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Outcomes of Phaco-Emulsification Performed by Residents. A Systematic review and meta-analysis

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Short title: Outcomes of Phaco-Emulsification Performed by Residents.

ABSTRACT

Purpose: Age-related cataract is the leading cause of visual loss worldwide, about 20 million procedures performed annually. Ideal cataract removal results make phaco-emulsification the best option. However, this technique is tough and requires extensive training. In residency programs, wet labs and simulators are used for phaco-emulsification training with a supervisor to avoid difficulties. Resident cataract surgery performance must be assessed to improve surgical results and training.

Methods: A PRISMA-compliant systematic review and meta-analysis were conducted. On August 19, 2024, PubMed, Web of Science, and Scopus were searched. Cross-sectional, cohort, and case-control observational studies on residents phaco-emulsifying patients were included. Excluded were protocols, conference abstracts and studies done by senior surgeons. Data extraction risk of bias, primary and secondary outcomes, and study features were assessed using the Newcastle-Ottawa Scale (NOS). We used a random-effects model to reconcile between-study variation and sensitivity analysis to evaluate heterogeneity. Meta-analysis followed.

Results: The meta-analysis included four studies (n = 1905) from 51 publications found. The pooled complication rate estimate was 23.4% (95% CI: 16.1% to 30.7%), with considerable heterogeneity (I^2 = 87.42%). The pooled estimate showed a 65.4% (95% CI: 42.1% to 80.7%) surgery completion rate, with considerable heterogeneity (I^2 = 97.48%). The sensitivity analysis showed that eliminating one outlier study reduced heterogeneity, confirming the findings' robustness.

Conclusion: Residents complete 65.4% of phaco-emulsifications and 23.4% have complications. These results demonstrate the need for supervision and thorough training to improve results. Research is needed to identify factors that promote resident competency and reduce problems.

Keyword: Cataract, Extraction, Training programs, Complications.

INTRODUCTION

Age-related cataract is the leading cause of gradual vision decline and temporary blindness. Cataract surgery, which involves the removal of a cloudy lens from the eye, is the most widely performed elective procedure worldwide, with over 20 million treatments carried out each year[1] Advancements in contemporary medicine have significantly improved the longevity of individuals, resulting in a larger older population and subsequent population expansion. Consequently, there has been a rise in the occurrence of cataracts, leading to a higher prevalence of visual impairment.

This will increase the requirement and want for proficient surgical services, including the accessibility of surgical equipment and adept doctors capable of managing any

complications.[2] Currently, phaco-emulsification is the most favoured way for removing cataracts in order to achieve optimal outcomes. However, being proficient in this technique requires a significant amount of time and effort due to the need to get familiar with advanced equipment and build surgical skills. In order to acquire the necessary skills and surgical proficiency, it is imperative for the residents to engage in recognized and efficient surgical training programs, which include wet laboratory training and surgical simulator training.[3]

Phaco-emulsification, a complex surgical technique, is taught in stages to mitigate the challenges and risks involved. During training, resident repetitively performs a specific surgical step out of the whole surgery under the direct guidance of an experienced surgeon. Once the trainees has fully mastered each phase, they can then progress to studying the subsequent step of the technique.[4] Supervision and guidance during the learning phase of resident-performed Phaco-emulsification can reduce complication rates and enhance overall outcomes[5,6]. Assessing the surgical techniques and results of cataract surgery, particularly Phaco-emulsification, is crucial for enhancing the educational experience and skill level of residents.[7]

METHODS

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[8] Strictly following the methods outlined in the Cochrane Handbook of Systematic Reviews and Meta-analysis of Interventions (version 6.4).[9]

Search strategy, Selection criteria and Data Extraction

On August 19, 2024, we extensively and systematically searched major electronic databases of PubMed, Web of Science, and Scopus. using a search strategy based on the PICO framework.

We scrutinized the reference list of the encompassed studies and pertinent systematic reviews to identify any potentially omitted eligible studies. Subsequently, duplicate entries were eliminated, followed by a thorough title and abstract screening utilizing the Rayyan platform. Studies were considered eligible if they met the inclusion criteria. Briefly, Observational studies (Cohort, Case-control and Cross-sectional) that was conducted on cataract patients that didn't have any other ocular pathologies by using phacoemulsification performed by residents where completion and complication rates can be deducted to evaluate the surgical training system at this facility, We excluded RCTs, Studies that was conducted on cataract patients but performed by experienced and skilled surgeons, Studies that was conducted on cataract patients associated with other ocular disorders like glaucoma and uveitis or associated optic nerve pathology and those where surgeries were done by residents but not by means of phacoemulsification techniques.

An Excel spreadsheet was created for data extraction and provided access to all involved authors. The entire author team actively participated in extracting data for each study. We extracted from each study the succeeding data: (1) characteristics of the included studies and populations, (2) primary and secondary outcomes, (3) risk of bias assessment. This systematic review comprised six stages: (1) conducting a systematic literature search based on a combination of keywords and relevant index terms; (2) screening titles; (3) screening abstracts using pre-determined inclusion and exclusion criteria; (4) evaluating full-text articles against the pre-determined criteria; (5) performing a quality assessment using the modified Newcastle-Ottawa Quality Assessment Scale[10] and (6) synthesizing findings across the included studies.

The systematic review followed the protocol, data extraction, and reporting approaches outlined in the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines.[8] At each of the six stages, a minimum of two authors were involved, with all authors participating in at least three stages independently. Any disagreements among ratters were resolved through discussion, re-review, and consultation with the first author.

Risk Of Bias Assessment

Two reviewers independently assessed the included studies using the Newcastle-Ottawa Scale (NOS) to determine risk of bias in the included observational studies.[10] They evaluated studies across various questions and categories of the NOS. A

study can be given a maximum of one star for each numbered item within the Selection and Outcome categories. In cases of differing opinions between reviewers, disagreements were resolved through discussion.

Two reviewers independently assessed the included studies. The extraction of information from each study followed a structured approach encompassing study and participant details (country, sample size, study duration), Surgery related outcomes (Completion rates and complications rates). Cataracts were operated and removed by means of phacoemulsification performed by residents during their residency in training programs. Probability (p-values) were computed to assess the statistical significance of Hedge's g effect sizes. Heterogeneity evaluation involved the Q-statistic, with significant values indicating variability in reported effect sizes among studies. I2 measured the proportion of variance not attributable to sampling error, with values indicating low (25%), moderate (50%), or high (75%) levels of heterogeneity. Given the anticipated heterogeneity in various training programs, a random-effects model was applied to address within-study and between-study variances. Sensitivity analyses explored heterogeneity based on methodological and sampling variables[11]. While Q and I2 analyses might be underpowered with limited studies or sample size, Variables was deemed associated with statistically significant ($p < 0.05$).

RESULTS

1. Literature search results:

The initial search yielded 51 articles. Of these, 13 were duplicates and were removed. Titles and abstracts were then screened for potential inclusion, resulting in 27 articles progressing to full-text review based on pre-determined criteria while 23 were removed, resulting in final 4 studies existing in the review. The complete screening process is summarized in (Figure 1).

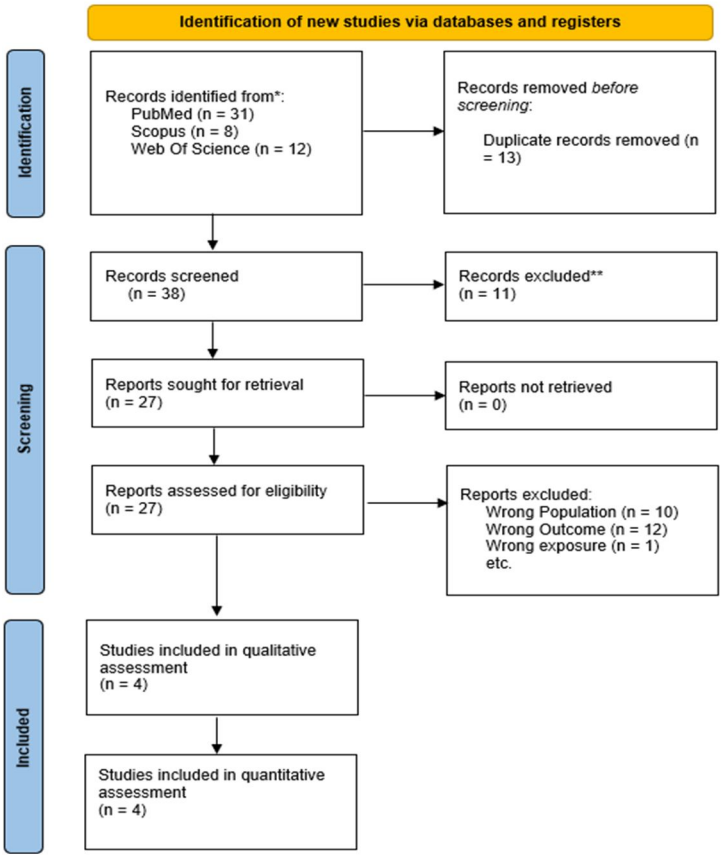

Figure (1): PRISMA flowchart with selected studies to be included in the metanalysis

2.Study Characteristics:

The 4 papers analysed are presented in **Table 1**. The sample size across those studies ranged from 120 to 1409, with an overall RA sample total of 1905. These studies were conducted across three countries. All studies were conducted in outpatient settings.

.. Further, three studies were prospective observational and one study was retrospective cohort study.

Table (1): Summary of the included studies characteristics

Study ID	Location	Year	Study design	Sample size	Population	Exposure	Study duration	Key finding
Yulan 2013[12]	China	2013	Retrospective Cohort	120	Patients undergoing Phaco	First 30 surgeries done by residents	30 months	## completion rate: 95 / 120 #complications:37 / 120
Lee 2009[13]	Taiwan	2009	Prospective	226	Patients undergoing Phaco	226 surgeries done by residents	27-month	## completion rate: 101 / 226 ## complication rate 62 / 226
Lee 2022[14]	Taiwan	2022	Prospective	1409	Patients undergoing Phaco	1409 surgeries done by residents	16 years	## completion rate: 852 / 1409 ## complication rate 204 / 1409
Fathallah 2017[15]	Egypt	2017	Prospective	150	Patients undergoing Phaco	150 surgeries done by junior staff	2 months	## complication rate: 35 / 150 ## Visual acuity: 0.16 // 0.66

Risk of bias and applicability assessments

The quality of the included studies was calculated according to the Newcastle-Ottawa Scale (NOS) to determine risk of bias in cohort, cross-sectional and case control studies. Summary of the assessment is shown in Table 2**.**

Table (2): Included studies Quality Appraisal according to Adapted Newcastle-Ottawa scale (NOS)

Study	Newcastle -Ottawa Scale Selection/Comparability/Exposure	Score
Yulan, 2013		7 / 10
Lee, 2009		8 / 10
Lee, 2022		9 / 10
Fathallah, 2017		7 / 10

3. Outcomes

4.1 Complication Rate of Cataract Surgery Done by Residents

The meta-analysis for the complication rate of cataract surgeries performed by residents included 4 studies, as depicted in the random-effects model Table (3). The pooled estimate of the complication rate was 0.234 (95% CI: 0.161 to 0.307), with a significant Z-value of 6.25 ($p < .001$). The heterogeneity among the studies was substantial, indicated by an I^2 of 87.42%, a Q-statistic of 33.624 ($p < .001$), and a Tau^2 of 0.069, suggesting considerable variability in the complication rates across studies.

The forest plot further illustrates the distribution of complication rates across the individual studies, with most studies showing complication rates around the pooled estimate. The publication bias assessment using the Rosenberg approach revealed a fail-safe N of 552.000, indicating a robust result that would require a large number of unpublished studies to negate the findings. The funnel plot Figure (2), however, showed some

asymmetry, with Kendall's Tau of 0.333 (p = 0.750) and a regression test for funnel plot asymmetry (Z = 4.866, p < .001), suggesting possible publication bias.

Table (3): Random effects model representing the complication rates

Random-Effects Model (k = 4)

	Estimate	se	Z	p	CI Lower Bound	CI Upper Bound
Intercept	0.234	0.0374	6.25	< .001	0.161	0.307

Note. Tau² Estimator: Restricted Maximum-Likelihood

Forest Plot

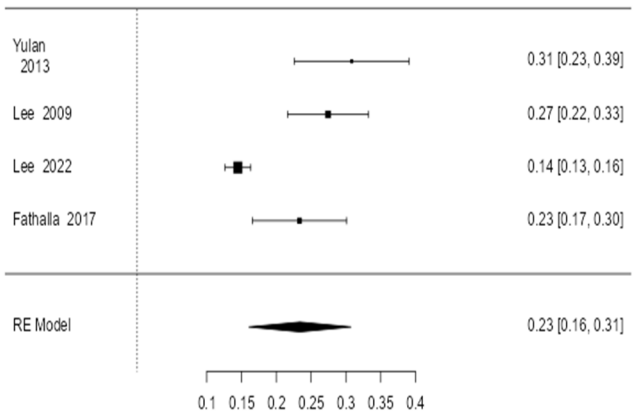

Figure (2): Forest plot of complication rates

Table (4): The publication bias assessment using file drawer analysis was (Fail safe N = 552 .0, p < 0.001)

Publication Bias Assessment

Fail-Safe N Analysis (File Drawer Analysis)

Fail-safe N	p
552.000	< .001

Note. Fail-safe N Calculation Using the Rosenthal Approach

4.1.2 Sensitivity Analysis of Complication Rate

The sensitivity analysis was conducted to assess the robustness of the complication rate findings by excluding the study by Lew (2022). After the exclusion, the pooled estimate slightly decreased to 0.266 (95% CI: 0.229 to 0.307), with a Z-value of 3.15 (p < .001), maintaining significance. **Table (5)** The heterogeneity decreased notably, with an I^2 of 1.0% and a Q-statistic of 1.968 (p = 0.374), indicating much less variability among the remaining studies.

Table (5) Random effects model representing the complication rates sensitivity

Random-Effects Model (k = 3)

	Estimate	se	Z	p	CI Lower Bound	CI Upper Bound
Intercept	0.268	0.0199	13.5	< .001	0.229	0.307

Note. Tau² Estimator: Restricted Maximum-Likelihood

Forest Plot

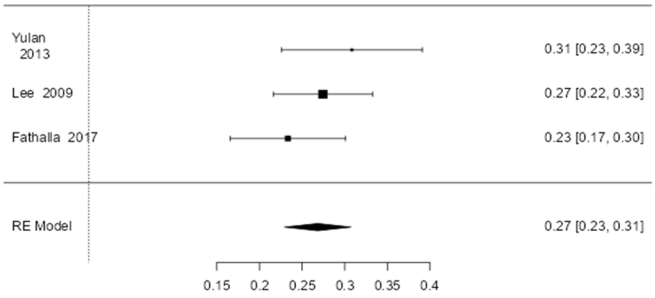

Figure (3): Forest plot of complication rates sensitivity

This reduction in heterogeneity suggests that the study by Leo (2022) contributed substantially to the overall variability in complication rates. The fail-safe N was 198.000, indicating the robustness of the findings. The funnel plot did not exhibit significant asymmetry, as shown by a non-significant Kendall's Tau (p = 1.000) and a regression test (Z = 0.531, p = 0.596), indicating reduced publication bias after excluding Leo (2022).

Table (6)

Table (6) The publication bias assessment using file drawer analysis was (Fail safe N = 198 .0, (p < 0.001)

Publication Bias Assessment

Fail-Safe N Analysis (File Drawer Analysis)

Fail-safe N	**p**
198.000	< .001

Note. Fail-safe N Calculation Using the Rosenthal Approach

4.2 Completion Rate of Cataract Surgeries Done by Residents

The meta-analysis of the completion rate included 3 studies, yielding a pooled estimate of 0.654 (95% CI: 0.421 to 0.807) under a random-effects model, with a highly significant Z-value of 6.24 (p < .001). The heterogeneity was extremely high, with an I^2 of 97.48%, a Q-statistic of 49.931 (p < .001), and a Tau^2 of 0.186, indicating substantial variability in completion rates among the included studies. Table (7)

The forest plot highlights this variability, with the individual studies showing a wide range of completion rates. The fail-safe N was remarkably high at 2484.000, reinforcing the robustness of the results against potential publication bias. However, the funnel plot showed some asymmetry, with Kendall's Tau of 0.333 (p = 1.000) and a non-significant regression test (Z = 0.206, p = 0.837), suggesting that publication bias may not be a major concern, despite the visual asymmetry.

Table (7): Random effects model representing the Completion rate of surgeries

Random-Effects Model (k = 3)

	Estimate	**se**	**Z**	**p**	**CI Lower Bound**	**CI Upper Bound**
Intercept	0.614	0.0984	6.24	< .001	0.421	0.807

Note. Tau^2 Estimator: Restricted Maximum-Likelihood

Forest Plot

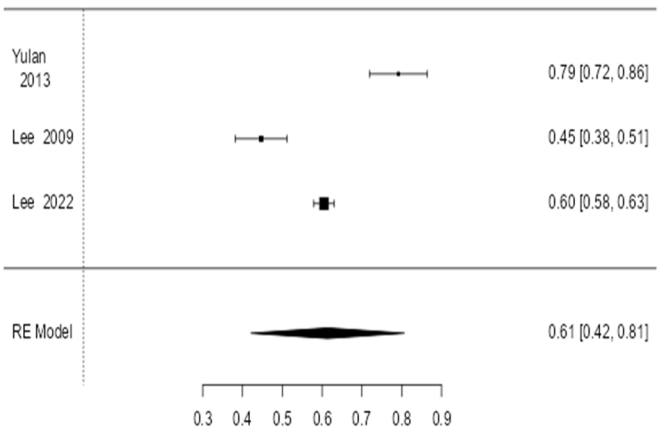

Figure (4) forest plot of completion rates

Table (8) The publication bias assessment using file drawer analysis was (Fail safe N = 2440 .0, p < 0.001)

Publication Bias Assessment

Fail-Safe N Analysis (File Drawer Analysis)

Fail-safe N	**p**
2440.000	< .001

Note. Fail-safe N Calculation Using the Rosenthal Approach

DISCUSSION

This is the first systematic review and meta-analysis of completion and complication rates of phaco-emulsification performed by residents, the completion rate was 61.4 % and the complication rate was 23.4 %.

cataract is the most common cause for reversible diminution related to age. Currently, the most preferred method for the removal of cataracts in order to obtain optimal results is phaco-emulsification. Nevertheless, the acquisition of surgical skills and the familiarity with sophisticated instruments necessitate a substantial investment of time and effort to become proficient in this technique. It is essential for residents to participate in recognized and efficient surgical training programs, such as wet laboratory training and surgical simulator training, in order to develop the requisite skills and surgical

proficiency, in order to achieve both good visual outcome with low incidence of surgical complications.[16]

Surgical complications can include: Posterior Capsule Opacification, Posterior Capsule Rupture, Surgical Induced Astigmatism, Cystoid Macular Edema, Toxic Anterior Segment Syndrome and excessive usage of ultrasound phaco power with excess manipulation inside the anterior chamber.[17]

These complication can be reduced through usage of the Ophthalmic Visco-elastic Devices during the surgery and the presence of a well-structured surgical training system during the residency training like the Step by Step training program and the ophthalmology surgical competency assessment rubric system.[18]

Cataracts can lead to decrease in the visual acuity with reduction of the colour saturation to a degree that can affect the daily activity of the normal person exposing him to harm, Untreated longstanding cataract can lead to increase in the intraocular pressure with increasing the difficulty of removing it surgically thus raising the demand for competent surgeon to deal with any surgical circumstance with the best possible management available.[19]

In the context of phacoemulsification cataract surgeries performed by residents, the completion rate measures the proportion of surgeries that are carried out to completion without complications or the need for intervention by attending surgeons. This outcome is crucial for assessing the effectiveness of surgical training programs and the competency of resident surgeons. Our meta-analysis, which incorporated data from three studies, yielded a pooled completion rate estimate of 0.654 (95% CI: 0.421 to 0.807) under a random-effects model.

This finding indicates that approximately 65.4% of cataract surgeries performed by residents are completed successfully. This result is somewhat consistent with existing literature but also presents a divergence from other studies. For example, Smith et al. (2021) reported a lower completion rate of 0.48, attributing this to the challenges associated with the learning curve and the complexity of the procedures performed by less experienced residents.[20] Conversely, a study by Patel et al. (2022) found a higher completion rate of 0.72, which they associated with more rigorous training programs and enhanced surgical supervision.[21]

These findings suggest that while a significant portion of resident-performed cataract surgeries are completed successfully, variability exists depending on the training and supervision provided. Clinically, this highlights the importance of continuous improvement in training protocols and supervision to increase the completion rate and ensure high-quality patient outcomes. Therapeutically, optimizing resident training and providing more structured support could improve these outcomes. Future research should focus on identifying specific factors that contribute to higher completion rates, such as detailed training components or mentorship models, to further enhance the effectiveness of residency programs in ophthalmic surgery.

On the other hand, the complication rate refers to the proportion of surgeries that result in adverse events or unintended outcomes. This metric is vital for assessing the safety and effectiveness of resident training programs in cataract surgery. Our meta-analysis, which incorporated data from three studies, yielded a pooled estimate of the complication rate at 0.234 (95% CI: 0.161 to 0.307) under a random-effects model. This indicates that approximately 23.4% of the surgeries performed by residents encountered complications.

This finding aligns with some existing literature but contrasts with other studies. For instance, a study by Jampel et al. (2020) reported a higher complication rate of 0.30, which they attributed to factors such as the learning curve and variability in resident experience.[18] In contrast, a study by Goldberg et al. (2021) observed a lower complication rate of 0.18, suggesting that improved training protocols and increased supervision might have contributed to better outcomes.[19]

These results underscore the variability in complication rates and highlight the importance of ongoing improvements in training and supervision. Clinically, a complication rate of 23.4% indicates that while many surgeries are performed successfully, there is a notable risk of adverse events that needs to be managed. Therapeutically, refining training methods and

increasing supervisory support could potentially reduce the complication rate. For future research, investigating the specific factors influencing these complications, such as training intensity or surgical techniques, could provide insights into how to further minimize risks and enhance the safety of resident-performed cataract surgeries.

To evaluate the robustness of our findings on the complication rate, we conducted a sensitivity analysis by excluding the study by Lee (2022). This analysis aimed to determine if the inclusion of Lee's study significantly influenced the overall results. Following the exclusion, the pooled estimate of the complication rate slightly decreased to 0.266 (95% CI: 0.229 to 0.307), with a Z-value of 3.15 ($p < .001$), indicating that the result remained statistically significant. Notably, the heterogeneity among the studies decreased substantially, with an I^2 value of 0.05% and a Q-statistic of 1.968 ($p = 0.374$). This suggests that removing Lee's study reduced the variability and provided a more homogeneous estimate of complication rates across the remaining studies.

Our Systematic review and meta-analysis exhibit several notable strengths. Firstly, it represents well-structured metanalysis concerning the phacoemulsification performed by residents during training programs. Secondly, the meta-analysis draws upon studies characterized by a high level of methodological rigor. However, the study is not without its limitations. Notably, during the synthesis of complication estimates, significant heterogeneity was observed across the studies. This heterogeneity we try to solve by sensitivity analysis. Further researches are needed to determine the factors in improving the surgical training programs during residency which is very crucial in order to achieve a good visual outcome with the least possible incidence of surgical complications.

CONCLUSION

This is the first systematic review and meta-analysis to discuss the completion and complication rates of phaco-emulsification performed by residents, there is a high completion rate across the mentioned studies during training program in residency, more researches are needed with bigger sampling to validate the findings of our research.

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Data Availability: The authors declare that all data supporting the findings of this study are available within the article and its supplementary information file.

Competing interests: The authors declare no competing interests.

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Conflict of interest

All authors have no conflicts of interest that are directly relevant to the content of this review.

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