but not at 1 week or 1 month post-operatively. Thirdly, patients not on anti-inflammatory medications post-operatively in both DM and non-DM patients were more likely to have increased CT. Lastly, CT in Caucasian, but not Asian patients who underwent phacoemulsification was significantly thicker at 1 week and 1 month post-operatively, compared to pre-operative baselines.

CT did not change significantly at 1 week, 1 month, and 3 months post-operatively compared to baseline

The main finding of our study was the lack of a significant change in CT after cataract surgery in non-DM patients in both phacoemulsification and FLACS groups throughout the 3 follow-up periods, from 1 week to 3 months post-operatively. Results from a previous meta-analysis in 2018 by Zeng et al. [5] appears to contradict our findings, observing that there was significant increase in CT throughout the 3-month post-operative period in eyes treated with standard

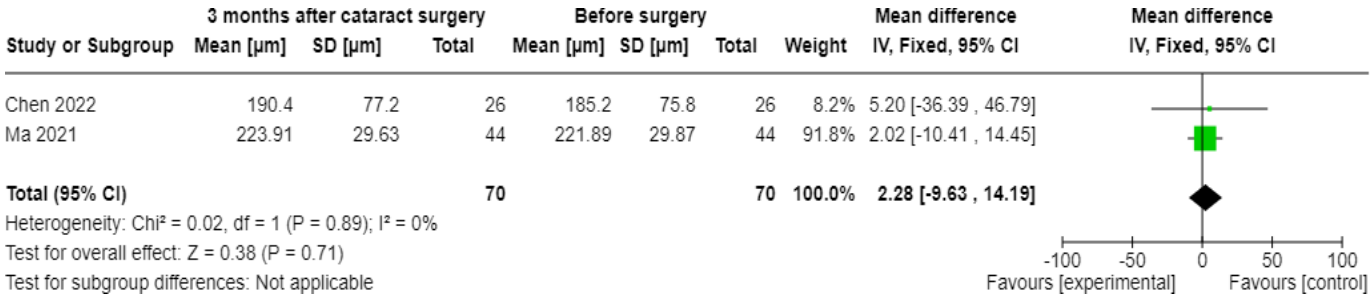

Figure 3f: *FLACS choroidal thickness difference between control and 3-months after surgery.*

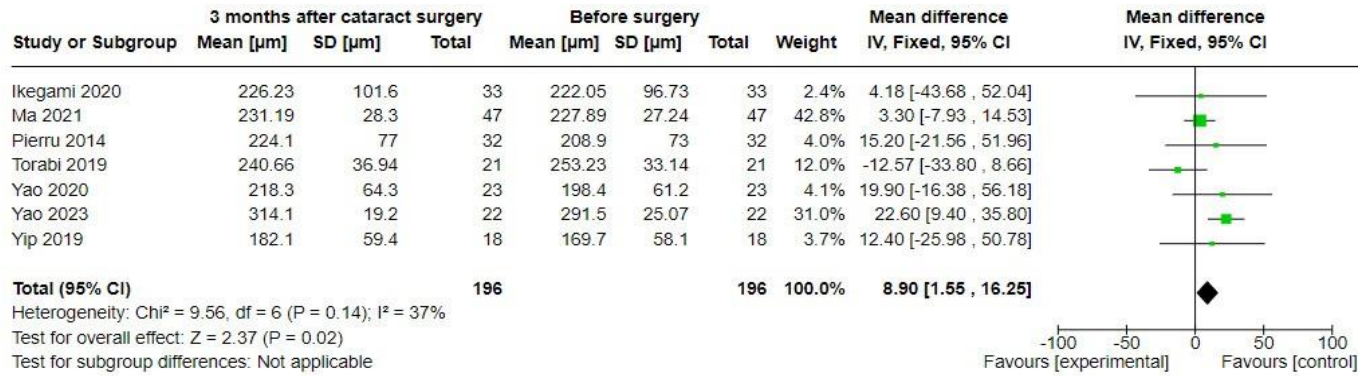

Figure 4a: *Choroidal thickness comparison for DM patients at 3 months compared to pre-operatively.*

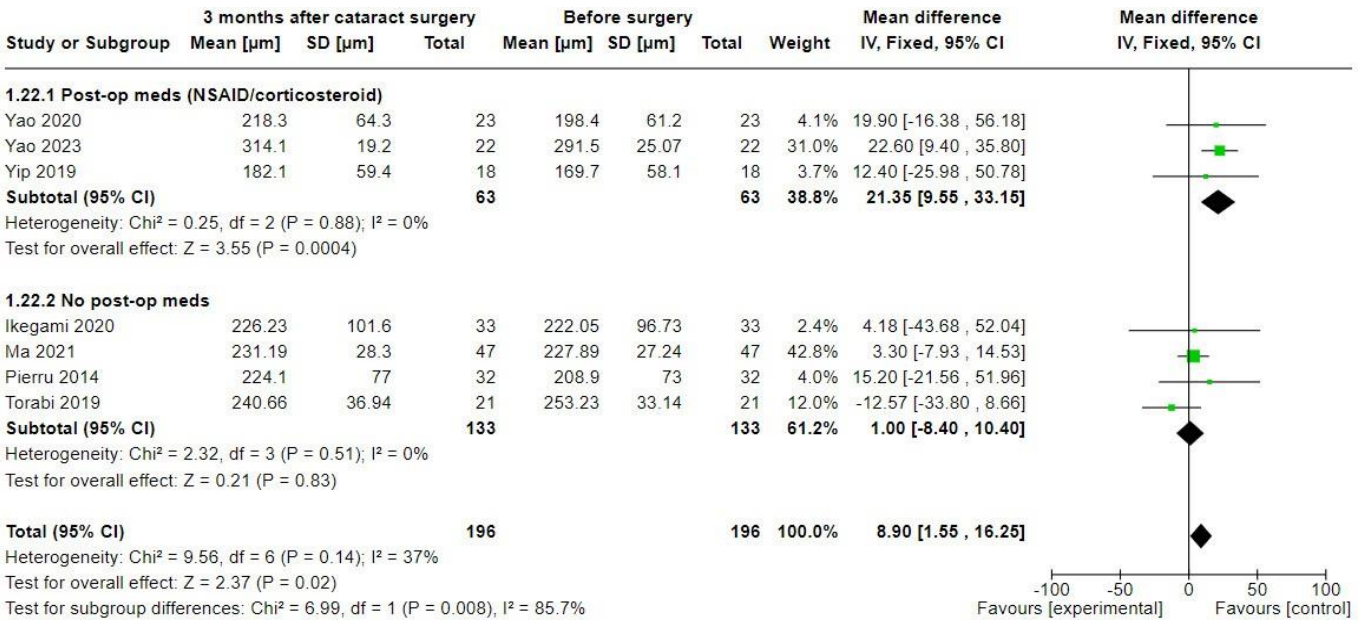

Figure 4b: *Choroidal thickness comparison of DM patients on topical steroids at 3 months compared to pre-operatively.*

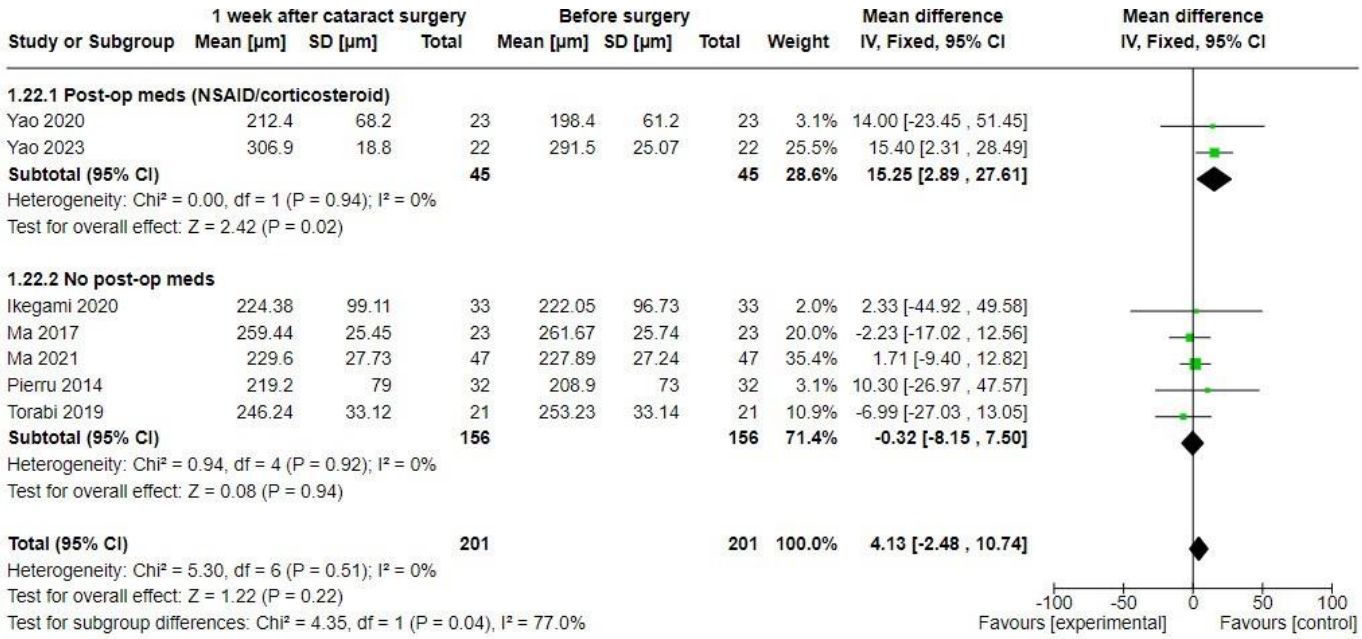

Figure 4c: *Choroidal thickness comparison of DM patients on topical steroids at 1 week compared to pre-operatively.*

phacoemulsification. However, Zeng's study included 13 studies which were all published prior to 2018. Our review incorporated an additional 16 studies published between 2018 and 2023. We observed that older studies tended to report more significant CT changes. Notably, 75% (3/4) of recent studies that compared FLACS to phacoemulsification reported a lesser change in CT in the standard phacoemulsification group compared to the FLACS group. This discrepancy may be attributed to modern machines having more advanced phacodynamics with more efficient energy delivery. These advancements lead to reduced ultrasound time and energy usage, and may therefore result in decreased inflammation and swelling of the choroid.[18] Secondly, our methodology differs slightly from that of Zeng et al., in that our study exclusively examined subfoveal CT, in contrast to Zeng's meta-analysis which included analysis of the temporal and nasal CT as well [5]. CT has been found to vary across different regions [19] and this may have further contributed to the discrepancy in findings in both studies.

The absence of a statistically significant increase in CT following phacoemulsification may also be explained by inflammation following phacoemulsification being insufficient to cause significant CT changes [14, 15]. This could be due to advancements in modern phacoemulsification technology and machines, which offer improved control over ultrasound energy, reduced cumulative dissipated energy and shorter procedural times [20]. These improvements may lead to less

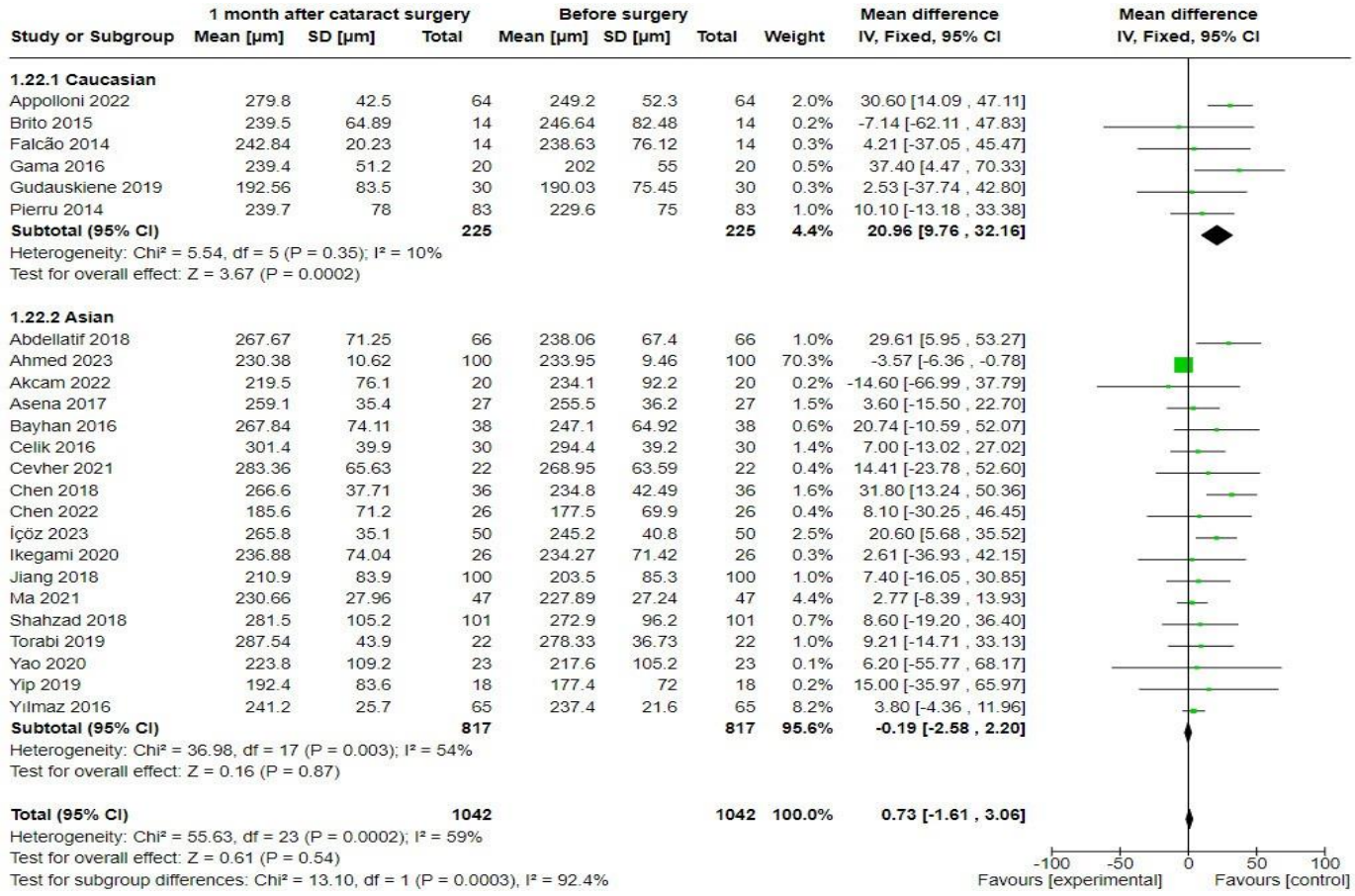

Figure 5: *Choroidal thickness comparison by ethnicity at 1 month.*

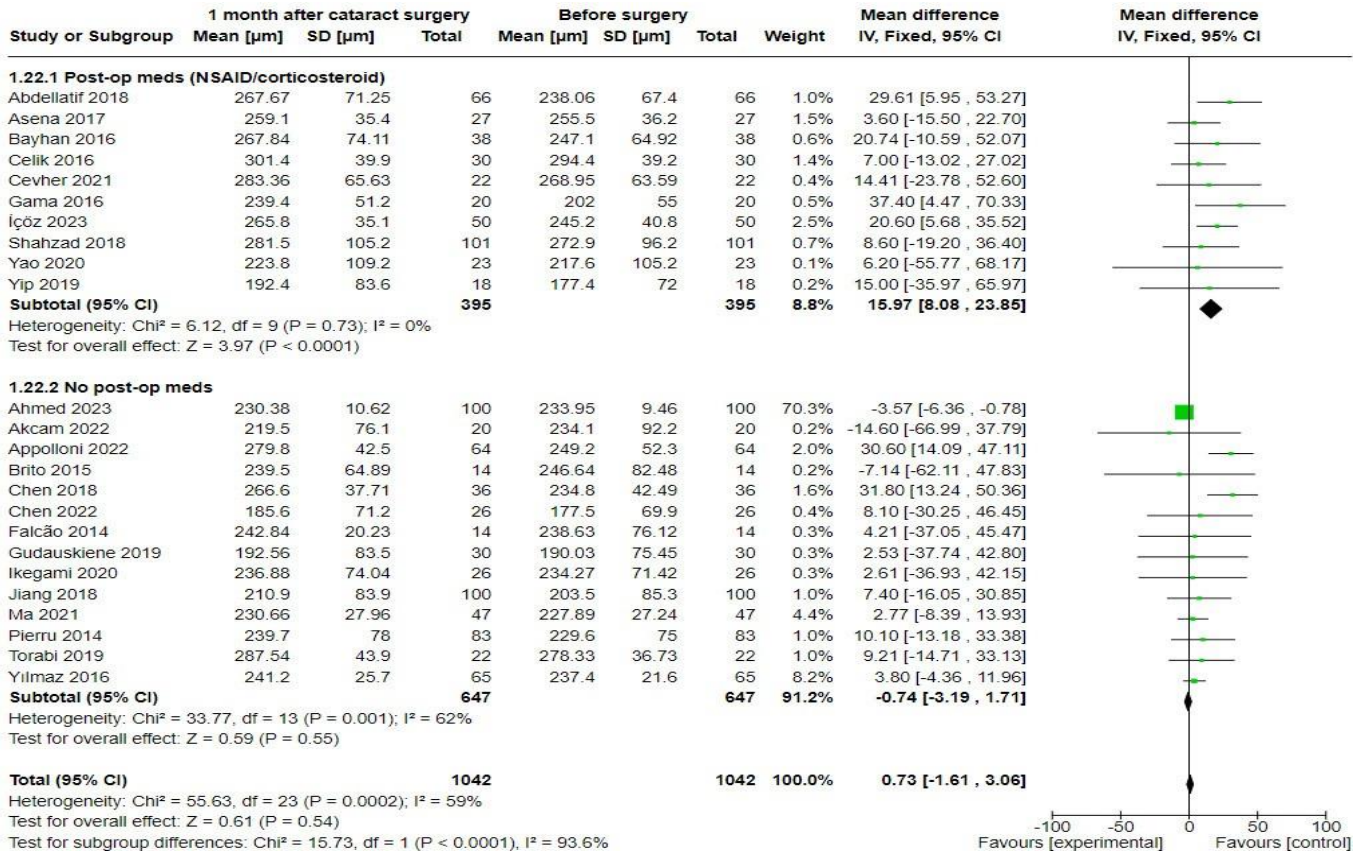

Figure 6a: *Choroidal thickness comparison for phacoemulsification non-DM patients on NSAIDs at 1 month.*

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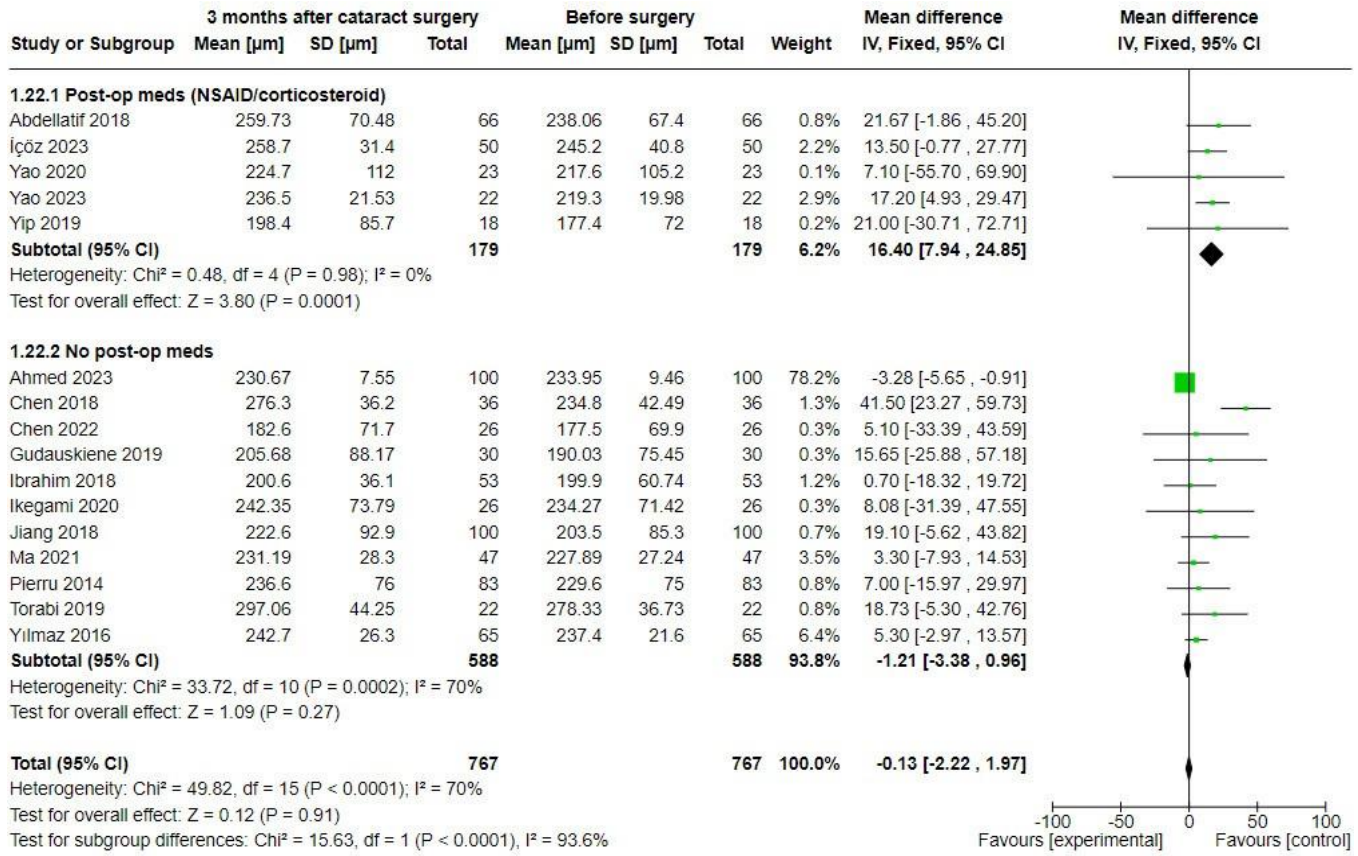

Figure 6b: *Choroidal thickness comparison for phacoemulsification non-DM patients on NSAIDs at 3 months.*

manipulation of the anterior segment during surgery, resulting in less inflammation and reduced release of prostaglandins within the eye, and therefore minimal changes to CT post-cataract surgery. Future research can further explore the impact of different phacoemulsification techniques and settings – such as torsional ultrasound or pulsed energy delivery – on post-operative CT. This may aid in the refinement of existing surgical techniques and settings to minimize choroidal inflammation.

Some subgroup analyses yielded wide confidence intervals, particularly for the FLACS group. This was likely due to smaller sample sizes or heterogeneity across the studies. Although there was minimal differences in choroidal thickness postoperatively, we are unable rule out the possibility of clinically relevant effects. Future studies with larger, more homogenous samples are needed to more precisely estimate the true effect size and to clarify the clinical implications of these changes in choroidal thickness.

The CT of DM patients significantly increased at 3 months post-operatively

Our study demonstrated that diabetic patients who underwent phacoemulsification had significantly greater CT at 3 months but not at 1 week or 1 month post-operatively, compared to pre-operative baselines. This finding is consistent with the results of previous studies [14, 21]. Yasuko et al's [22] study in diabetic eyes showed a similar significant increase in CT at 3 months. DM is a well-established risk factor for macular edema, and it has been shown that CT increases with the severity of macular edema [4]. DM patients have been estimated to have a 4-fold risk of developing macular edema, compared to healthy patients post-cataract surgery [23].

While CT was thicker in DM patients at 3 months, the difference was not statistically significant at 1 week or 1 month after surgery. One possible explanation for this finding could be that many of the included eyes were in the early stages of retinopathy (70%). As such, angiopathic changes in the choroidal capillaries may be less severe and therefore not detectable by OCT [14]. Yip et al., [24] proposed that the functional integrity of the choroid in diabetic retinopathy remains intact after initial damage, as the choroid is relatively resistant to the effects of diabetic retinopathy due to an abundance of choroidal vessels and adequate blood flow. While most studies identify the peak risk for post-operative CME to be at around 1 month after surgery, Noda et al., [25] suggested that the increased light exposure from cataract surgery, leading to metabolic activation in the RPE, potentially induces angiogenesis and contributes to sustained increase in CT beyond 1 month. Hence, factors beyond the initial inflammatory response may be influencing changes in the CT over a longer period of time post-operatively.

Reduction of anti-inflammatory medication dose was more likely to increase CT

The use of topical anti-inflammatory in both DM and non-DM patients who underwent phacoemulsification showed significantly thicker CT, specifically at 1 month for non-

DM patients and at 1 week for DM patients, compared to before surgery. Zeng et al., [5] suggested that topical anti-inflammatory should be used 3 times daily up to 1 month post-surgery to decrease the risk of postoperative swelling and pain. However, all 3 studies in our analysis that used anti-inflammatory medications post-operatively only did so for 1 week before reducing dosages. Yao et al 2020 [26] and Yao et al 2023 [11] both used tobramycin-dexamethasone eyedrops administered 4 times a day for 1 week, then prednisolone acetate 1.0% and levofloxacin 0.5% eyedrops administered 3 times a day for 3 weeks. Yip et al [24] used one month of topical steroids (prednisolone acetate eye drops every 3 hourly for a week, then 4 times a day for 3 weeks). Notably, the relative increase in CT coincided with the reduction of dose of topical anti-inflammatory following the 1-week timepoint. Another study by Hoffam et al., [27] also demonstrated that decreasing dosage of steroids results in less reduction in choroidal edema.

In real-life clinical practice, the inflammatory insult caused by phacoemulsification is counteracted by post-operative topical steroids or NSAIDs [27]. However, despite the use of steroids or NSAIDs, surgery still appeared to induce a significant increase in CT in DM patients, in our pooled analysis. Studies on CT in diabetics have conflicting results and have reported both a decrease [28] and increase [11, 24, 26] in CT. Studies have also demonstrated a significant change in CT with fluctuation in plasma glucose levels [23, 29, 30], suggesting that the severity of DM may affect CT as well.

CT changes may vary in different ethnicities

Post-operative CT increased at both 1 week and 1 month for Caucasian, but not Asian eyes. In contrast, the meta-analysis by Zeng et al [5] showed this effect in Asian patients but not in Caucasian patients. To date, there have been few studies investigating changes in CT among different ethnicities after cataract surgery. A large multi-ethnic epidemiological study demonstrated that subfoveal CT is influenced by age, gender, and ethnicity [31]. A study analysing 25000 cases of CME in the United States from 2016 to 2019 revealed that Asians were 0.75 times less likely to develop CME compared to Whites. Our findings showed a greater post-operative increase in CT for Caucasians compared to Asians, which may suggest a correlation between increased CT and a higher incidence of CME [32]. Ethnic variations in choroidal vascular structure, inflammatory response, or vascular endothelial function may contribute to differential choroidal thickening. Systemic conditions such as hypertension and diabetes, which vary in prevalence and phenotype across ethnicities, could further modulate post-surgical CT response. Environmental influences, including diet and UV exposure, may also play a role. Further research into the underlying mechanisms of these ethnic disparities may encourage more informed personalized post-operative care, targeting specific ethnic groups at a higher risk for complications such as CME.

Study limitations

Several limitations should be considered for the interpretation of our results. Firstly, many of the studies did not control for the duration of the surgery, the time and energy used in phacoemulsification, or the surgeon's level of expertise. Additionally, the presence of intraoperative complications were not excluded. These factors could significantly impact CT outcomes post cataract surgery [19]. We were not able to control these factors as studies did not document these characteristics. Secondly, we were unable to include time points earlier than 1 week, as almost all the studies only examined CT from 1 week postoperatively onwards. Studies have shown that changes to CT can occur earlier than 1 week postoperatively [15, 19]. Third, variations in optical coherence tomography imaging protocols and devices use across studies may influence measurements and variability in reported outcomes.

Directions for future research

In addition to the abovementioned, other potential aspects of further research may include the role of pre-and intra-operative OCT Angiography (OCTA), the influence of other common systemic diseases beyond DM on post-phacoemulsification CT changes, as well as differences in CT changes following unilateral versus simultaneous bilateral phacoemulsification.

Firstly, OCTA could play a pivotal role in pre- and intra-operatively assessing the choroidal microvascular environment during cataract surgery. Pre-operative OCTA may identify subtle choroidal capillary changes that are not evident in standard structural OCT, while intra-operative OCTA could offer real-time insights into how cataract surgery impacts the choroidal vasculature. These approaches may help stratify patients at risk for post-surgical CT changes and improve our understanding of why certain patients, such as those with DM, exhibit significant changes later in the post-operative period. Secondly, while our review focused on patients with DM, other common systemic conditions such as hypertension, cardiovascular disease, and other chronic inflammatory diseases may also play a critical role in influencing CT after cataract surgery. Hypertension, for instance, is known to affect the choroidal vasculature and could contribute to changes in CT, especially when combined with the inflammatory stress of cataract surgery. Investigating the relationship between these systemic diseases and CT changes may uncover additional risk factors for post-operative complications and guide tailored management strategies for these patients. Finally, simultaneous bilateral cataract surgery is becoming increasingly common, yet its impact on CT is not well-studied. Given that bilateral surgery may induce a greater systemic inflammatory response compared to unilateral procedures, it is possible that this approach could lead to greater changes in CT. Future studies would aid in understanding whether performing bilateral surgeries at the same time would influence the inflammatory and healing processes in the choroid, to the same degree as unilateral surgery.

In summary, the findings of our meta-analysis suggest that CT does not exhibit a significant increase at 1 week, 1 month, and 3 months post-cataract surgery, following either phacoemulsification or FLACS. However, in diabetic patients, CT showed an increase at the 3-month post-operative timepoint. The administration of NSAIDs post-surgery may

lead to increased CT at the 3-month follow-up, observed in both diabetic and non-diabetic patients. Finally, Caucasians appeared to exhibit thicker CT after cataract surgery. Expanding future studies to include these aspects will provide a more holistic view of the factors influencing choroidal thickness after cataract surgery and could lead to improved patient outcomes through more personalized surgical and postoperative care.

References

1. Cicinelli MV, Buchan JC, Nicholson M, Varadaraj V, Khanna RC. Cataracts. The Lancet. 2023;401(10374):377-89.
2. BRADFORD DJ, Wilkinson CP, BRADFORD JR RH. Cystoid macular edema following extracapsular cataract extraction and posterior chamber intraocular lens implantation. Retina. 1988;8(3):161-4.
3. Seth I, Bulloch G, Tan A, Thornell E, Agarwal S. Incidence of pseudophakic cystoid macular oedema post-cataract surgery in Illawarra Shoalhaven Local Health District, Australia. Biomed hub. 2022;7(1):1-0.
4. Amjad R, Lee CA, Farooqi HM, Khan H, Paeng DG. Choroidal thickness in different patterns of diabetic macular edema. J Clin Med. 2022;11(20):6169.
5. Zeng S, Liang C, He Y, Chen Y, Zhao Q, Dai S, Cheng F, Zhang J, Jiang X. Changes of Subfoveal Choroidal Thickness after Cataract Surgery: A Meta- Analysis. J Ophthalmol. 2018;2018(1):2501325.
6. Aljundi W, Gradinger F, Langenbucher A, Sideroudi H, Seitz B, Abdin AD. Choroidal thickness as a possible predictor of non-response to intravitreal bevacizumab for macular edema after retinal vein occlusion. Sci Rep. 2023;13(1):451.
7. Appolloni R, Viggiano P, Carrella ML, Evangelista F, Appolloni A, Toto L, Mastropasqua L. Femto-assisted versus conventional phacoemulsification differently impact on choroid structure after surgery. Eur J Ophthalmol. 2022;32(4):2194-200.
8. Asena BS, Karahan E, Kaskaloglu M. Retinal and choroidal thickness after femtosecond laser-assisted and standard phacoemulsification. Clin Ophthalmol. 2017 Aug 21:1541-7.
9. Chen W, Chen H, Mi L, Li J, Lin H, Chen W. Subfoveal choroidal thickness after femtosecond laser-assisted cataract surgery for age-related cataracts. Frontiers Med. 2022;9:826042.
10. Ma LY, Rong A, Jiang Y, Deng SY. Effects of femtosecond laser-assisted cataract surgery on macular and choroidal thickness in diabetic patients. Ophthalmol Ther. 2021;10(1):137-50.
11. Yao H, Yang Z, Cheng Y, Shen X. Macular changes following cataract surgery in eyes with early diabetic retinopathy: an OCT and OCT angiography study. Frontiers Med. 2023;10:1290599.
12. Tranos P, Dimacali V, Vasileiou D, et al., The Effects of Uneventful Phacoemulsification on Subfoveal Choroidal Thickness. Ophthalmol Ther. 2023;12(6):3013-23.
13. İçöz M. Evaluation of structural and vascular changes in the choroid after uneventful phacoemulsification surgery. Rom J Ophthalmol. 2023;67(1):50.
14. Brito PN, Rosas VM, Coentrão LM, Carneiro ÂV, Rocha-Sousa A, Brandão E, Falcão-Reis F, Falcão MA. Evaluation of visual acuity, macular status, and subfoveal choroidal thickness changes after cataract surgery in eyes with diabetic retinopathy. Retina. 2015;35(2):294-302.
15. Falcão MS, Gonçalves NM, Freitas-Costa P, Beato JB, Rocha-Sousa A, Carneiro Â, Brandão EM, Falcão-Reis FM. Choroidal and macular thickness changes induced by cataract surgery. Clin Ophthalmol. 2013:55-60.
16. Yilmaz T, Karci AA, Yilmaz İ, Yilmaz A, Yildirim Y, Sakalar YB. Long-term changes in subfoveal choroidal thickness after cataract surgery. Med Sci Monit: Int Med J Exper Clin Res. 2016;22:1566.
17. Tugwell P, Tovey D. PRISMA 2020. J Clin Epidemiol. 2021;134:A5-6.
18. Balas M, Kwok JM, Miguel A, Rai A, Rai A, Ahmed II, Schlenker MB. The cataract surgery learning curve: quantitatively tracking a single resident's operative actions throughout their training. Am J Ophthalmol.. 2023;249:82-9.
19. Ohsugi H, Ikuno Y, Ohara Z, Imamura H, Nakakura S, Matsuba S, Kato Y, Tabuchi H. Changes in choroidal thickness after cataract surgery. J Cataract Refract Surg. 2014;40(2):184-91.
20. Nagy ZZ, Ecsedy M, Kovács I, et al., Macular morphology assessed by optical coherence tomography image segmentation after femtosecond laser–assisted and standard cataract surgery. J Cataract Refract Surg. 2012;38(6):941-6.
21. Kim SJ, Equi R, Bressler NM. Analysis of macular edema after cataract surgery in patients with diabetes using optical coherence tomography. Ophthalmol. 2007;114(5):881-9.
22. Ikegami Y, Takahashi M, Amino K. Evaluation of choroidal thickness, macular thickness, and aqueous flare after cataract surgery in patients with and without diabetes: a prospective randomized study. BMC ophthalmol. 2020;20(1):102.
23. Lee HK, Lim JW, Shin MC. Comparison of choroidal thickness in patients with diabetes by spectral-domain optical coherence tomography. Kor J ophthalmol: KJO. 2013;27(6):433.
24. Yip VC, Laude A, Tan KA, Ding J, Wong E, Agrawal R. A longitudinal study of choroidal changes following cataract surgery in patients with diabetes. Diab Vasc Dis Res. 2019;16(4):369-77.
25. Y, N., et al., Long-term increase in subfoveal choroidal thickness after surgery for senile cataracts. Am J Ophthalmol., 2014. 158(3): p. 455-9.e1.

26. Yao H, Gao S, Liu X, Zhou Y, Cheng Y, Shen X. Choroidal Structural Changes Assessed with Swept-Source Optical Coherence Tomography after Cataract Surgery in Eyes with Diabetic Retinopathy. J ophthalmol. 2020;2020(1):5839837.
27. Hoffman RS, Braga-Mele R, Donaldson K, et al., Cataract surgery and nonsteroidal antiinflammatory drugs. J Cataract Refract Surg. 2016;42(9):1368-79.
28. Torabi H, Sadraei M, Jadidi K, Alishiri AA. Choroidal thickness changes following cataract surgery in patients with type 2 diabetes mellitus. J Curr Ophthalmol. 2019;31(1):49-54.
29. Ţălu Ş, Nicoara SD. Malfunction of outer retinal barrier and choroid in the occurrence and progression of diabetic macular edema. World J Diabetes. 2021;12(4):437.
30. Abalem MF, Nazareth Santos Veloso H, Garcia R, et al., The effect of glycemia on choroidal thickness in different stages of diabetic retinopathy. Ophthal Res. 2020;63(5):474-82.
31. Song Y, Tham YC, Chong C, et al., Patterns and determinants of choroidal thickness in a multiethnic Asian population: the Singapore Epidemiology of Eye Diseases Study. Ophthalmol Retina. 2021;5(5):458-67.
32. Iftikhar M, Dun C, Schein OD, et al., Cystoid macular edema after cataract surgery in the United States: IRIS® Registry (Intelligent Research in Sight) analysis. Ophthalmol. 2023;130(10):1005-14.
33. Abdellatif MK, Ebeid WM. Variations in choroidal and macular thickness maps after uneventful phacoemulsification. Semin Ophthalmol. 2018 (Vol. 33, No. 5, pp. 719-725). Taylor & Francis.
34. Ahmed J, Mukhtar A, Mehboob MA, et al., Effect of Phacoemulsification on Sub Foveal Choroidal and Central Macular Thickness as measured by Swept Source Optical Coherence Tomography. Pak J Med Sci. 2023;39(4):941.
35. Akcam HT, Ozmen MC, Ceylanoglu KS, et al., Changes in choroidal and foveal retinal thickness after cataract surgery: Our results. The Surg. 2022;20(5):e266-72.
36. Aslan Bayhan S, Bayhan HA, Muhafiz E, et al., Evaluation of choroidal thickness changes after phacoemulsification surgery. Clin Ophthalmol. 2016:961-7.
37. Celik E, Cakır B, Turkoglu EB, et al., Effect of cataract surgery on subfoveal choroidal and ganglion cell complex thicknesses measured by enhanced depth imaging optical coherence tomography. Clin Ophthalmol. 2016:2171-7.
38. Cevher S, Aydoğdu G. How does nepafenac affect the choroidal thickness after uneventful cataract surgery?. Eur J Ophthalmol. 2021;31(5):2319-28.
39. Chen H, Wu Z, Chen Y, et al., Short-term changes of choroidal vascular structures after phacoemulsification surgery. BMC ophthalmol. 2018;18(1):81.
40. Ghiasian L, Aghdam KA, Azizi E, et al., Choroidal thickness after phacoemulsification: nonrandomized comparison of postoperative topical ketorolac vs dexamethasone vs combination of ketorolac–dexamethasone eyedrops. J Cataract Refract Surg. 2021;47(1):46-52.
41. Gudauskiene G, Matuleviciute I, Mockute R, Maciulaityte E, Zaliuniene D. Changes in subfoveal choroidal thickness after uncomplicated cataract surgery. Biomed Papers. 2019;163(2):179-83.
42. Ibrahim AM, Elgouhary SM, Nassar MK, El Batanony AH. Changes in choroidal thickness after cataract surgery. Semin Ophthalmol. 2018 (Vol. 33, No. 5, pp. 664-670). Taylor & Francis.
43. Jiang H, Li Z, Sun R, Liu D, Liu N. Subfoveal choroidal and macular thickness changes after phacoemulsification using enhanced depth imaging optical coherence tomography. Ophthalmic Res. 2018;60(4):243-9.
44. Ma B, Liu Y, Liu S, Luo M. Evaluation of the effect of intracameral cefuroxime on macular and subfoveal choroidal thickness and macular sensitivity in diabetic patients after cataract surgery. J Cataract Refract Surg. 2017;43(2):201-6.
45. Pierru A, Carles M, Gastaud P, Baillif S. Measurement of subfoveal choroidal thickness after cataract surgery in enhanced depth imaging optical coherence tomography. Invest Ophthalmol Vis Sci. 2014;55(8):4967-74.
46. Shahzad R, Siddiqui MR, Zafar S, Kausar F, Shahzad MH. Choroidal thickness changes following cataract surgery using swept source optical coherence tomography. Can J Ophthalmol. 2018;53(1):60-4.