



# A systematic review of single-handed coaxial phacoemulsification technique for cataract surgery

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## ABSTRACT

**Background:** Currently, cataract surgery is categorized into two main techniques: phacoemulsification and femtosecond-laser-assisted-ataract-surgery (FLACS).

**Objective:** The objective of this study was to present a comprehensive review of the existing literature on the single-handed coaxial phacoemulsification technique used in cataract surgery.

**Methods:** The study conducted a systematic review of PubMed, EMBASE, and Scopus databases. The participants included in our study were individuals diagnosed with simple cataract. These individuals had treatment using either single-handed or two-handed phacoemulsification or FLACS techniques. Publications predating the year 2000 were omitted from consideration. The abstracts of the publications were analyzed utilizing the PRISMA diagram, and those deemed to be somewhat and highly pertinent were incorporated. In total, a comprehensive analysis was conducted on six research, consisting of two randomized controlled trials (RCTs) and four non-randomized controlled trials (nonRCTs).

**Results:** The visual acuity (VA) showed a statistically significant improvement in the single-handed group compared to the two-handed group at the one-week postoperative assessment. However, this difference was not observed at the one-month and three-month postoperative assessments. The single-handed group had a smaller angle of error (AE) compared to the two-handed group. Additionally, another study observed an improvement in visual acuity (VA) in individuals who underwent single-handed, two-handed group, and femtosecond laser-assisted cataract surgery (FLACS). However, the study did not identify any statistically significant variations in VA improvement across the three groups. There was no statistically significant difference observed among the three groups concerning ECL and CCT. The intraoperative phacoparameter exhibited a statistically significant decrease in the single-handed group compared to the two-handed group, while it did not differ substantially from the femtosecond laser-assisted cataract surgery (FLACS) group.

**Conclusion:** When comparing the two-handed phacoemulsification technique to FLACS, it was observed that a single-handed method exhibited a reduced angle of error, minimized corneal damage, and exhibited early visual outcomes. Further study should be performed to explore potential technological improvements or modifications to FLACS that could lower costs and enhance its economic viability.

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## 1. Introduction

A cataract<sup>1</sup> is defined as any level of opacity in the lens, which is also a major contributor to preventable blindness<sup>2</sup> worldwide. Cataract surgery has continued to develop over the past 50 years. Since the 1960s when phacoemulsification was invented, phacoemulsification using a clear corneal incision (CCI) has become the gold standard<sup>3</sup>. In coaxial phacoemulsification, the smaller incision (2.2–2.4mm) offers rapid wound healing<sup>4</sup>, better anterior chamber stabilization<sup>5</sup>, less risk of endophthalmitis<sup>6</sup>, and less surgically induced astigmatism (SIA)<sup>7</sup>. Presently, coaxial phacoemulsification is divided into single-handed

phacoemulsification which is performed through the main incision only, and two-handed phacoemulsification which is performed through the main incision with the help of a chopper through a corneal side port<sup>8</sup>.

In 2008, femtosecond laser-assisted cataract surgery (FLACS) was introduced as a new method in cataract surgery, that showed promising treatment outcomes<sup>9</sup>. There have been several studies comparing the efficacy and safety of FLACS and phacoemulsification as cataract surgery. A perspective literature review by Soong et al<sup>10</sup> and Conrad-Hengerer et al<sup>11</sup>, demonstrated better surgical safety, efficiency, speed, and versatility of FLACS thus leading to a safer surgery with lower corneal endothelial cell loss

(ECL) and corneal edema in the early postoperative period when compared to conventional (two-handed) phacoemulsification. However, other studies reported FLACS has a higher cost and did not provide an additional benefit over phacoemulsification for patients or healthcare systems<sup>12, 13</sup>.

The previous study conducted by Gigliola et al<sup>14</sup> also compared FLACS with single-handed and two-handed phacoemulsification. They found that the single-handed technique had the advantage of less trauma to the cornea and less time-consuming compared with two-handed phacoemulsification or FLACS. Based on previous research, we aim to review single-handed coaxial phacoemulsification techniques for cataract surgery.

## 2. Methods

This systematic review is based on conducted studies from PubMed, Embase, and Scopus according to the Preferred Reporting for Systematic Reviews and Meta-Analyses (PRISMA) guidelines<sup>15</sup>. We included comparative studies, such as prospective randomized controlled trials (RCTs), prospective non-RCTs, and retrospective comparative studies, using the following keywords: femtosecond or femtolaser, one-handed, two-handed or conventional, phacoemulsification, cataract, or a combination of those. The exclusion criteria are articles with two conditions such as 1) Combined surgery data such as cataract and glaucoma surgery, or Combined cataract and vitreoretinal surgery, and 2) Publication before the year 2000. We looked at studies in which uncomplicated cataract patients older than 18 years were treated with single-handed or two-handed phacoemulsification, or FLACS. We considered the intraoperative outcome, such as Ultrasound time (US<sub>t</sub>), Effective phaco-time (EP<sub>t</sub>); and the clinical outcomes including visual acuity (VA), endothelial cell loss (ECL), central corneal thickness (CCT) central macular thickness (CMT), and corneal endothelial cell density (ECD). The flow chart for the search selection and identification process is illustrated in Figure 1. Initially, a total of 248 studies were identified. Duplicates were rejected and the remaining studies were screened by title and abstract. Of these studies, 62 were excluded because their titles or abstracts did not meet the inclusion criteria. A full-text review was performed when necessary. From these 32 citations, 26 studies were excluded for the following reasons, duplication, not fulfilling inclusion criteria, and not providing primary outcomes.

Table 1. Characteristics of studies included in the systematic review.

Author	Year	Country	Study Design	N	Group	Follow up period	Outcome indicators	Study Quality*	Reference
Chen et al.	2017	China	Non RCTs	95 eyes	FLACS compared with two-handed phacoemulsification technique	1 week, 1 month, 3 months	1,2,3,4,5,6,7	17	[18]
Day et al.	2020	United Kingdom	RCT	770 patients	FLACS compared with two-handed phacoemulsification technique	3 months	3,4	17	[16]
Dzhaber et al.	2020	USA	RCT	110 eyes	FLACS compared with two-handed phacoemulsification technique	1 month and 3 months	3,4	17	[17]
Li et al.	2018	China	Non RCTs	210 eyes	Single-handed compared with two-handed phacoemulsification technique	1 month and 3 months	1,2,3,4,5,6,7	18	[23]
Li et al.	2019	China	Non RCTs	209 eyes	Single-handed compared with two-handed phacoemulsification technique	1 week, 1 month, 3 months	1,2,3,4,5,6,7	18	[19]
Gigliola et al.	2021	Italy	Non RCTs	69 patients	Single-handed compared with two-handed phacoemulsification technique	1 month	1,2,4,5,6,7	18	[14]

Outcome indicator: 1. Effective phacoemulsification time (EP<sub>t</sub> (s)); 2. Phaco-power (%); 3 Uncorrected distance visual acuities (UDVA (logMAR)); 4. Corrected distance visual acuities (CDVA (logMAR)); 5. Corneal Central Thickness (CCT(μm)); 6. Endothelial Cell Density (ECD(/mm<sup>2</sup>)); 7. Endothelial Cell Loss (ECL(%))

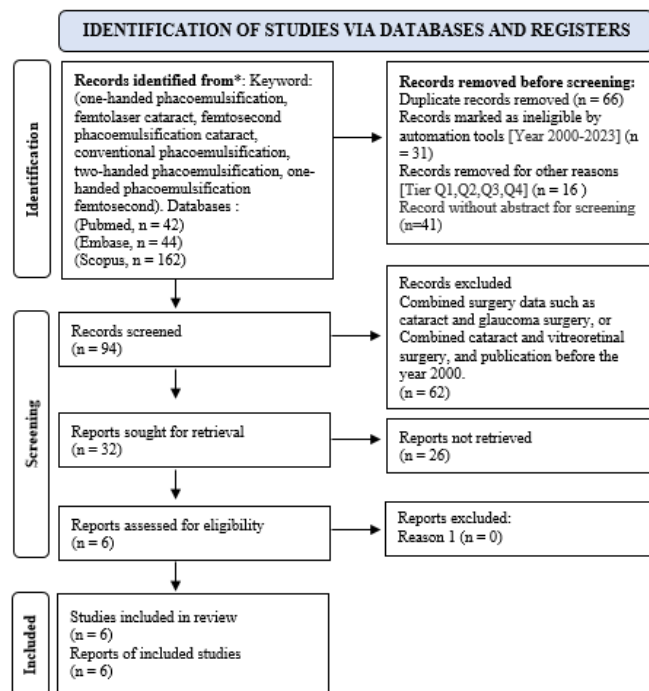


Figure 1. Flow Diagram of the Study Selection Process

We reviewed the effectiveness of single-handed, and two-handed phacoemulsification techniques, as well as FLACS for cataract surgery by systematically reviewing related studies as described in Table 1. We also reviewed two RCTs<sup>16, 17</sup> and four non-RCT<sup>14, 18–20</sup>. The risk of bias and applicability were assessed using the QUADAS-2 tool but not for the systematic reviews. Two authors independently extracted the eligible studies retrieved from the study selection process (Figure 1).

## 3. Result

Three studies that compared FLACS with the two-handed phacoemulsification technique<sup>10,14,15</sup> showed that Uncorrected Distance Visual Activity (UDVA) and Corrected Distance Visual; Acuity (CDVA) were similar between the two groups over the follow-up period (table 2). We found that Chen et al<sup>18</sup> and Dzhaber et al<sup>17</sup> reported a different outcome in the UDVA and CDVA at 1 month and also at 3 months postoperatively.

Compared with the baseline, UDVA and CDVA were better at all follow-up points in both single-handed and two-handed phacoemulsification groups (table 3). At 1 week and 1 month postoperatively, there were UDVA and CDVA improvements compared with those in the two-handed group. However, there were limited data outcomes at 3 months postoperatively<sup>19, 20</sup>. Gigliola et al<sup>14</sup> also reported the improvement of visual acuity in single-handed, two-handed, and FLACS groups.

The surgical parameters among the three groups

are presented in Table 4. Two studies showed that the ultrasound total time (U/S total time), Cumulative Dissipated Energy (CDE), and total surgical time were slightly higher in single-handed than in the two-handed group<sup>19,20</sup>. However, Gigliola et al<sup>14</sup> reported the U/S total time and CDE in the single-handed group was significantly shorter than that in the two-handed group, but significantly longer compared with FLACS. Yet, the total surgical time in the single-handed group was shorter than in the other two groups.

The mean ECD was decreased postoperatively in all three groups at any follow-up points. All studies reported the ECL was lower in the single-handed group than that in the two-handed group at all follow-up points<sup>14, 19, 20</sup>. However, it was reported that the ECL in the FLACS group was the lowest compared with the single-handed group.

Table 2. Postoperative Visual Outcome LogMar (mean ± SD)

Author	Parameter	Group		Reference		
		FLACS	Two-handed phacoemulsification			
Chen et al.	<b>UDVA (logMAR)</b>					
	Pre-op	0.2±0.4	0.23±0.41	[18]		
	1 week	0.18±0.31	0.21±0.39			
	1 month	0.17±0.28	0.22±0.33			
	3 months	0.12±0.18	0.15±0.28			
	<b>CDVA (logMar)</b>					
	Pre-op	0.15±0.35	0.18±0.28			
	1 week	0.1±0.23	0.17±0.27			
	1 month	0.07±0.14	0.13±0.24			
	3 months	0.05±0.12	0.08±0.18			
	Day et al.	<b>UDVA (logMAR)</b>				
		Pre-op	NE		NE	[16]
1 week		NE	NE			
1 month		NE	NE			
3 months		0.13±0.23	0.14±0.26			
<b>CDVA (logMar)</b>						
Pre-op		NE	NE			
1 week		NE	NE			
1 month		NE	NE			
3 months		0.01±0.19	0.01±0.21			
Dzhaber et al.		<b>UDVA (logMAR)</b>				
		Pre-op	0.3±0.2	0.3±0.2	[17]	
	1 week	0.1±0.2	0.1±0.2			
	1 month	0.1±0.1	0.1±0.2			
	3 months	0.1±0.1	0.06±0.1			
	<b>CDVA (logMar)</b>					
	Pre-op	NE	NE			
	1 week	NE	NE			
	1 month	0.03±0.08	0.02±0.07			
	3 months	0.05±0.07	-0.008±0.06			

UDVA = Uncorrected distance visual acuities; CDVA = Corrected distance visual acuities; NE = Not Evaluated

As shown in Table 5, the mean CCT was significantly thicker in both single-handed and two-handed groups at 1 week and 1 month postoperatively<sup>14, 19</sup>. There was also a slightly better outcome of CCT in the FLACS group compared with both single-handed and two-handed groups, yet there was no reported data about CCT outcome at 3 months postoperatively in the FLACS and single-handed group<sup>14</sup>.

A Meta-analysis study conducted by Marko P et al<sup>24</sup> comparing manual surgery and FLACS showed no significant differences in terms of surgery time (manual surgery, ranged from 6 to 53.6 minutes; FLACS ranged from 6.2 to 50.4 minutes) probably due to the differences in surgical equipment, surgeon skill, and patient selection. However, the EPt was longer in the conventional approach (two-handed phacoemulsification) than FLACS without a difference in CDE.

Table 3. Postoperative Visual Outcome LogMar (mean ± SD)

Author	Parameter	Group			Reference		
		Single-handed phacoemulsification	Two-handed phacoemulsification	FLACS			
Liet al. (2018)	<b>UDVA (logMAR)</b>						
	Pre-op	0.69±0.14	0.71±0.15	NE	[23]		
	1 week	0.11±0.12	0.18±0.16	NE			
	1 month	0.10±0.11	0.13±0.11	NE			
	3 months	NE	NE	NE			
	<b>CDVA (logMar)</b>						
	Pre-op	0.58±0.14	0.60±0.17	NE			
	1 week	0.01±0.11	0.05±0.12	NE			
	1 month	0.00±0.10	0.01±0.09	NE			
	3 months	NE	NE	NE			
	Li et al. (2019)	<b>UDVA (logMAR)</b>					
		Pre-op	0.70±0.14	0.71±0.15		NE	[19]
1 week		0.11±0.12	0.17±0.16	NE			
1 month		0.11±0.10	0.13±0.10	NE			
3 months		0.12±0.10	0.12±0.10	NE			
<b>CDVA (logMar)</b>							
Pre-op		0.59±0.16	0.60±0.17	NE			
1 week		0.01±0.09	0.06±0.12	NE			
1 month		0.01±0.10	0.01±0.08	NE			
3 months		0.02±0.10	0.03±0.09	NE			
Gigliola et al.		<b>UDVA (logMAR)</b>					
		Pre-op	NE	NE	NE	[14]	
	1 week	NE	NE	NE			
	1 month	NE	NE	NE			
	3 months	NE	NE	NE			
	<b>CDVA (logMar)</b>						
	Pre-op	0.71±0.31	0.77±0.21	0.73±0.22			
	1 week	NE	NE	NE			
	1 month	0.14±0.06	0.15±0.04	0.12±0.03			
	3 months	NE	NE	NE			

UDVA = Uncorrected distance visual acuities; CDVA = Corrected distance visual acuities; NE = Not Evaluated

Among various surgical techniques for cataract management, the innovative bimanual approaches called “Phaco-rolling technique” for soft and medium-hard nuclear cataract was defined to reduce phacoemulsification time and energy during cataract extraction, maintaining constant irrigation or aspiration, minimizing instrument movement within the eye and decreasing corneal distortion<sup>19</sup>. Management of hard cataract is difficult, even with the phacoemulsification technique. Most cataract techniques focus on how well the surgeon divides the hard nucleus. The majority of techniques use a chopper to divide or rotate the lens through a corneal side port<sup>20</sup>.

A bimanual cataract extraction using the endocapsular carousel technique in the posterior chamber was dependent on the newly designed tip with a 3-port irrigation system. Its technique also used a chopper through a corneal side port<sup>20</sup>.

Table 4. Intraoperative phaco parameters and total surgical time

Author	Parameter	Group			Reference
		Single-handed phacoemulsification	Two-handed phacoemulsification	FLACS	
Li et al. (2018)	U/S Total time (s)	27.44±19.34	23.79±19.14	NE	[23]
	CDE	5.24±3.71	4.85±3.63	NE	
	Total surgical time (s)	350.98±58.85	343.40±46.11	NE	
Li et al. (2019)	U/S Total time (s)	30.72±23.13	26.23±20.28	NE	[19]
	CDE	5.57±4.19	5.29±4.27	NE	
	Total surgical time (s)	353.77±59.86	350.07±50.79	NE	
Gigliola et al. (2021)	U/S Total time (s)	26.91±15.73	41.25±25.72	17.99±9.41	[14]
	CDE	0.66±0.70	1.35±0.86	0.44±0.21	
	Total surgical time (s)	367±81	510±11.1	459±99	

U/S total time = ultra sound total time; CDE = Cumulative dissipated energy; NE = Not Evaluated

#### 4. Discussion

The use of a chopper has some advantages, such as an increase in the risk of anterior or posterior capsule tear, causing zonulysis or lens drop, an increase in the risk of transient postoperative corneal edema, endophthalmitis related to the potential leakage from the incision, and also the creation of a corneal side port can rotate the axis of astigmatism<sup>21,22</sup>. Therefore, if the use of a chopper is not mandatory, to avoid a side-port incision, reduce surgical manipulations, and minimize ultrasound energy, a single-hand phacoemulsification technique can be the option<sup>23</sup>.

A Meta-analysis study conducted by Marko P et al<sup>24</sup> comparing manual surgery and FLACS showed no statistically significant differences in terms of surgery time (manual surgery, ranged from 6 to 53.6min; FLACS ranged from 6.2 to 50.4min) probably due to the differences in surgical equipment, surgeon skill, and patient selection. However, the EPt was longer in the conventional approach (two-handed phacoemulsification) than FLACS without a difference in CDE.

Marko P et al<sup>24</sup> also summarized no significant difference in visual outcomes between two-handed phacoemulsification and FLACS. Another Meta-analysis of 989 eyes from 9 randomized controlled trials also reported no significant difference in visual improvement between FLACS and two-handed phacoemulsification at 1-3 months postoperatively<sup>23</sup>.

Gigliola et al<sup>14</sup> reported the 1-month visual acuity was improved without significant differences between single-handed, two-handed, and FLACS. Similar to Gigliola et al<sup>14</sup>, the study by Panpan Li et al<sup>19, 20</sup> showed better visual acuity at all follow-up points in both single-handed and two-handed groups. At 1 week postoperatively, visual outcomes in the single-handed group were better than those in the two-handed group. The improvement of early visual acuity is associated with corneal trauma.

Table 5. Central corneal thickness and corneal endothelial cell counts/size

Author	Parameter	Group			Reference
		Single-handed phacoemulsification	Two-handed phacoemulsification	FLACS	
CCT (µm)					
Liet al. (2018)	Pre-op	529.77±32.37	529.97±31.34	NE	[23]
	1 week	545.07±31.70	553.80±31.27	NE	
	1 month	531.68±32.80	533.85±33.08	NE	
	3 months	NE	NE	NE	
ECD (mm <sup>2</sup> )					
Liet al. (2018)	Pre-op	253.36±239.15	2574.84±270.44	NE	[23]
	1 week	2354.32±242.15	2368.26±272.09	NE	
	1 month	2348.29±232.02	2356.75±263.44	NE	
	3 months	NE	NE	NE	
ECL (%)					
Liet al. (2019)	1 week	6.97±3.44	8.05±3.33	NE	[19]
	1 month	7.14±4.12	8.42±4.75	NE	
	3 months	NE	NE	NE	
	3 months	NE	NE	NE	
CCT (µm)					
Liet al. (2019)	Pre-op	512.35±25.19	538.56±38.75	516.17±25.12	[19]
	1 week	NE	NE	NE	
	1 month	516.26±22.16	542.65±37.43	521.04±26.37	
	3 months	NE	NE	NE	
ECD (mm <sup>2</sup> )					
Gigliola et al. (2021)	Pre-op	2566.78±310.25	2354.70±411.72	2410.70±381.21	[14]
	1 week	NE	NE	NE	
	1 month	2321.52±441.80	2103.09±464.72	2202.70±356.11	
	3 months	NE	NE	NE	
ECL (%)					
Gigliola et al. (2021)	1 week	NE	NE	NE	[14]
	1 month	9.86±10.27	11.35±8.48	8.29±7.35	
	3 months	NE	NE	NE	
	3 months	NE	NE	NE	

CCT= Central corneal thickness; ECD = Endothelial cell density; ECL = Endothelial cell loss; NE = Not evaluated

A Single-handed rotational technique takes shorter EPt (effective phacotime) and lower phacopower, and therefore lower CDE than two-handed phacoemulsification, but seems not different to FLACS regarding EPt and CDE<sup>14, 25</sup>. The prospective study by Panpan Li et al<sup>18</sup> also reported the angle of error (AE) was significantly smaller in the steep-axis one-handed group than in the steep-axis two-handed group.

The single-handed technique was performed in the endocapsular region and has less trauma also the angle of error. Hydrodissection plays a significant role in this technique, due to a single instrument rotating the nucleus (figure 2).

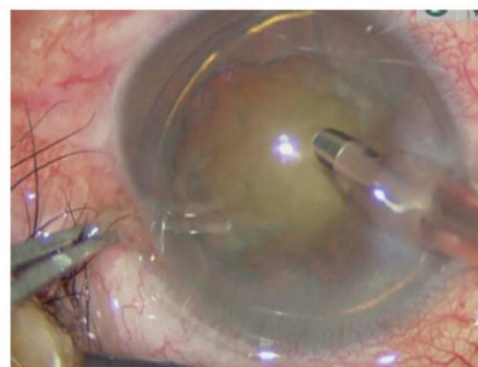


Figure 2. Single-handed coaxial phacoemulsification technique



A single-handed technique mitigates leakage through the corneal side incisions compared with the two-incision technique, which could improve anterior chamber stability. The main disadvantage of the technique is the decreased controllability of the nucleus without the help of a chopper, especially in cases of hard or large nuclei, in patients with small pupils or a shallow anterior chamber<sup>19</sup>.

Corneal endothelial injury after phacoemulsification is generally assessed by specular microscopy in terms of changes in corneal endothelial cells. In our study, no significant difference in ECD was noted between the single-handed and two-handed group at any follow-up point, but the mean ECL in the single-handed group was decreased compared with that in the two-handed group<sup>19,20</sup>.

There were some limitations in our study such as few studies about the single-handed phacoemulsification technique, and the difficulty in collecting study that compares the single-handed technique with FLACS.

## 5. Conclusion

Compared with the two-handed phacoemulsification technique and FLACS, a single-handed method demonstrated a lower angle of error, less trauma to the cornea, and revealed early visual outcomes. However, it was noted that the outcomes also depend on surgical equipment and surgeon skills. Furthermore, improvements or modifications of FLACS still need to be developed to enhance its economic viability while maintaining high standards of patient care. Further study should be performed to explore potential technological improvements or modifications to FLACS that could lower costs and enhance its economic viability.

## Ethical Approval

This study was conducted after obtaining ethical approval from the Ethics Commission of the Faculty of Medicine University of Universitas Muhammadiyah Yogyakarta

## Conflicts of Interest

All authors declare no conflict of interest.

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## Author Contributions

Conceptualization: Yunani Setyandriana; methodology, Yunani Setyandriana. Formal analysis: Yunani Setyandriana and Nurul Attikah Zain. Data curation: Yunani Setyandriana and Nurul Attikah Zain. Writing original draft preparation: Yunani Setyandriana. Writing review and editing: Yunani Setyandriana.

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