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Original Article

Efficacy and safety of anterior capsule polishing in cataract patients: a meta-analysis

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Abstract: Objective: This research summarizes and analyzes the effects of polishing of the anterior capsule (PAC) on visual function, maintenance of effective lens position (ELP), and postoperative complications in various studies, so as to determine whether PAC can be used to improve the surgical outcome of cataracts. Methods: The literature related to PAC published before June 2022 was searched in PubMed, Web of Science, EMBASE, Cochrane, Google, Wanfang, Weipu and CNKI databases. Changes in visual function [uncorrected visual acuity (UCVA) and spherical equivalent refraction (SER)], effective lens position (ELP), and postoperative complications [anterior capsular opacification (ACO) and posterior capsular opacification (PCO)] in the PAC intervention group were summarized and analyzed, and the standardized mean difference (SMD) or odds ratio (OR) with 95% CI was calculated by Review Manager 5.3. Results: By screening the literature, this meta-analysis finally included 10 studies with 2,639 eyes. The UCVA of patients was significantly improved in the PAC intervention group, while the root mean square of ELP (ELP_{RMS}) level and ACO incidence decreased. In addition, PAC did not obviously reduce the incidence of PCO after cataract surgery. Conclusion: PAC can effectively maintain the axial stability of the implanted lens and reduce the possibility of developing ACO, thus improving patients' visual function, which can effectively improve both the efficacy and safety of cataract surgery.

Keywords: Polishing of anterior capsule, meta-analysis, intraocular lens, visual function, capsular opacification

Introduction

Cataracts, as a common visual impairment in ophthalmology, can lead to a poor life and psychological status in patients. Among various factors leading to cataract, senile cataract caused by aging is the most common cause, and is typical in China [1]. Age-related cataract is increasing with the aging of society. Therefore, a variety of effective ways might be used to prevent and treat senile cataract in China, thus improving patients' life quality. At present, surgery is the most effective approach, and can quickly and effectively restore patients' visual function [2]. However, with the improvement in living standards, patients have a higher need for postoperative vision. Therefore, higher requirements are put forward for patients' postoperative visual function after intraocular lens (IOL) surgery. Clinically, a few patients with IOL implantation, especially those with multifocal IOL implantation, will have refractive deviation postoperatively, which will adversely affect vision. With the axial movement of the IOL, patients will develop myopic or hyperopic deviation [3]. Therefore, maintaining the axial stability of the IOL and reducing effective lens position (ELP) level are the keys to improving patients' vision after cataract surgery.

Relevant studies have found that axial movement of the IOL after cataract surgery is not only related to the type of IOL used, but also to the proliferation and fibrosis of residual lens epithelial cells (LECs) [4]. IOL implantation will block the circulation of aqueous humor in the capsule, which has been proven to be an important inhibitor of LEC proliferation, while TGF-β2 contained in aqueous humor can effectively inhibit LEC activity and induce apoptosis [5, 6]. Therefore, once the aqueous circulation in the capsule is blocked by the IOL, the process of intracapsular fibrosis will be accelerated. Moreover, the IOL acts as a scaffold for the attachment of LECs, which will further enhance LEC activity and induce fibrosis, resulting in capsular contraction [7]. The resulting contractile force will cause the IOL axis to shift axially back and forth, which will adversely affect patients' postoperative vision. In addition, the occurrence of proliferation or fibrosis of residual LECs on the capsule surface will also lead to anterior capsular opacification (ACO) and posterior capsular opacification (PCO), further compromising patients' vision and life quality [8]. Therefore, inhibiting the proliferation of LECs after IOL implantation is the key to maintaining IOL stability and reducing complications.

At present, various approaches, such as antimetabolic drug mitomycin [9], drug loaded delivery system [10], and physical heating, cryotherapy [11], are performed to clear LECs in clinical practice, but they all come along with some defects. For example, the toxic effect of mitomycin on intraocular tissue, the safety of the drug-loaded delivery system, and the damage of physical therapy all limit their use in clinical application. In contrast, polishing of the anterior capsule (PAC) is the most widely used approach. With the development of medical device technology, the performance of polishing instruments (ultrasonic I/A, double headed capsule polisher, etc.) used in this procedure is also constantly being refined [12, 13], which not only assists doctors to effectively remove residual LECs from the anterior capsule with a more intuitive vision, but also ensures the safety of the operation.

Through literature search, we find that there are many studies regarding the effect of PAC on maintaining IOL in a steady state and improving the clinical treatment effect of cataract surgery. These are small studies, however, with discrepancies in results of postoperative visual acuity changes, IOL stability, and complications, that to some extent, limit the guiding role in clinical work. Various studies have been carried out on the influence of PAC on PCO, ACO and the size of capsular opening after implantation of different IOLs [14]. It is demonstrated that PAC during the operation can increase the axial position stability of the IOL. After the operation, the capsule bag collapses, and the residual LECs in the front come into contact with the anterior surface of the optic nerve, leading to fibrosis. These metaplastic LECs contain a large amount of α-smooth muscle actin, resulting in anterior capsule contraction such as ACO and capsulorhexis opening constriction [7]. The axial position of IOLs becomes more stable when LECs underneath the anterior capsule and the equatorial ones are mostly removed by the capsule polisher [15]. However, Liu et al. [12] found *in vitro* that PAC did not reduce the growth of residual cells; instead, it enhanced cell proliferation in bag cultures. However, LECs may exhibit different cellular behaviors *in vivo*. Therefore, this meta-analysis summarizes and analyzes the data of previous studies to determine the effectiveness and safety of PAC during cataract therapy, so as to provide clinical guidance for maintaining ELP of the IOL and inhibiting ACO/PCO occurrence after surgery.

Materials and methods

Search strategy

This meta-analysis was carried out in strict accordance with the Cochrane Handbook for Systematic Reviews and Meta-Analysis (PRISMA) guidelines. We searched the literature from PubMed, Web of Science, Embase, Cochrane, Google, Wanfang, Weipu and China National Knowledge Infrastructure (CNKI) databases through January 2000 to June 2022. No date, language, or research design restrictions were set in the electronic search of these tests. "Anterior capsule polishing" or "cataract" or "Intraocular lens" or "Vision" or "Diopter" or "Effective lens position" or "Anterior capsular opacification" or "Posterior capsular opacification" were the main terms used for comprehensive literature search to identify relevant studies. First, two reviewers (BCL and LJZ) selected studies according to the title and abstract, and then screened the full text based on the inclusion criteria. Further manual retrieval was carried out for the references of the selected papers to expand the research samples. With the help of the third author (SFF), any problems during literature selection were solved. The following search formula was used for PubMed: ("anterior capsule polishing" OR "intraocular lens") AND ("intraocular lens" OR "vision" OR "diopter" OR "effective lens position") AND ("anterior capsular opacification" OR "posterior capsular opacification"). The search formulas for EMBASE, the Cochrane Library, CNKI, and google database were similar to the PubMed search formula.

Inclusion criteria

(1) All included studies were randomized controlled trials (RCTs); (2) IOL implantation for cataract patients; (3) Patients in the PAC group received PAC treatment; (4) Study indicators include related visual acuity indexes (uncorrected visual acuity [UCVA] or spherical equivalent refraction [SER]), ELP or complications after cataract surgery (ACO or PCO).

Exclusion criteria

(1) Case reports, reviews, comments, and guidelines; (2) Pseudo RCTs; (3) Unavailable complete data; (4) Literature with no relevant study indicators; (5) Duplicate literature.

Data extraction

For the articles included in the study, we extracted information such as the authors, year of publication, follow-up time, number of samples, UCVA, SER, ELP, ELP_{RMS}, ACO, and PCO. If necessary, the authors of the article were contacted for more detailed data. Two reviewers (BCL and LJZ) selected studies according to the title and abstract, and then screened the full text according to the inclusion criteria. Further, the references of the selected papers were searched manually to expand the research samples. With the help of the third author (SFF), problems encountered in the literature selection were addressed.

Quality evaluation of included literature

The Cochrane RCT bias risk assessment tool [16] was adopted to assess the quality of the included literature.

Statistical analysis

Revman 5.3 was used for meta-analysis. The continuous variables such as vision, diopter, and ELP were expressed by Mean ± Standard deviation and 95% CI, while the dichotomous variables like capsular opacification were represented by OR and 95% CI. A forest plot was generated by the random- or fixed-effects model. For each meta-analysis, Cochran Q and I^2 were used to evaluate the heterogeneity of the study, with a I^2 of 25%, 50%, and 75% interpreting as low, moderate, and high levels of heterogeneity, respectively. When heterogeneity was observed (I^2 > 50%), the random-effects model was used; otherwise, the fixed-effects model was used. For the Cochran Q test, a *P* value of < 0.05 was considered heterogeneity among studies, for which the random-effects model was used; otherwise, the fixed-effects model was adopted. Meanwhile, funnel plot distribution was used to determine whether there was publication bias in the included literature. For the outcome indicators with publication bias, Stata 14.0 was used to evaluate the impact of publication bias on the results through trim-and-fill method (metatrim). If the combined SMD or OR of 95% CI or in the meta-analysis did not overlap with 0, the effect of the outcome index was considered to be significant.

Results

Literature search

A total of 1,675 related papers were retrieved. After deleting the duplicate literature, we screened the remaining 1,238 records according to the title and abstract, and a total of 989 records were excluded. The remaining 249 studies were further screened, among which 239 were excluded (24 case reports, 113 reviews, 24 studies with less than 10 samples, 56 studies with insufficient data, and 22 animal studies). Finally, 10 studies with 2,639 eyes were included [1, 2, 7, 8, 14-19]. In all studies, PAC group was intervened with PAC during IOL implantation, while PAC was not performed in non-PAC group. The retrieval process and research characteristics are shown in **Figure 1** and **Table 1**, respectively.

Quality evaluation

Through the Cochrane RCT bias risk assessment tool, we evaluated the quality of included literature and found that the total risk of bias was moderate. After the included studies generated the risk of bias graph and bias summary, we found that the low bias risk was mainly concentrated in "blinding of participants and personnel" and "selective reporting". Also, nine studies mentioned random assignment, the date of one study was incomplete, and five documents did not mention whether there was "allocation consideration" or "blinding of outcome assessment" (**Figure 2**).

Effect of PAC on UCVA after IOL implantation

After IOL implantation, the change in visual acuity is the most real index for patients to feel.

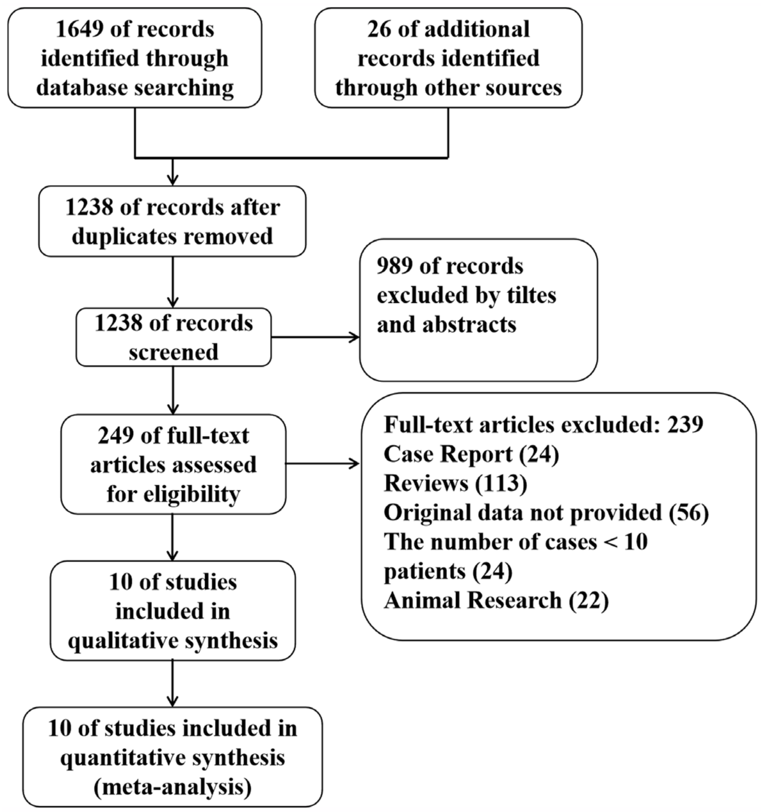

Figure 1. Flow diagram of data retrieval and collection.

Therefore, the detection of UCVA can subjectively reflect the role of PAC in the long-term maintenance of visual acuity after IOL surgery. The changes of UCVA after PAC therapy were reported in four studies we included. Since there were relatively few UCVA data at the same time point, we conducted subgroup analysis according to different time periods and summarized the results. It showed that patients' UCVA in PAC group was higher than that in non-PAC group at 3 months, 3-6 months, and more than 6 months after operation, with the combined MD of 0.15 (95% CI: 0.14 to 0.15; P < 0.001), 0.19 (95% CI: 0.18 to 0.2; P < 0.001), and 0.2 (95% CI: 0.18 to 0.22; P < 0.001), respectively (**Figure 3**). Hence, PAC can better improve patients' UCVA after IOL implantation.

Effect of PAC on SER after IOL implantation

In addition to subjective detection of UCVA, SER is also a commonly used detection index in ophthalmology to further objectively reflect patients' visual changes after IOL implantation. By summarizing and analyzing the data of 13 groups in three studies, we further divided SER data into different subgroups according to different time periods to analyze and summarize the data of each group. It was found that the SER value in PAC group was higher than that in non-PAC group at different time points, with the combined MD of 0.09 (95% CI: 0.08 to 0.1; P < 0.001), 0.09 (95% CI: 0.07 to 0.11; P < 0.001), and 0.09 (95% CI: 0.09 to 0.1; P < 0.001), respectively (**Figure 4**).

Effect of PAC on ELP and ELP_{RMS} after IOL implantation

After IOL implantation, the axial position change of IOL will cause a negative impact on the vision and diopter of patients. Therefore, taking effective measures to maintain IOL stability and reduce the change of ELP is an important part of cataract surgery. Through the comprehensive analysis of ELP data from 17 groups in four studies, we found that the ELP value of patients with PAC treatment or not did not change significantly at 3 months and 3-6 months postoperatively, while the ELP value in PAC group was higher than that in non-PAC group at more than 6 months after the operation, with the combined MD being -0.03 (95% CI: -0.07 to 0; P = 0.06), -0.03 (95% CI: -0.09 to 0.03; P = 0.26), and 0.13 (95% CI: 0.04 to 0.21; P = 0.005) at 3 months and 3-6 months, and > 6 months after operation, respectively (**Figure 5A**). Since the ELP mean value had some defects in reflecting the axial movement of IOL, we adopted the ELP_{RMS} to further accurately evaluate the axial stability of IOL. The results showed that ELP_{RMS} decreased significantly in PAC group, and its combined MD was -0.05 (95% CI: -0.06 to -0.04; P < 0.001) (**Figure 5B**). Therefore, PAC can better maintain the axial stability of the IOL.

Effect of PAC on ACO/PCO after IOL implantation

The body's wound repair reaction caused by IOL implantation, an invasive procedure, will cause the proliferation and fibrosis of residual LECs

Table 1. Basic information and relevant ophthalmic examination indicators of included studies

Author, year	Total eyes (number)		Follow-up (month)	UCVA (Log MAR)		SER (D)		ELP (mm)		ELP_{RMS}		ACO (number)		PCO (number)	
	PAC	non-PAC		PAC	non-PAC	PAC	non-PAC	PAC	non-PAC	PAC	non-PAC	PAC	non-PAC	PAC	non-PAC
Baile [1], 2012	1009	981	12									0/1009	960/981	8/1009	9/981
Bang [2], 2018	30	30	2	0.08±0.1	0.07±0.1			3.43±0.23	3.41±0.18	0.124±0.034	0.246±0.038				
				0.06±0.09	0.05±0.08			3.43±0.23	3.44±0.2						
				0.03±0.06	0.03±0.06			3.39±0.25	3.42±0.22						
				0.03±0.06	0.02±0.06			3.4±0.29	3.53±0.32						
				0.02±0.05	0.01±0.04			3.42±0.32	3.61±0.35						
Gao [7], 2015	20	20	6	0.07±0.09	0.07±0.1	-0.45±0.18	-0.33±0.18	4.02±0.32	3.97±0.27	0.05±0.02	0.07±0.02				
				0.08±0.09	0.08±0.09	-0.53±0.44	-0.42±0.26	3.99±0.29	3.93±0.25						
				0.08±0.09	0.09±0.1	-0.46±0.47	-0.36±0.24	3.99±0.26	3.97±0.23						
				0.1±0.08	0.1±0.12	-0.48±0.22	-0.36±0.44	3.97±0.27	3.98±0.24						
				0.1±0.08	0.1±0.11	-0.48±0.21	-0.41±0.22	3.97±0.28	3.92±0.25						
Leng [8], 2022	21	17	12	0.42±0.22	0.49±0.42										
				0.31±0.38	0.35±0.4										
Menapace [17], 2005	18	18	36											0/39	0/39
														11/39	4/39
														10/39	10/39
Sachdev [18], 2020	69	30	12									9/69	6/30		
												30/69	19/30		
												30/69	20/30		
Sacu [19], 2004	34	34	36									6/34	9/34		
Shah [24], 2009	60	60	6									26/60	54/60		
												59/60	60/60		
Wang [25], 2018	38	38	6			-3.05±0.91	-2.7±1.06								
						-3±0.77	-2.76±1.12	0.32±0.16	0.38±0.19						
						-2.92±0.74	-2.76±1.03	0.37±0.17	0.49±0.22						
						-2.97±0.74	-2.99±1.11	0.42±0.14	0.55±0.21						
Zhu [26], 2017	56	56	18	0.66±0.02	0.48±0.01	0.23±0.03	0.14±0.02	4±0.3	3.93±0.25			1/56	3/56	2/56	4/56
				0.65±0.03	0.45±0.04	0.23±0.05	0.14±0.05	4±0.28	3.9±0.3						
				0.65±0.08	0.45±0.05	0.21±0.02	0.12±0.01	4±0.35	3.88±0.32						
				0.64±0.12	0.43±0.1	0.21±0.05	0.11±0.04	4±0.32	3.87±0.33						

Notes: UCVA = uncorrected visual acuity; SER = spherical equivalent refraction; ELP = effective lens position; ACO = anterior capsular opacification; PCO = posterior capsular opacification; PAC = polishing of the anterior capsule; RMS = root mean square; D = diopter; mm = millimeter.

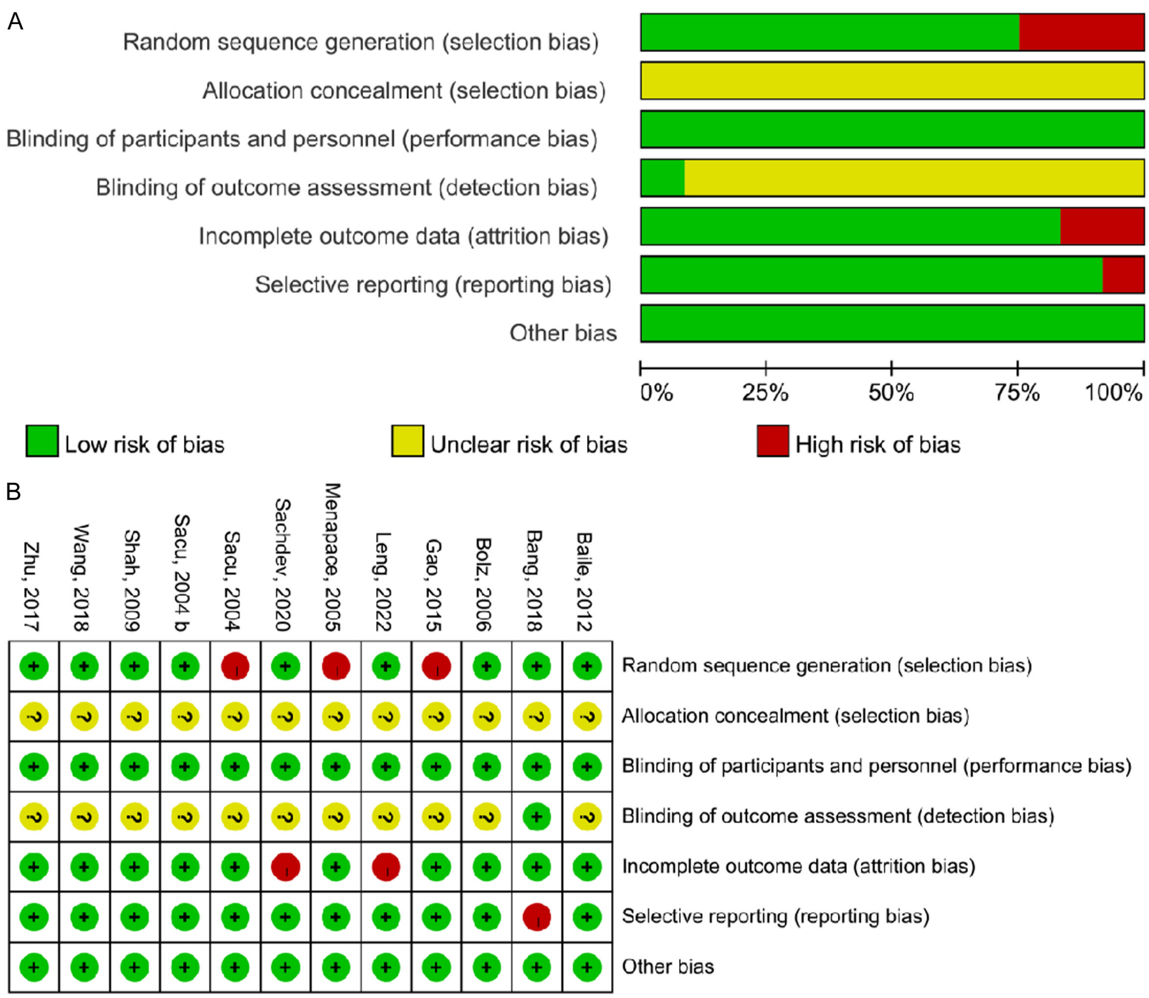

Figure 2. Risk of bias graph (A) and bias summary (B) of included studies.

on the capsular surface, thus leading to the occurrence of ACO and PCO that are common adverse reactions of cataract surgery. In order to judge whether PAC can reduce the occurrence of ACO and PCO, we summarized and analyzed data from 13 groups in six studies that reported ACO or PCO. The results showed that PAC could effectively reduce the incidence of ACO, and its combined OR was 0.02 (95% CI: 0.02 to 0.03; P < 0.001) (**Figure 6A**). However, PCA could not significantly inhibit the occurrence of PCO, and its combined OR was 1.16 (95% CI: 0.67 to 2.02; P = 0.6) (**Figure 6B**).

Publication bias analysis of included literature

The funnel diagram of ELP outcome indicators with the most research results is basically symmetrical, indicating that there is no obvious publication bias (**Figure 7A**). The funnel diagram of SER, one of the main outcome measures, was not very symmetrical, indicating that there was publication bias (**Figure 7B**). Subsequently, we added 7 virtual documents by trim-and-fill method (**Figure 7C**), and the combined MD changed from 0.09 (95% CI: 0.09 to 0.09; P < 0.001) to 1.10 (95% CI: 1.10 to 1.10; P < 0.001), indicating that the results were stable, and publication bias would not affect the results.

Discusssion

As the most direct and effective way to treat cataract, surgery enables cataract patients to recover their vision, thus greatly improving their life quality. However, the postoperative complications caused by IOL implantation can-

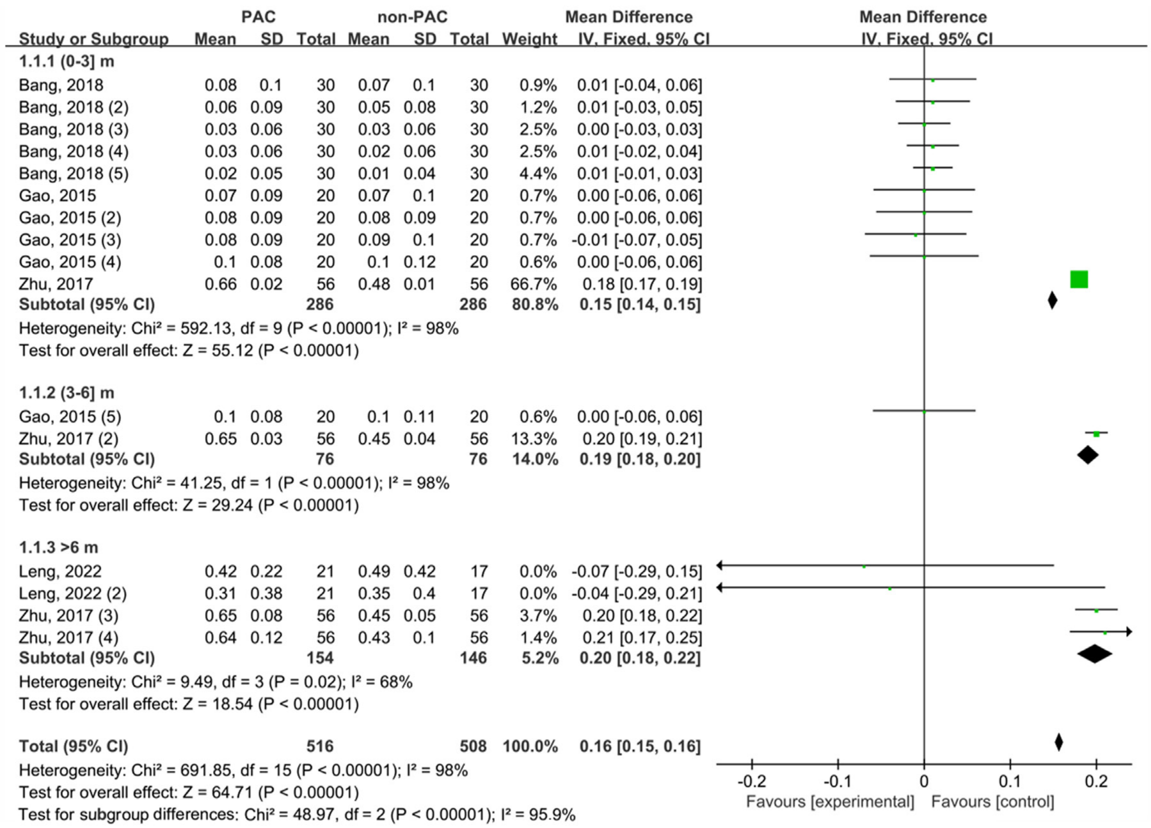

Figure 3. Meta analysis of UCVA after PAC treatment in different time periods. (Notes: UCVA = uncorrected visual acuity; PAC = polishing of the anterior capsule).

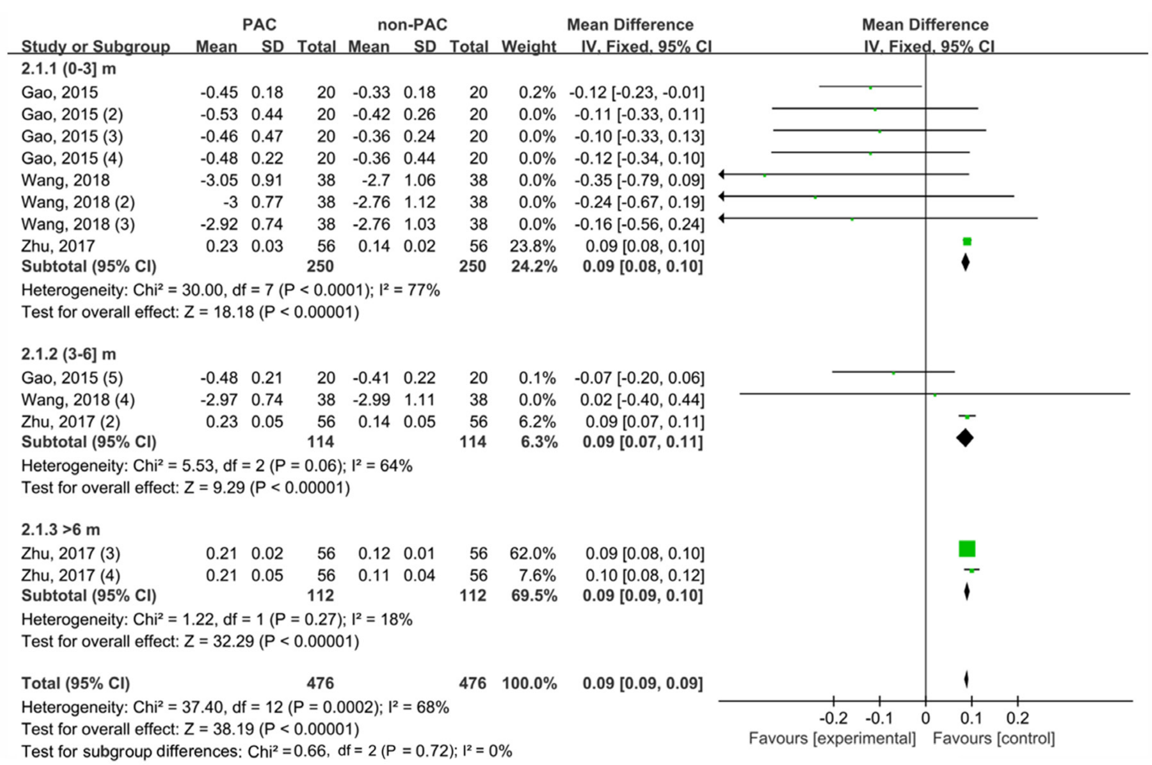

Figure 4. Meta analysis of SER after PAC treatment in different time periods. (Notes: SER = spherical equivalent refraction; PAC = polishing of the anterior capsule).

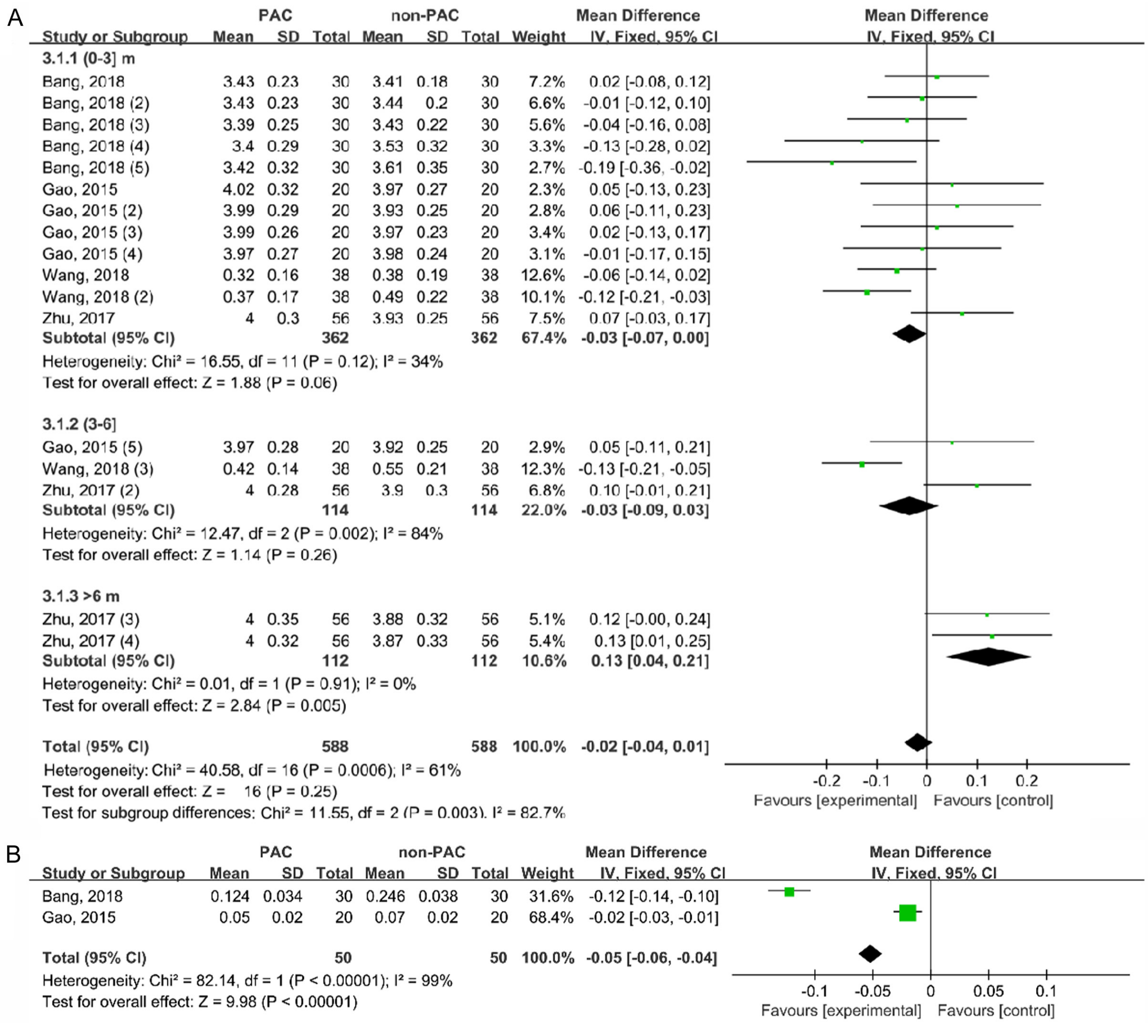

Figure 5. Meta analysis of ELP (A) and ELP_{RMS} (B) after PAC treatment in different time periods. (Notes: ELP = effective lens position; PAC = polishing of the anterior capsule; RMS = root mean square).

not be ignored during clinical treatment. IOL implantation can effectively play the role of light refraction, helping patients better achieve effective focusing during the viewing process. However, it also blocks the circulation of aqueous humor and provides adhesion points for residual LEC proliferation, which adversely affects the maintenance of ELP [17]. The main reason may be that LECs in contact with IOL are easily induced to differentiate into myofibroblasts that are rich in actin, which produces greater contractile force to contract the capsule [18]. In addition, the blocking of aqueous circulation will increase LEC activity, thus further accelerating cystic fibrosis and leading to capsular contraction [19]. The force produced by the contraction of anterior and posterior capsule can affect IOL stability, and subsequently, cause serious adverse effect on patients' visual function. Therefore, residual LECs occupy a decisive role in the occurrence of complications after cataract surgery. At present, with the improvement of medical technology, the migration of LECs can be inhibited by changing the manufacturing materials and edge morphology of IOL, with good results achieved. For example, Wirtitsch [20] et al. found that the implantation of one-piece hydro-

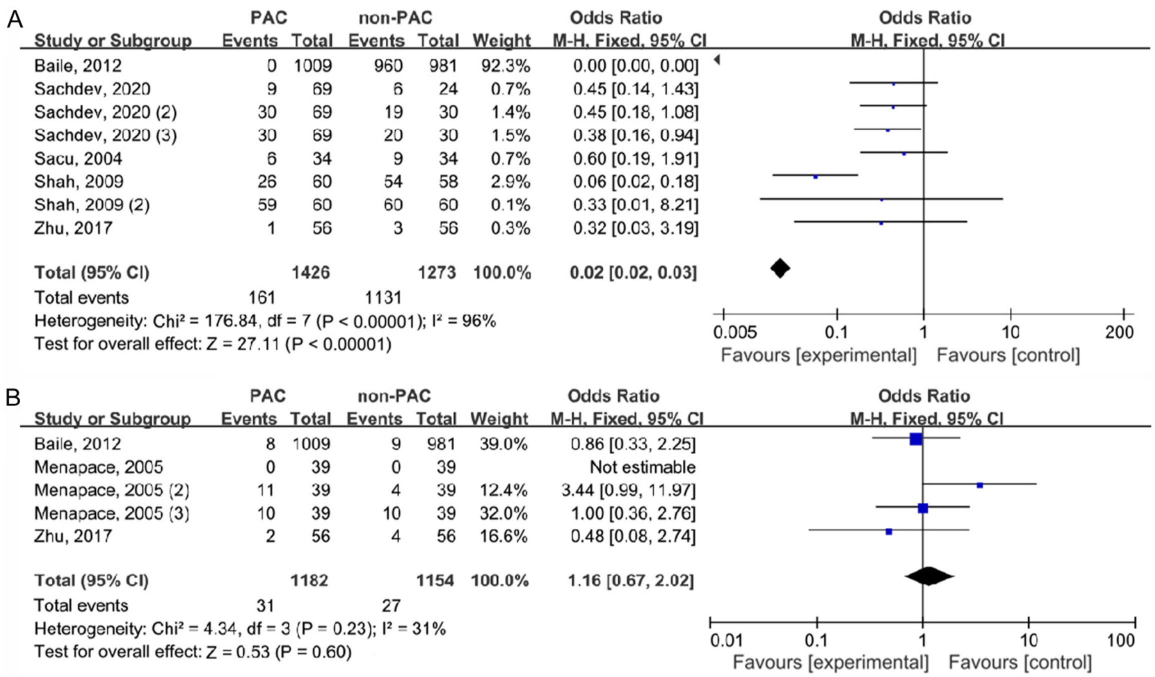

Figure 6. Meta analysis of ACO (A) and PCO (B) occurrence after PAC treatment. (Notes: ACO = anterior capsular opacification; PCO = posterior capsular opacification; PAC = polishing of the anterior capsule).

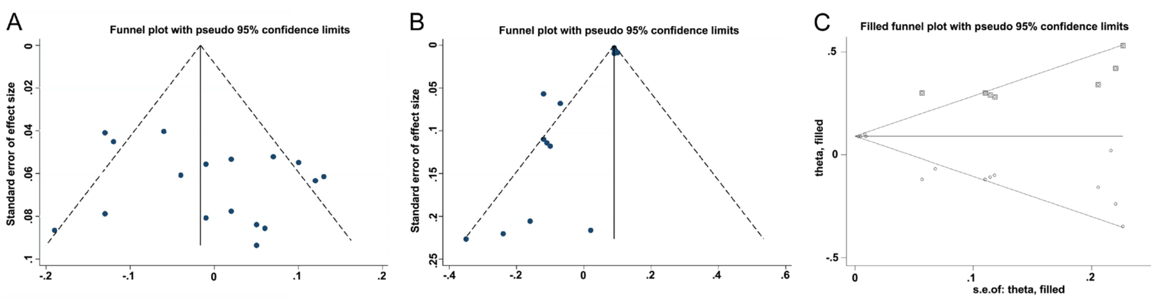

Figure 7. Evaluation of publication bias of key indicators in the included study. A: Funnel diagram of ELP; B: Funnel diagram of SER before trim-and-fill method; C: Filled funnel plot of effect estimate by standard error in means. (Notes: ELP = effective lens position; SER = spherical equivalent refraction).

phobic acrylate IOL had better axial stability. Besides, hydrophobic acrylate IOL with sharp edges is more likely to lead to ACO, but has an inhibitory effect on PCO, which may be related to blocking the migration path of LECs [21, 22]. In addition to improving IOL, PAC is also an effective method to remove residual LECs. At present, there are many studies on PAC inhibition of complications after IOL implantation, but there are many observation indicators and different conclusions. Therefore, we summarized and analyzed the effects of PAC on UCVA, Diopter, ELP, and capsular opacification after cataract surgery in various studies, thus analyzing the necessity and effect of PAC during cataract surgery.

UCVA and SER can reflect patients' visual function after cataract surgery from both subjective and objective aspects, and are commonly used detection indicators for postoperative review. As patients' demand for vision improvement increases, they are no longer satisfied with the best corrected visual acuity to achieve good visual requirements, but require naked vision that can meet their needs in daily life and cultural entertainment. Therefore, we summarized and analyzed the data related to UCVA and SER of 29 groups in five studies and found that PAC could more effectively improve cataract patients' visual function after surgery. In a 2019 meta-analysis of four observational cohort studies, Han et al. concluded that eyes with PAC had better UCVA and a reduced incidence of PCO over a period of 6 months to 3 years postoperatively [23].

To analyze the reasons why PAC improves patients' UCVA level, we studied ELP, an important factor affecting postoperative vision and diopter. After IOL implantation, if the IOL moves forward axially under the traction of anterior capsule contraction force, the patient will have myopic deviation. On the contrary, hyperopia offset will appear when the IOL moves towards the posterior axis under the influence of the posterior capsule contraction force. Through the comprehensive analysis of ELP data of 17 groups in four studies, PAC was found in 8 groups of data to effectively reduce ELP and better maintain IOL stability. However, after a comprehensive summary, it was found that PAC had no obvious effect on ELP within 6 months after surgery. It is important to note that at more than 6 months postoperatively, the data of both groups showed that PAC increased ELP, which was inconsistent with the result that PAC could improve UCVA. The reason may be that ELP has some defects in judging IOL stability, which may lead to deviations from the actual results. For example, in group A, half of the IOL moved forward by 0.9 mm, and the rest moved backward by 0.9 mm; similarly, half of the IOL in group B moved forward by 0.4 mm, and the rest moved backward by 0.4 mm. Obviously, the stability of the implanted IOL in group A is significantly lower than that in group B, but the mean change of ELP is the same in both groups, which impairs its accuracy in evaluating IOL stability. Therefore, we used ELP_{RMS} to further analyze the axial movement of IOL. The results of both groups of data in the two studies showed that PAC could significantly reduce ELP_{RMS}, suggesting that it can better maintain the stable state of IOL, thereby improving the UCVA of patients.

As another important factor affecting patients' UCVA level, capsular opacification is also an important index we observed. First, after comprehensive analysis of eight groups of data on ACO in five studies, we found that the risk of ACO after PAC decreased significantly. Among these studies, the data of one showed that 1,009 eyes treated with PAC did not develop ACO one year after surgery, while in the non-PAC group, 960 of the 981 eyes had ACO, suggesting that PAC can effectively avoid LEC proliferation and fibrosis on the surface of the capsule to effectively protect patients' visual function. Subsequently, we summarized the data related to PCO in the literature and found that PAC could not significantly reduce the incidence of PCO. The reason may be that an IOL with sharp edges will closely fit with the posterior capsule after implantation, so as to block the backward migration of LECs in the anterior capsule. Therefore, PAC can only avoid fibrotic PCO after implantation of a sharp-edged IOL. In addition, because regenerative PCO is caused by the proliferation of LECs at the equator, PAC cannot avoid its occurrence.

The heterogeneity of this meta-analysis may be due to the relatively small number of experimental studies on the correlation between PAC and visual function included in this study, as well as certain differences in the measurement methods of various research indicators. In addition, since most of the included studies had some bias, we did not perform a sensitivity analysis comparing low risk of bias studies with high risk of bias studies. In a follow-up study, we will further collect data to make a more detailed summary and clarify the role of PAC in cataract therapy, so as to better guide the clinical treatment of cataract.

Conclusion

PAC can effectively maintain ELP, reduce postoperative complications such as ACO, and improve patients' UCVA, thus effectively improving the efficacy of cataract surgery.

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Disclosure of conflict of interest

None.

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