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REVIEW

Phaco-Chop versus Divide-and-Conquer in Patients Who Underwent Cataract Surgery: A Systematic Review and Meta-Analysis

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Background: Cataract surgery is one of the most frequently performed eye surgeries worldwide, and among several techniques, phacoemulsification has become the standard of care due to its safety and efficiency. We evaluated the advantages and disadvantages of two phacoemulsification techniques: phaco-chop and divide-and-conquer.

Methods: PubMed, Cochrane, Embase, and Web of Science databases were queried for randomized controlled trial (RCT), prospective and retrospective studies that compared the phaco-chop technique over the divide-and-conquer technique and reported the outcomes of (1) Endothelial cell count change (ECC); (2) Ultrasound time (UST); (3) Cumulated dissipated energy (CDE); (4) Surgery time; and (5) Phacoemulsification time (PT). Heterogeneity was examined with I^2 statistics. A random-effects model was used for outcomes with high heterogeneity.

Results: Nine final studies, (6 prospective RCTs and 3 observational), comprising 837 patients undergoing phacoemulsification. 435 (51.9%) underwent the phaco-chop technique, and 405 (48.1%) underwent divide-and-conquer. Overall, the phaco-chop technique was associated with several advantages: a significant difference in ECC change postoperatively (Mean Difference [MD] −221.67 Cell/mm^2; 95% Confidence Interval [CI] −401.68 to −41.66; p < 0.02; I2=73%); a shorter UST (MD −51.16 sec; 95% CI −99.4 to −2.79; p = 0.04; I2=98%); reduced CDE (MD −8.68 units; 95% CI −12.76 to −4.60; p < 0.01; I2=84%); a lower PT (MD −55.09 sec; 95% CI −99.29 to −12.90; *p* = 0.01; I2=100). There were no significant differences in surgery time (MD −3.86 min; 95% CI −9.55 to 1.83; p = 0.18; I2=99%).

Conclusion: The phaco-chop technique proved to cause fewer hazards to the corneal endothelium, with less delivered intraocular ultrasound energy when compared to the divide-and-conquer technique.

Keywords: meta-analysis, systematic review, cataract, cataract extraction, phaco-chop, divide-and-conquer, phacoemulsification

Introduction

Cataracts are one of the leading causes of blindness worldwide, defined as loss of lens transparency, alteration of refractive properties, and elevated light scattering, resulting in progressive loss of vision.[1] The cataract prevalence is higher in older age, a common age-related condition, but also develops due to other factors. The number is expected to increase to 40 million in 2025 with the aging of the world's population and greater life expectancies.[2]

Phacoemulsification is a widely used technique in cataract surgery, introduced by Charles Kelman in 1967, which has become the standard of care due to its safety and efficiency.[3,4] The employment of phacoemulsification techniques with the insertion of a foldable intraocular lens (IOL) is the procedure of choice for treatment, contributing to better outcomes using lower energy and, therefore, less corneal endothelial cell injury due to the amount of intraocular ultrasound energy dispensed.[5]

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Advancements in cataract surgery technology have increased the efficiency of phacoemulsification. In 1985, Gimbel described "divide-and-conquer" as the first nucleofractis cracking technique developed.[6] At the 1993 meeting of the American Society of Cataract and Refractive Surgery, Kunihiro Nagahara presented a technique known as "phaco-chop".[7]

With advancements in this technology, incision size, phacoemulsification energy, endothelial cell count (ECC), ultrasound energy dispensed, and cumulative dissipated energy (CDE) have been reduced, and several techniques have been described to optimize phacoemulsification, including phaco-chop and divide-and-conquer.[7–9] However, it's unclear if phaco-chop is truly superior when compared to divide-and-conquer.

In light of this controversy, we performed meta-analysis evaluating the efficacy and safety of the phaco-chop technique compared to the divide-and-conquer technique. We explored populations with cataracts in patients who underwent phacoemulsification and studies with a follow-up of 8 weeks. To the best of our knowledge, this is the first systematic review and meta-analysis comparing phaco-chop with the divide-and-conquer technique.

Methods

This meta-analysis was performed according to the guidelines of the Declaration Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) and the recommendations of the Cochrane Collaboration.[10,11] The protocol was registered in the International Prospective Register of Systematic Reviews (PROSPERO) under registration number CRD42023474315.

Eligibility Criteria

The inclusion criteria of this study were as follows: (1) Participants: patients who underwent cataract surgery; (2) Intervention: the use of the phaco-chop technique; (3) Comparison to divide-and-conquer technique; (4) At least one or more clinical outcomes: change endothelial cell count (ECC), ultrasound time (UST), cumulated dissipated energy (CDE), surgery time and phacoemulsification time; (5) Type of study: randomized clinical trials (RCT) and observational (OB) studies. The exclusion criteria were as follows: (1) non-comparative studies, case reports or series (with cases <10 patients), and animal studies; (2) editorials, letters, and conference proceedings without efficient data.

Information Source

Two authors (S.P. and D.A.) searched PubMed, Scopus, and Cochrane Central Register of Controlled Trials inception to October 2023 with the following search terms: "phacoemulsification" OR "phaco" AND "cataract" AND "phaco-chop", AND "divide-and-conquer". Two authors (L.H. and A.F.) independently extracted the data following predefined search criteria and quality assessment. Furthermore, the references from all included studies were also searched manually for any additional studies. Eventual conflicts were resolved by consensus among the authors.

Search Strategy

The following terms were used in this search strategy: "phacoemulsification" OR "phaco" AND "cataract" AND "phaco-chop", AND "divide-and-conquer".

We did not use publication date or language restrictions in our electronic search for the randomized clinical trials.

Study Selection

We imported search results into the Zotero software, and duplicated records were excluded. Two independent authors (S.P. and D.A.) applied eligibility criteria to screen the titles and abstracts. After that, the full text of potentially eligible studies was appraised.

Endpoints and Subgroup Analysis

Outcomes included change in endothelial cell count (ECC), ultrasound time (UST), cumulated dissipated energy (CDE), surgery time, and phacoemulsification time.

Risk of Bias Assessment

We evaluated the risk of bias in randomized studies using version 2 of the Cochrane Risk of Bias assessment tool. Non-randomized studies were assessed with the Risk of Bias in Non-randomized Studies - of Interventions tool (ROBINS-I).[12] Two independent authors completed the risk of bias assessment (L.H. and A.F). Disagreements were resolved through a consensus after discussing reasons for the discrepancy. Potential publication bias was evaluated through visual inspection of funnel plots and analysis of the control lines.[13]

Subgroup Analysis and Leave-One-Out Analysis

Subgroup analysis was conducted in outcomes with at least 4 articles based on the design of the article (RCT or observational) to identify if heterogeneity of results would arise from different design settings. The stability of the pooled estimates was appraised by leave-one-out analysis, sequentially removing data from one study and re-analyzing the remaining dataset to ascertain that the aggregated effect sizes were unaffected by a single study`s influence. A leave-one-out sensitivity analysis was also conducted in outcomes with at least 4 articles.[14,15]

Statistical Analysis

This systematic review and meta-analysis were performed in accordance with the Cochrane Collaboration and the PRISMA statement guidelines.[10] Continuous outcomes were compared with mean differences (MD). Heterogeneity across studies was evaluated using Cochran's Q test, I^2 test, and τ2 test. An I^2 value greater than 25% was considered indicative of high statistical heterogeneity, for which a random-effects model was used. A random-effects model was used for all analyses due to heterogeneity. Publication bias was investigated by funnel-plot analysis.[16] Review Manager 5.3 (Cochrane Centre, The Cochrane Collaboration, Denmark) was used for statistical analysis.

Results

Study Selection and Baseline Characteristics

As detailed in Figure 1, we found 103 articles, with 21 in PubMed (MedLine), 27 in Embase (Elsevier), 46 in Web of Science, and 9 in Cochrane databases. Of these, 32 were removed as duplicates. After the removal of duplicate records and ineligible studies, 11 remained and were thoroughly reviewed based on inclusion criteria. Next, three articles were excluded as per our exclusion criteria. Finally, eight studies were included in this review, six prospective randomized controlled trials (RCTs)[7,8,17–20] and three observational studies.[9,20,21] A total of 837 patients underwent phacoemulsification. 435 (51.9%) underwent the phaco-chop technique, and 405 (48.1%) underwent divide-and-conquer. Study characteristics are reported in Table 1.

Pooled Analysis

Among the included studies, 5 reported ECC count after surgery. For these studies, the pooled results revealed a significant difference between patients in phaco-chop and divide-and-conquer groups (MD: −221.67 Cell/mm^2; 95% CI: −401.68 to −41.66; $p < 0.02$; I2=73%; Figure 2). The results showed that the application of phaco-chop in cataract surgery has a smaller ECC when compared with the divide-and-conquer technique.

Among the included studies, four studies reported CDE after surgery. For these studies, the pooled results revealed a significant difference between patients in phaco-chop and divide-and-conquer groups (MD −8.68 units; 95% CI −12.76 to −4.60; $p < 0.01$; I2=84%; (Figure 3). The results showed that the application of phaco-chop in cataract surgery has a shorter ECC when compared with the divide-and-conquer technique.

Among the included studies, three studies reported the incidence of UST in surgery. For these studies, the pooled results revealed a significant difference between patients in phaco-chop and divide-and-conquer groups (MD −51.16 sec; 95% CI −99.4 to −2.79; $p = 0.04$; I2=98%; Figure 4). The results showed that the application of phaco-chop in cataract surgery has a shorter UST when compared with the divide-and-conquer technique.

Among the included studies, four studies reported the surgery time in surgery. For these studies, the pooled results revealed no significant difference between patients in phaco-chop and divide-and-conquer groups (MD −3.86 min; 95% CI −9.55 to 1.83; $p = 0.18$; I2=99%; Figure 5).

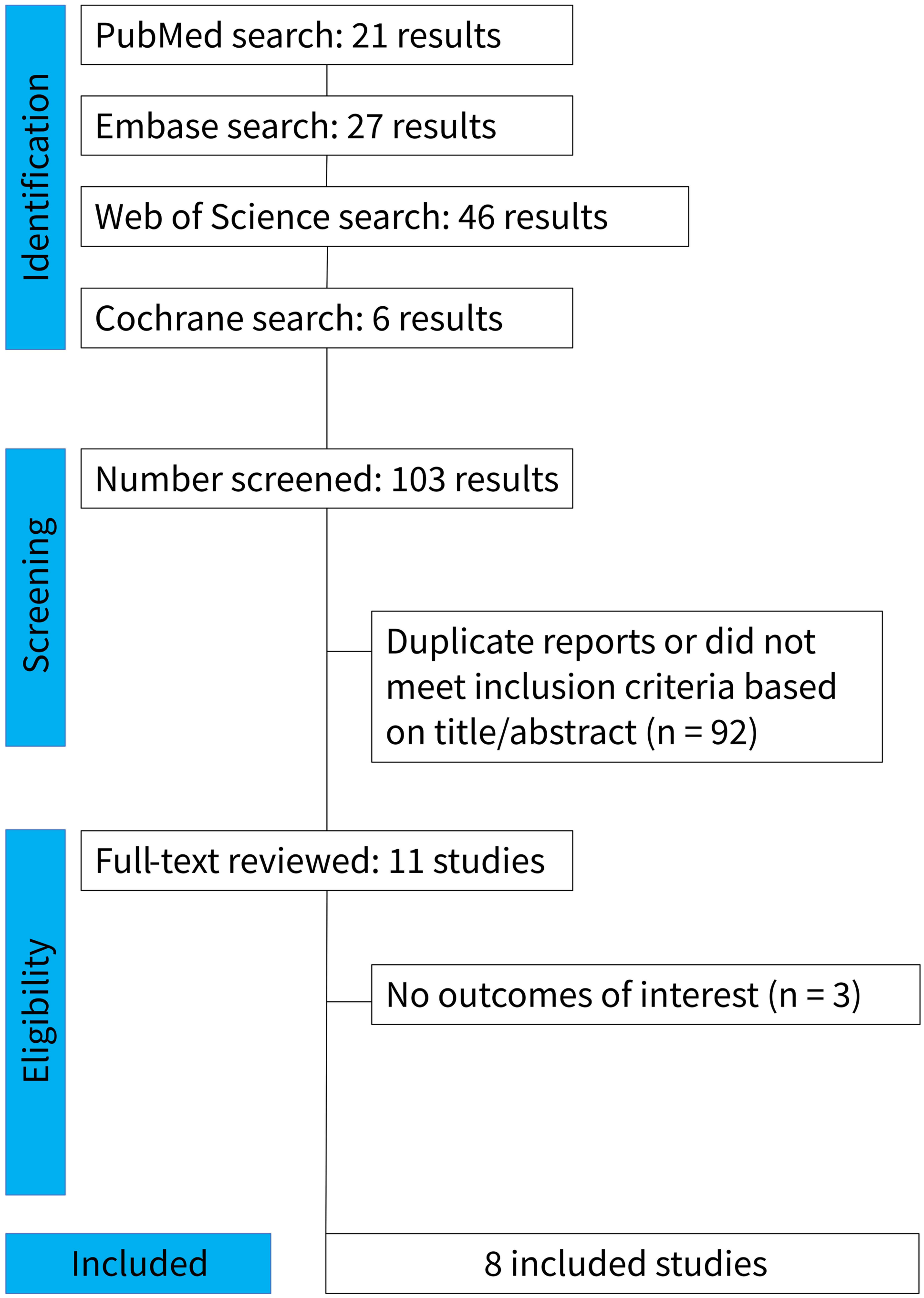

Figure 1 PRISMA flow diagram of study screening and selection process.

Among the included studies, five studies reported the incidence of phacoemulsification time in surgery. For these studies, the pooled results revealed a significant difference between patients in phaco-chop and divide-and-conquer groups (MD −55.09 sec; 95% CI −99.29 to −12.90; $p = 0.01$; I2=100%; Figure 6). The results showed that the application of phaco-chop in cataract surgery has a reduced phacoemulsification time compared to the divide-and-conquer technique.

Leave-One-Out Sensitivity Analysis

Performing the leave-one-out analyses in ECC, when the study conducted by Storr-Paulsen et al was excluded, ECC exhibited statistical significance. However, we noticed a worsening in heterogeneity after excluding this study.[19]

Table 1 Baseline Characteristics of Included Studies

Study	Type of Study	Location	Follow-up (Months)	Population	Eye PC/DC	Mean Age (yr) PC/DC	Outcomes Avaliable
Fernández 2023[9]	Observational	México	1	90	28/30	72.64 ± 9.27 / 70.39 ± 14.31	ECC, CDE, UST, Visual acuity, CCT
Keck 2016[21]	Observational	NA	NA	137	70/67	NA	ECC, CDE, UST, Visual acuity, CCT
Park 2013[8]	RCT	South Korea	2	135	45/45 15*/15*	72.6 ± 7.3 / NA	ECC, CDE, UST, Visual acuity, CCT
Pirazzoli 1996[18]	RCT	Italy	2	100	50/50	NA	ECC, CDE, UST, Visual acuity, CCT
Prasad 2020[7]	RCT	India	1.5	100	50/50	60.58 ± 5.89 / 59.72 ± 5.75	ECC, CDE, UST, Visual acuity, CCT
Storr-Paulsen 2008[19]	RCT	Denmark	12	60	30/30	75.3 ± 9.3 / 74.9 ± 7.8	ECC, CDE, UST, Visual acuity, CCT
Tsorbatzoglou 2007[17]	RCT	Hungary	1	50	25/25	70.7±10.9 / 70.0 ± 8.7	ECC, CDE, UST, Visual acuity, CCT
Wong 2000[20]	Observational	United Kingdom	4	125	75/50	72.4 ± 1.5 / 69.4 ± 1.3	ECC, CDE, UST, Visual acuity, CCT
Wong 2000[20]	RCT	United Kingdom	NA	117	62/55	74.0 ± 1.3 / 71.2 ± 1.3	ECC, CDE, UST, Visual acuity, CCT

Abbreviations: CCT, Central corneal thickness; CDE, Cumulated dissipated energy; ECC, Endothelial cell count; PT, Phacoemulsification time; RCT, Randomized controlled trial; UST, Ultrasound time; *NO4, population for dense cataract; NA, Not available.

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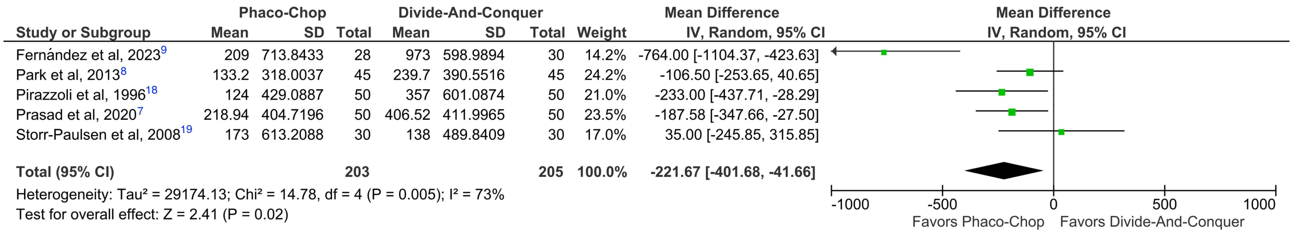

Figure 2 Endothelial Cell Count Forest plot.

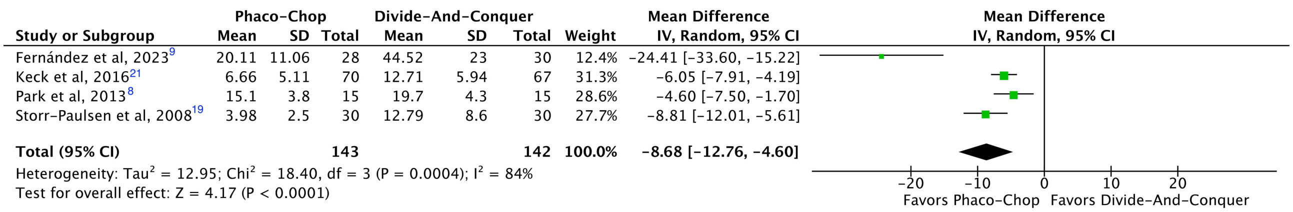

Figure 3 Cumulated Dissipated Energy Forest plot.

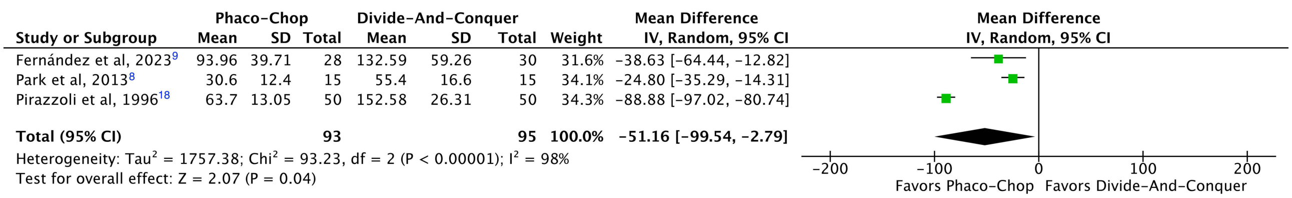

Figure 4 Ultrasound Time Forest plot.

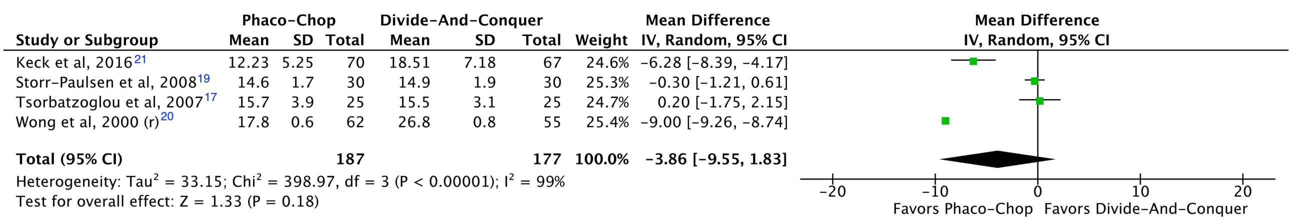

Figure 5 Surgery time forest plot.

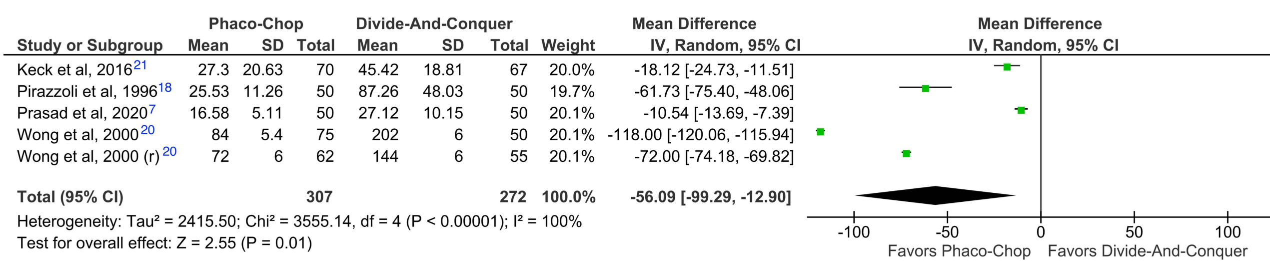

Figure 6 Phacoemulsification time forest plot.

Performing the leave-one-out analyses in phacoemulsification time, when the study conducted by Wong et al, 2000 (r) was excluded, phacoemulsification time did not exhibit statistical significance. However, we noticed a high heterogeneity after excluding this study.[20] In the CDE and surgery time outcomes, the leave-one-out analysis did not reveal any significant deviation from the primary findings. (Table 2)

Table 2 Leave One-Out-Analysis

Study Omitted	Pooled Analysis ECC
Fernández et al, 2023[9]	MD 82.54; CI [−18.59, 185.68]; p = 0.11; I²= 62%
Park et al, 2013[8]	MD 274.64; CI [−6.95, 556.22]; p = 0.06; I²= 91%
Pirazzoli et al, 1996[18]	MD 198.10; CI [−30.04, 426.23]; p = 0.09; I²= 91%
Prasad et al, 2020[7]	MD 262.54; CI [−22.83, 547.92]; p = 0.07; I²= 92%
Storr-Paulsen et al, 2008[19]	MD −40.00; CI [−244.72, 164.72]; p = 0.02; I²= 91%
Study omitted	**Pooled Analysis CDE**
Fernández et al, 2023[9]	MD −6.34; CI [−8.39, −4.29]; p = 0.001; I²= 44%
Keck et al, 2016[21]	MD −10.99; CI [−18.12, −3.86]; p = 0.003; I²= 89%
Park et al, 2013[8]	MD −11.00; CI [−16.99, −5.00]; p = 0.00003; I²= 87%
Storr-Paulsen et al, 2008[19]	MD −9.23; CI [−14.95, −3.50]; p = 0.002; I²= 88%
Study omitted	**Pooled Analysis Surgery Time**
Tsorbatzoglou et al, 2007[17]	MD −5.19; CI [−11.65, 1.27]; p = 0.12; I²= 99%
Keck et al, 2016[21]	MD −3.07; CI [−10.07, 3.94]; p = 0.39; I²= 99%
Wong et al, 2000[20] (r)	MD −2.05; CI [−5.55, 1.44]; p = 0.25; I²= 93%
Storr-Paulsen et al, 2008[19]	MD −5.08; CI [−10.70, 0.54]; p = 0.08; I²= 98%
Study omitted	**Pooled Analysis Phacoemulsification Time**
Keck et al, 2016[21]	MD −65.59; CI [−113.54, −17.65]; p = 0.007; I²= 100%
Pirazzoli et al, 1996[18]	MD −54.71; CI [−103.34, −6.08]; p = 0.03; I²= 100%
Prasad et al, 2020[7]	MD −67.60; CI [−104.70, −30.50]; p = 0.0004; I²= 100%
Wong et al, 2000[20]	MD −40.49; CI [−79.74, −1.23]; p = 0.04; I²= 100%
Wong et al, 2000[20] (r)	MD −52.10; CI [−121.47, −17.28]; p = 0.14; I²= 100%

Abbreviations: OR, odds ratio; CI, confidence interval; ECC, endothelial cell count; CDE, cumulated dissipated energy; r, Retrospective;

Subgroup Analysis

A subgroup analysis was conducted based on the type of study for the CDE. In RCTs, the pooled results indicated no significant difference between patients treated with phaco-chop and divide-and-conquer (MD −6.65 units; 95% CI −10.77 to −2.52; p = 0.002; I² = 73%). In the same way, in observational studies, the pooled results also showed no significant difference between patients treated with phaco-chop and divide-and-conquer (MD −14.66 units; 95% CI −32.61 to 3.30; p = 0.11; I² = 93%).

A subgroup analysis was conducted based on the type of study for the phacoemulsification time. In RCTs, the pooled results indicated no significant difference between patients treated with phaco-chop and divide and conquer (MD −63.43 sec; 95% CI −147.25 to 20.38; p = 0.14; I² = 100%). In the same way, in observational studies, the pooled results also showed no significant difference between patients treated with phaco-chop and divide-and-conquer (MD −45.65 sec; 95% CI −97.96 to 7.65; p = 0.09; I² = 100%).

A subgroup analysis was conducted based on the type of study for the surgery time. In RCTs, the pooled results indicated no significant difference between patients treated with phaco-chop and divide and conquer (MD −0.21 min; 95% CI −1.04 to

0.62; p = 0.62; I² = 0%). Conversely, in observational studies, the pooled results also showed a significant difference between patients treated with phaco-chop and divide-and-conquer (MD −7.85 min; 95% CI −10.48 to −5.22; p < 0.00001; I² = 84%).

Quality Assessment and Funnel Plot Analysis

Figures 7 and 8 present the risk of bias assessment for each study. Under RoB 2, six of the included studies raised concerns about bias due to deviations from the intended intervention. In the case of Robins-I, three observational studies were categorized as having a moderate risk due to confounding and participant selection issues.

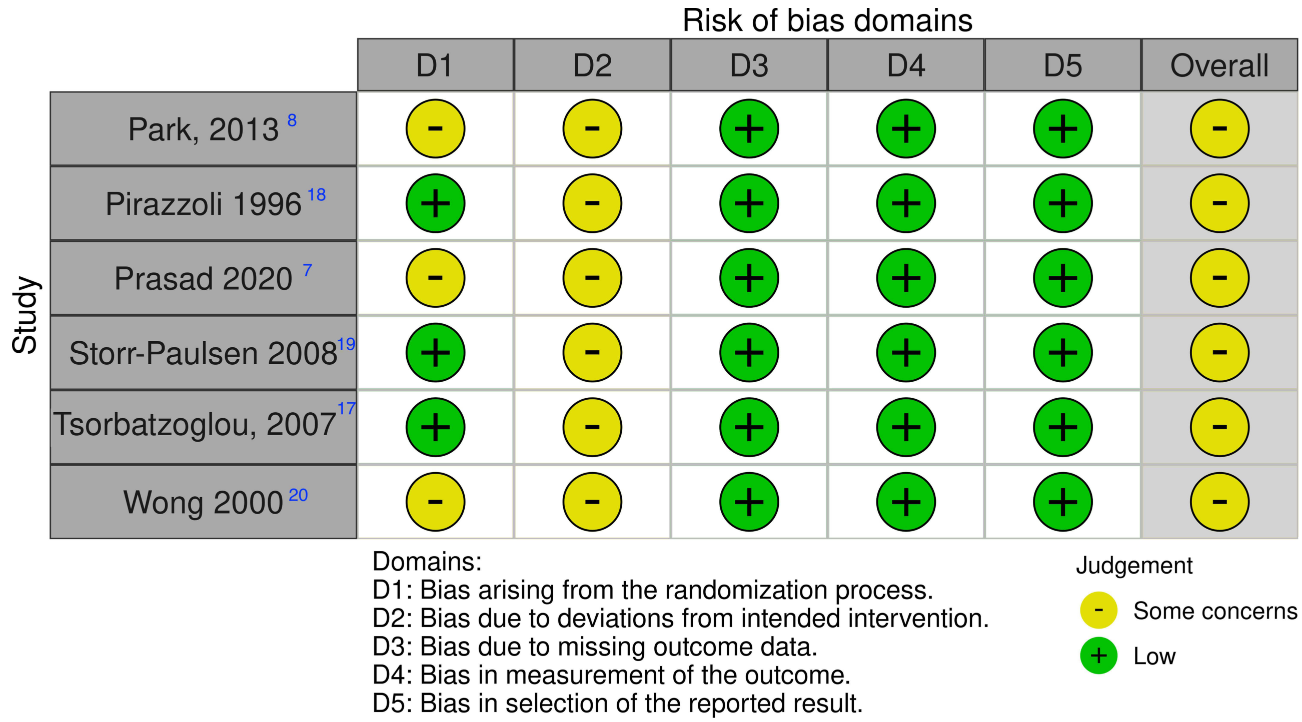

Figure 7 Risk of bias assessment of RCTs using the ROB-2 tool.

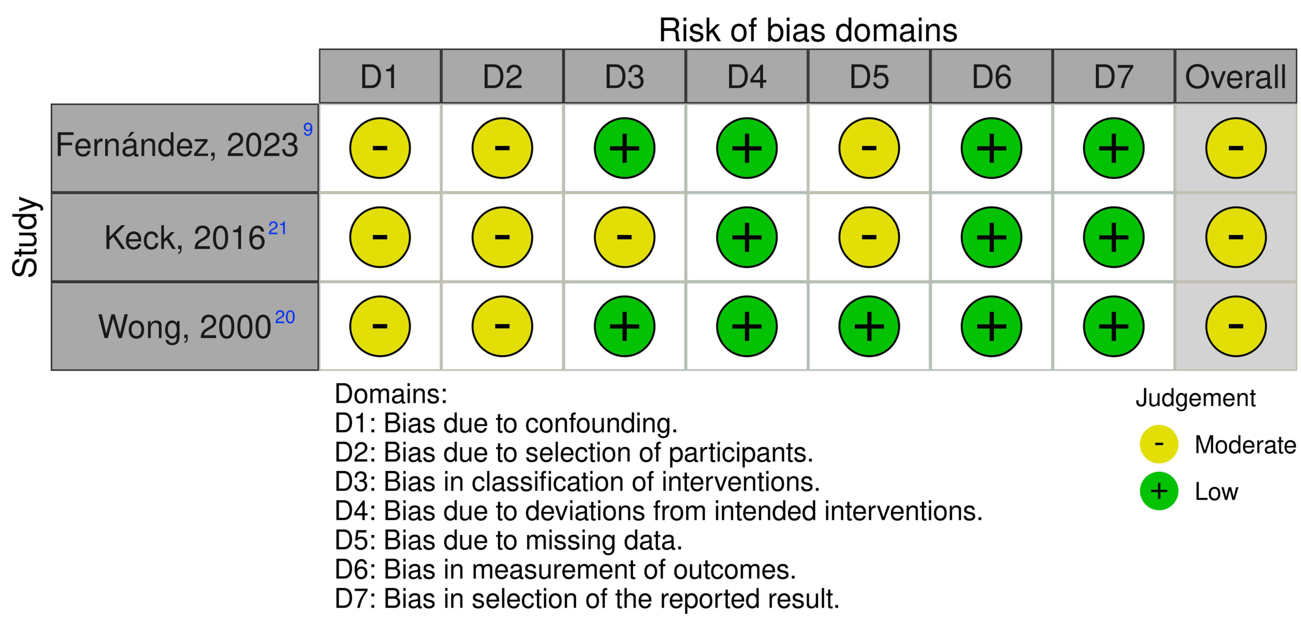

Figure 8 Risk of bias assessment of Observational studies using the ROBINS-I tool.

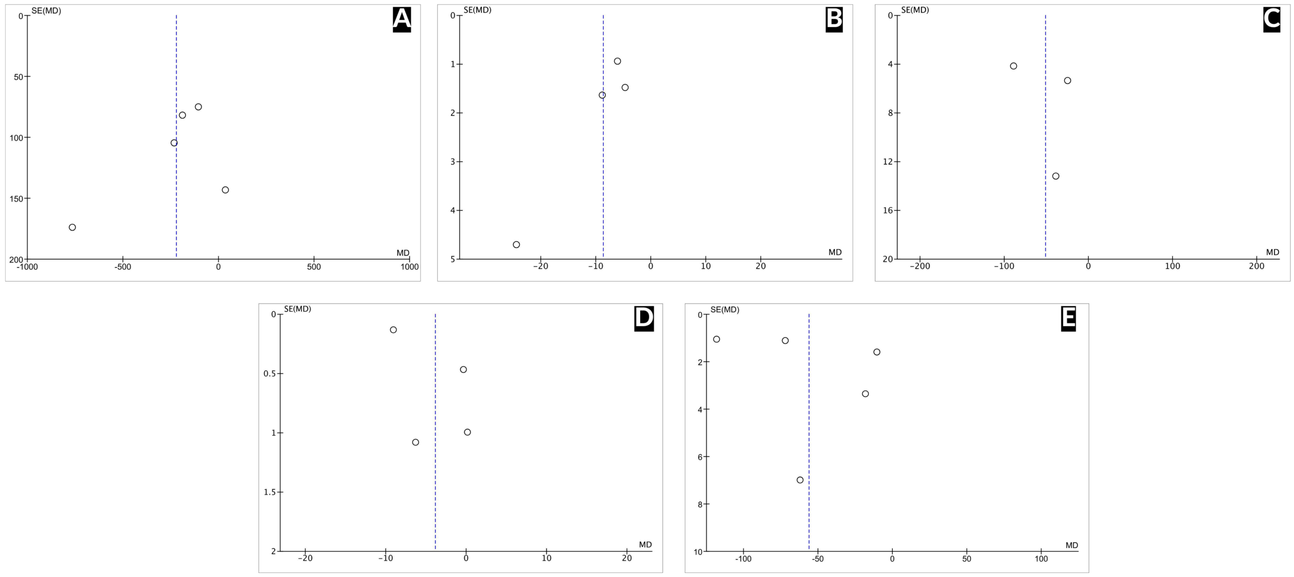

Figure 9 Funnel plot analysis. (**A**) Endothelial Cell Count. (**B**) Cumulated Dissipated Energy. (**C**) Ultrasound Time. (**D**) Surgery Time. (**E**) Phacoemulsification Time.

The funnel plot of the included studies appeared relatively symmetrical (Figure 9), suggesting a low likelihood of publication bias. However, it is important to consider that the accuracy of funnel plots is limited when there are fewer than 10 studies present.[22]

Discussion

Phacoemulsification might induces corneal endothelial damage through irrigation flow, turbulence, fluid movement, air bubbles, free radical release, and direct trauma from intraocular instruments or delivery of energy.[23–28] Extended phacoemulsification time and higher delivered ultrasound power may contribute to corneal endothelial cell damage.[18,29–33] Thus, endothelial damage depends on several factors, including surgeon's experience and ability, incision type, ophthalmic viscosurgical device (quality and quantity), intraocular lens type, irrigation solution composition, total phaco energy, and location of active phacoemulsification.[25]

We conducted a systematic review and meta-analysis of 8 studies and 837 patients to compare the effectiveness and safety of divide and conquer versus phaco chop for cataract surgery. In our study, the phaco-chop technique exhibited significantly lower ECC, CDE, UST, and Phacoemulsification times compared to the divide-and-conquer technique. These differences directly result from the reduced phaco energy used in the phaco-chop technique. According to the literature, this occurs because manual chopping is used to divide the nucleus into manageable fragments. The only significant use of phaco energy is during fragment emulsification, suggesting that the phaco-chop technique is superior in energy efficiency.[34–39]

Postoperative complications such as infectious endophthalmitis can be associated with greater surgical manipulation and longer surgical times.[40] In combination, phaco-chop is associated with less endothelial damage and damage to intraocular structures. Nevertheless, the strategy of divide-and-conquer has been effectively and safely implemented for a considerable duration, proving to be a more established technique than phaco-chop.[6,41]

The divide-and-conquer technique, commonly employed to penetrate the nucleus and streamline phacoemulsification, requires supplementary phaco energy for sculpting and segmenting the nucleus.[6] As the oldest and most frequently used phacoemulsification technique, it is often favored by novice surgeons.[42]

In contrast, the phaco-chop technique, introduced after divide-and-conquer, involves manually chopping the nucleus into smaller fragments, thus requiring less phaco energy for emulsification.[34] Although less frequently used by beginners, there is no evidence in the literature that it affects the learning curve.[42] Unlike the divide-and-conquer technique, the phaco-chop technique does not require nuclear sculpting.[20] Additionally, it directs the ultrasound away from the cornea, with the phaco-tip farther from the posterior capsule than in the divide-and-conquer technique.[20] This, combined with less rotational manipulation of the nucleus, results in less zonular stress and is associated with reduced corneal endothelial cell loss.[20] Furthermore, the total amount of phaco energy delivered into the eye is an important predictor for good vision and clear cornea postoperatively.[7]

These results provide valuable insights into the possible advantages of the phaco-chop technique over the divide-and-conquer technique. However, it is crucial to consider the study limitations, including non-randomized studies in our meta-analysis, potentially introducing sampling bias. A study conducted by Tabandeh H et al explains that lens hardness is an important factor in phacoemulsification and is associated with increased phacoemulsification time and power.[43] Furthermore, many studies have not provided data separation based on cataract classification, hindering the comparison of techniques based on cataract nuclear density. The studies incorporated in this analysis are of relatively short duration. Long-term studies are necessary to gain a more comprehensive understanding. A single surgeon did not carry out the procedures. Finally, our study do not analyze combination procedures, nor does it assess the potential corneal damage for future procedures.[44,45]

To address these issues, we performed a series of sensitivity tests and subgroup analyses. The use of the leave-one-out strategy was instrumental in evaluating study heterogeneity. This analysis indicates that no outlier studies are affecting the heterogeneity, thereby reinforcing the validity of our pooled results. Subgroup analysis, which was conducted based on the study design, found no inconsistencies between the RCT and observational groups regarding the comparison of phaco-chop versus divide-and-conquer techniques in terms of CDE. When it comes to phacoemulsification time, both the RCT subgroup and observational groups showed no significant differences between techniques, which contradicts earlier findings. However, it's important to note that there was a high level of heterogeneity (I^2 = 100%) observed in this analysis. Finally, in terms of surgery time, the RCT subgroup analysis confirmed previous findings and showed minimal variability (I^2 = 0%), contrasting with the observational group analysis.

Conclusions

This systematic review and meta-analysis was the first study conducted on this particular theme. In summary, the results of this systematic review and meta-analysis, including data from 837 patients, suggest that the phaco-chop technique is more effective than the divide-and-conquer approach for cataract surgery, particularly regarding corneal ECC, CDE, UST and phacoemulsification time. Our pooled data resolved discrepancies in previous literature by demonstrating significant differences favoring phaco-chop use in terms of safety and efficacy. We have emphasized a research gap concerning the effects of the therapy on various cataract nuclear densities, as well as the limited availability of RCTs with long-term follow-up on this topic. We encourage future research to address these gaps and contribute to filling this void.

Abbreviations

IOL, Intraocular Lens; ECL, Endothelial cell loss; CDE, Cumulative dissipated energy; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analysis; PROSPERO, International Prospective Register of Systematic Reviews; ECC, Endothelial cell count; UST, Ultrasound time; MD, Mean difference; SMD – Standard mean difference; ROBINS-I, Risk of Bias in Non-randomized Studies; ROB2, Risk-of-bias tool for randomized trials; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses; RCTs, Randomized controlled trials.

Data Sharing Statement

All relevant data are within the paper.

Author Contributions

All authors made substantial contributions to the conception and design, acquisition of data, or analysis and interpretation of data; took part in drafting the article or revising it critically for important intellectual content; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare that they have no affiliations with or involvement in any organization or entity with any interest in the subject matter or materials discussed in this manuscript.

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