

Original Article

Effect of postoperative nutrient management on macular edema and visual function following phacoemulsification for age-related cataract

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Abstract: Objective: To evaluate the effects of postoperative nutrient management combined with phacoemulsification on macular edema and visual function recovery in elderly patients with age-related cataracts. Methods: Patients who underwent phacoemulsification at Lishui Huaxia Eye Hospital between January 2022 and December 2024 were enrolled. After propensity score matching (PSM), 60 patients were assigned to each of the study and control groups. Clinical outcomes - including visual acuity, central macular thickness (CMT), total macular volume, incidence of macular edema, visual recovery time, intraocular pressure (IOP), corneal astigmatism, anterior chamber depth (ACD), adverse events, and patient-reported outcomes (sleep quality, pain, inflammation markers, quality-of-life scores) were evaluated and compared. Results: Baseline characteristics were comparable between the two groups ($P>0.05$). At postoperative weeks 1 and 12, visual acuity was significantly better in the study group than in the control group ($P<0.05$). At week 12, the study group exhibited significantly lower CMT ($P<0.05$), reduced total macular volume ($P<0.05$), lower incidence of macular edema (1.67% vs. 10.00%, $P<0.05$), improved visual field mean deviation ($P<0.05$), and shorter visual recovery time ($P<0.05$). IOP was also significantly lower in the study group ($P<0.05$), corneal astigmatism was reduced ($P<0.05$), and ACD was greater ($P<0.05$). Patient-reported outcomes favored the study group (all $P<0.05$). Moreover, the overall postoperative complication rate was significantly lower in the study group compared to the control group (10.00% vs. 23.33%, $P=0.05$). Conclusion: Postoperative nutrient management combined with phacoemulsification significantly reduces the incidence of macular edema and accelerates visual function recovery in elderly patients with age-related cataracts.

Keywords: Nutrient management, phacoemulsification, age-related cataracts, macular edema, visual function

Introduction

Age-related cataracts are a common vision-threatening condition, with prevalence increasing significantly among older populations [1]. Recent data indicate that cataracts remain a leading cause of blindness and visual impairment among adults aged ≥ 50 years, affecting approximately 15.2 million individuals globally in 2020 [2]. The hallmark pathologic feature of cataracts is progressive lens opacity, which impairs vision and, in severe cases, leads to blindness, thus substantially reducing patients' quality of life [3, 4].

Phacoemulsification is an effective and widely utilized surgical approach for restoring vision

in elderly patients with age-related cataracts, consistently demonstrating favorable clinical efficacy [5, 6]. This procedure employs ultrasound energy to emulsify and extract the cloudy lens, followed by precise implantation of an artificial intraocular lens, resulting in substantial visual improvement. Previous studies have shown that phacoemulsification notably enhances visual acuity, improves daily functioning, and lowers the risk of cataract-related blindness [7]. Nevertheless, postoperative complications may occur, with macular edema being the most frequent. Macular edema can delay visual recovery and adversely influence final visual outcome. Therefore, vigilant postoperative monitoring and timely intervention of complications, particularly macular edema, are

essential during the postoperative period to optimize surgical results and patient satisfaction.

Within the human body, numerous nutrients play crucial roles in maintaining health, particularly in preserving ocular function. Key nutrients, including lutein, vitamin A, vitamin E, and β -carotene, provide distinct physiological benefits. Lutein, a naturally occurring antioxidant, specifically accumulates in the macular region of the retina, effectively protecting retinal cells from oxidative stress by neutralizing harmful free radicals. Additionally, lutein inhibits inflammatory mediator release, thereby supporting the structural integrity and normal function of the retina. Vitamin A, an essential component of retinal rhodopsin, is indispensable for normal scotopic (night) vision. Vitamin E, another potent antioxidant, acts synergistically with lutein to mitigate oxidative damage. β -carotene serves as a precursor to vitamin A, ensuring sustained nutritional support for ocular health. Furthermore, α -linolenic acid, an essential polyunsaturated fatty acid, plays an important role in regulating ocular microcirculation by improving hemorheology, lowering blood viscosity, and enhancing vascular elasticity, thus promoting adequate oxygen and nutrient supply to the retina and optic nerve. Zinc gluconate participates in various biochemical processes within ocular tissues, facilitating cell proliferation, differentiation, and repair, thereby accelerating recovery and regeneration after ocular injury. Previous studies have suggested that these nutrients exert beneficial effects on eye health [8]; however, their efficacy and role in postoperative recovery following cataract surgery require further systematic evaluation. Determining whether targeted nutrient management, when integrated with phacoemulsification, can reduce macular edema and enhance visual function recovery is crucial for optimizing therapeutic strategies in patients with age-related cataract. This study aimed to evaluate the effectiveness of postoperative nutrient management combined with phacoemulsification in reducing postoperative macular edema and facilitating visual rehabilitation, providing a comprehensive and efficient therapeutic approach for elderly patients with cataracts.

Materials and methods

Experimental design

A retrospective analysis was conducted on 180 patients with age-related cataracts who underwent phacoemulsification at Lishui Huaxia Eye Hospital between January 2022 and December 2024. Patients were divided into either the study group (nutrient management, $n=85$) or the control group (no nutrient management, $n=95$) according to whether they received nutrient management during treatment. The two groups were matched in a 1:1 ratio using propensity score matching (PSM), with matching variables including gender, sex, body mass index (BMI), family history of cataracts, history of chronic diseases (e.g., hyperlipidemia, hypertension), and laterality of the affected eye. After matching, 60 patients were included in each group. The study protocol was reviewed and approved by Ethics Committee of Wenzhou Medical University (Ethical Approval No.: 2025. examine. No. 433). All study procedures were conducted in strict accordance with the principles outlined in the Declaration of Helsinki, and all research data underwent two independent reviews prior to use ([Supplementary Figure 1](#)).

Study participants

Inclusion criteria: (1) Patients who met the clinical diagnostic criteria for cataracts and indications for surgery [9]; (2) Aged over 60 years; (3) Patients with unilateral eye involvement and preoperative visual acuity <0.3 ; (4) Patients who underwent phacoemulsification for the first time. (5) Complete clinical data.

Exclusion criteria: (1) Presence of organ dysfunction, autoimmune diseases, hematological disorders, or malignancies; (2) History of intraocular infections, retinal detachment, or glaucoma.

Grouping

Both groups of cataract patients underwent phacoemulsification surgery: (1) Control group (Standard Postoperative Treatment): Patients received Tobramycin Dexamethasone eye ointment (ALCON, H20181126) applied to the conjunctival sac for 2 weeks after surgery, followed by Tobramycin Dexamethasone eye dro-

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ps (ALCON, H20150119) for 4 weeks. Calcium Dobesilate capsules (Ebewe, H20030202, 0.5 g/dose, thrice daily) were administered orally for 4 weeks. Patients maintained a normal diet without additional nutrient supplementation. (2) Study group (nutrient management plus standard care): On the basis of control group, patients received postoperative nutrient management for 12 weeks. In addition to their usual diet, patients consumed one packet of oral nutrient solution (240 kcal/300 ml) daily, taken 2 hours after a meal. The supplement provided: lutein (Shenzhen Oricon Biotechnology Co., Ltd.), 10 mg/day; α -linolenic acid (Wuhan Bailijian Biotechnology Co., Ltd.), 500 mg/day; vitamin A (Qingdao Shuangjing Pharmaceutical Co., Ltd.), 5000 IU/day; vitamin E (Zhejiang Yibaoxin Biotechnology Co., Ltd.), 400 IU/day; zinc gluconate (Sinopharm Xinjiang Pharmaceutical Co., Ltd.), 15 mg/day; β -carotene (Nanjing Songguan Biotechnology Co., Ltd.), 6 mg/day. Patients were given regular reminders to ensure adherence and recorded the timing and dosage of daily intake, enabling physicians to monitor compliance and adjust the regimen as needed.

Observational indicators

Primary outcomes: (1) Visual acuity [10]: Visual acuity was assessed using the International Standard Logarithmic Visual Acuity Chart at baseline and at 1, 4, 8, and 12 weeks postoperatively. Higher scores indicate better visual recovery. (2) Central macular thickness (CMT) and total macular volume [11]: At baseline and 12 weeks postoperatively, CMT and total macular volume were measured using optical coherence tomography (OCT; STRATUS3000). OCT scans were performed horizontally and vertically through the fovea, covering a total scan length of 4.0 mm. Automated analysis software subsequently calculated CMT and total macular volume. All OCT procedures were performed by the same qualified technician to ensure consistency. (3) Incidence of macular edema [12]: Record and compare the incidence of macular edema among the groups. (4) Visual field mean deviation (VFMD) [13]: Visual field function was assessed at baseline and 12 weeks postoperatively using standard automated perimetry (Humphrey Field Analyzer 24-2). The mean deviation (MD) was used as the global indicator of visual field performance, representing the aver-

age difference in light sensitivity between the patient's visual field and age-matched normal reference values, expressed in decibels (dB). A larger negative MD value indicates a greater overall reduction in visual field sensitivity, with the absolute value positively correlated with the severity of visual field loss. (5) Serum levels of inflammatory cytokines, including interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF- α), were measured using enzyme-linked immunosorbent assay (ELISA) with commercial kits (IL-6, Catalog #H007-1-2; TNF- α , Catalog #H052-1-2; Nanjing Jiancheng Bioengineering Institute, Nanjing, China) at baseline and 12 weeks postoperatively.

Secondary observational indicators: (1) Corneal astigmatism was measured using a fully automated computerized refractometer (Canon, Japan, model RK-F2). Additionally, intraocular pressure (IOP), anterior chamber depth (ACD), corneal endothelial cell density (ECD), and retinal nerve fiber layer (RNFL) thickness were assessed and compared between the two groups before and after surgery [14, 15]. (2) Postoperative ocular complications, including conjunctival injury (abrasions or hemorrhage), corneal edema confirmed by slit lamp examination, and any degree of anterior chamber hyphema detected via slit lamp, were recorded at each follow up visit, and the incidence of these events was compared between the two groups [16]. (3) Changes in sleep quality before and after surgery were evaluated using the Pittsburgh Sleep Quality Index (PSQI) scale [17]. The PSQI consists of 7 components, each scored from 0 to 3, with a full total score of 21. A score ≥ 7 indicates sleep disturbance. (4) Quality of life was assessed with the European Organization for Research and Treatment of Cancer Quality of Life Questionnaire (EORTC QLQ-C30) [18], which contains nine items scored from 1 to 10, with higher scores indicating better quality of life. Postoperative wound pain was assessed using a 10-cm Visual Analogue Scale (VAS) on the day of surgery and on the fifth postoperative day, where 0 represents "no pain at all" and 10 indicates "worst imaginable pain". Patient satisfaction was assessed with the Visual Function Questionnaire-25 (VFQ-25) [19], which includes 12 dimensions and 25 items. Each item is scored from 1 to 4, with a maximum score of 100. Higher scores indicate higher satisfaction.

Table 1. Comparison of baseline characteristics between two groups after PSM

Indicator	Study Group (n=60)	Control Group (n=60)	t/ χ^2	P
Age (years)	73.87±1.98	73.66±1.59	0.641	0.523
Sex (Male/Female)	33/27	31/29	0.134	0.714
BMI (kg/m ²)	23.78±1.85	23.94±1.92	0.465	0.643
Intraocular Pressure (mmHg)	27.64±5.13	27.78±5.05	0.151	0.881
Anterior Chamber Depth (mm)	1.67±0.23	1.71±0.33	0.77	0.443

Note: BMI, Body Mass Index.

Sample size estimation

The sample size was calculated based on the primary outcome of discharge preparedness, using a two-sample comparison of means. The formula applied was as follows: $n = 2[\sigma(t\alpha + t\beta)/\delta]^2$, where σ represents the population standard deviation, δ represents the mean difference, $\alpha=0.05$, $\beta=0.10$, $t\alpha=1.96$, $t\beta=1.28$. Based on previous literature [20], $\sigma=54.59$ and $\delta=26.69$. The calculated sample size was $n_1=n_2=44.72$ cases. Considering a 20% attrition rate, the required sample size was at least $n(1+20\%)=53.66$ cases per group. After rounding up, a final total of 60 cases were included in each group.

Statistical analysis

All statistical analyses were performed using SPSS 27.0 (IBM, Armonk, NY, USA). Propensity score matching (PSM) was conducted with a multivariate logistic regression model including age, sex, BMI, IOP, ACD, RNFL thickness, and ECD. Patients were matched 1:1 without replacement, using a caliper of 0.20 times the standard deviation of the propensity score logit. Balance between groups was considered acceptable if absolute standardized mean differences were <0.10 .

Continuous variables were tested for normality (Shapiro-Wilk) and variance homogeneity (Levene's test). Normally distributed variables were expressed as mean \pm standard deviation and analyzed by independent-samples t-tests, whereas non-normally distributed data were analyzed using the Mann-Whitney U test. Categorical variables were expressed as frequencies (percentages) and analyzed using χ^2 or Fisher's exact tests.

Repeated-measures data (e.g., visual acuity, IOP, ACD, CMT, macular volume, and question-

naire scores) were analyzed with two-way repeated-measures ANOVA; Greenhouse-Geisser correction was applied if sphericity was violated. Post-hoc comparisons used Bonferroni corrections. Single-time-point postoperative outcomes at week 12 were analyzed with independent-samples t-tests or Mann-Whitney U tests, as appropriate. Complication rates were compared using χ^2 or Fisher's exact tests. Effect sizes were presented as Cohen's d for t-tests and partial η^2 for ANOVA. Statistical significance was defined as $P<0.05$ (two-tailed).

Results

Baseline characteristics

After PSM, there were no significant differences between the two groups in terms of age (73.87±1.98 years vs. 73.66±1.59 years, $P=0.523$), sex distribution (male/female: 33/27 vs. 31/29, $P=0.714$), BMI (23.78±1.85 kg/m² vs. 23.94±1.92 kg/m², $P=0.643$), IOP (27.64±5.13 mmHg vs. 27.78±5.05 mmHg, $P=0.881$), or ACD (1.67±0.23 mm vs. 1.71±0.33 mm, $P=0.443$), as shown in **Table 1**.

Primary outcomes: visual function and macular health

Regarding the changes in visual acuity from baseline to postoperative weeks 1, 4, 8, and 12, the study group exhibited significantly higher visual acuity compared to the control group through postoperative week 1 to week 12 ($P<0.001$) (**Figure 1**).

Figure 2A and **2B** demonstrate the temporal progression of CMT and total macular volume, respectively. At 12 weeks postoperatively, the study group showed significantly lower CMT ($P<0.05$) and total macular volume ($P<0.05$) compared to the control group.

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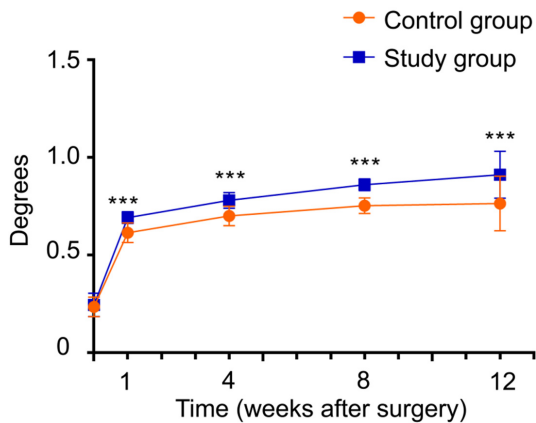


Figure 1. Visual acuity changes in two groups of patients. Note: Compared to control group, *** $P < 0.001$.

As presented in **Table 2**, at 12 weeks postoperatively, the incidence of macular edema in the study group (1.67%) was lower than that in the control group (10.00%) ($P > 0.05$). Preoperatively, there was no significant difference in VFMD between the two groups ($P > 0.05$), indicating comparability. At 12 weeks postoperatively, both groups showed a decrease, with the study group exhibiting a significantly lower level than the control group ($P < 0.05$).

Secondary outcomes: ocular structural and functional indicators

As shown in **Figure 3A**, IOP changes were compared between the two groups at baseline and postoperative weeks 1, 4, 8, and 12. No significant baseline difference was observed in IOP between the groups ($P > 0.05$). Postoperatively, at 1, 4, 8, and 12 weeks postoperatively, IOP gradually decreased in both groups, with the study group showing significantly lower values than the control group ($P < 0.05$).

Figure 3B depicts the temporal changes in ACD. There was no significant baseline difference in ACD between the two groups ($P > 0.05$). At 1, 4, 8, and 12 weeks postoperatively, ACD gradually increased in both groups, with the study group showing significantly higher values than the control group ($P < 0.05$).

Preoperative comparisons of corneal astigmatism, RNFL thickness, and ECD between the two groups showed no significant differences, indicating comparability ($P > 0.05$). At 12 weeks postoperatively, corneal astigmatism was sig-

nificantly lower in the study group compared to the control group ($P < 0.05$), whereas no significant differences were found in RNFL thickness and ECD between the two groups ($P > 0.05$) (**Table 3**).

Secondary outcomes: systemic and patient-reported outcomes

As shown in **Figure 4A** and **4B**, Preoperatively, there was no significant difference in EORTC QLQ-C30 scores and VFQ-25 scores between the two groups ($P > 0.05$), indicating comparability. At 12 weeks postoperatively, EORTC QLQ-C30 scores and VFQ-25 scores improved in both groups, with the study group showing significantly higher scores than the control group ($P < 0.05$).

Secondary outcomes: comparison of PSQI, VAS and inflammatory cytokines

Preoperatively, no significant differences were observed between the two groups in PSQI, VAS, and inflammatory cytokine levels (interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF- α)), all with $P > 0.05$, indicating comparability. At 12 weeks postoperatively, PSQI, VAS, IL-6, and TNF- α levels decreased in both groups, with the study group showing significantly lower values than the control group ($P < 0.05$). On the fifth postoperative day, VAS scores decreased in both patient groups, with the study group showing a lower score than the control group ($P < 0.05$) (**Table 4**).

Comparison of postoperative complications between the two groups

As shown in **Table 5**, complications in the study group included iris injury (n=1), corneal edema (n=2), hyphema (n=1), capsular opacity (n=1), and elevated IOP (n=1), resulting in a total incidence rate of 10.00% (6/60). In comparison, the control group exhibited a significantly higher incidence of 23.33% (14/60) ($P = 0.05$), including corneal edema (n=6), hyphema (n=1), capsular opacity (n=4), and elevated IOP (n=3).

Discussion

Age-related cataracts are a leading cause of visual impairment and blindness globally, and improving treatment strategies remains a major focus in ophthalmology [21]. Phacoemulsification, the mainstream surgical method for

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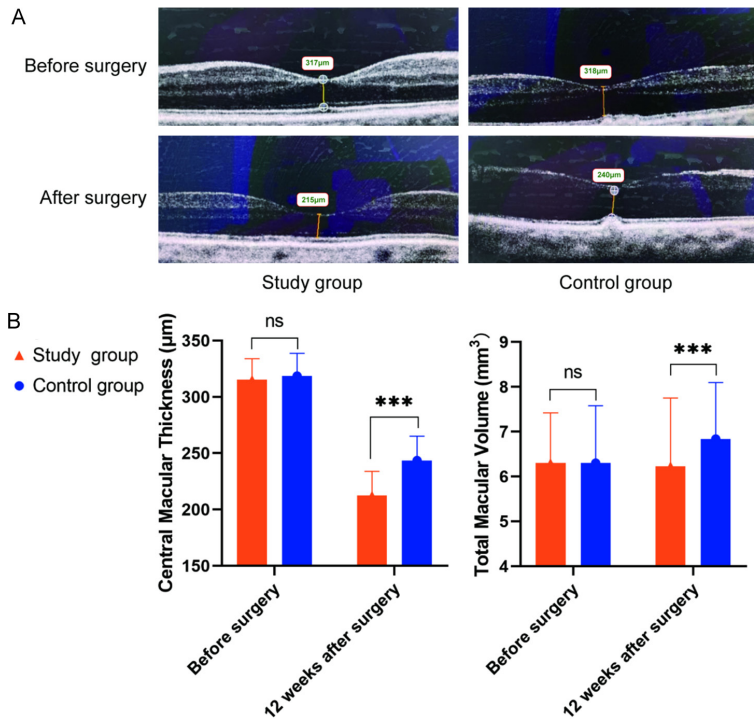


Figure 2. Comparison of CMT and total macular volume between the two groups before and after treatment. A. Representative OCT images of CMT before and 12 weeks after surgery; B. Quantitative comparisons of CMT and total macular volume between the study and control groups at baseline and 12 weeks postoperatively. Note: CMT, Central Macular Thickness; OCT, optical coherence tomography. Compared to control group, *** $P < 0.001$; ns, not significant.

treating cataracts, is favored for its advantages of minimal trauma, quick recovery, and a low complication rate. However, postoperative macular edema is a frequent complication that can delay visual recovery and impair patients' quality of life [22, 23]. Therefore, exploring effective adjuvant therapies to reduce postoperative macular edema and accelerate visual recovery is of significant clinical importance. In this study, we applied PSM to balance baseline characteristics between the study and control groups to enhance result reliability. Our findings demonstrated that phacoemulsification assisted by postoperative nutrient management significantly lowers the incidence of postoperative macular edema and promotes more efficient recovery of visual function.

The results of this study indicated that at postoperative weeks 1, 4, 8, and 12, patients in the study group achieved higher visual acuity and a shorter time to visual recovery than those in the control group. At week 12, the CMT and

total macular volume were also significantly lower in the study group, and the incidence of macular edema was significantly reduced compared with the control group. These results suggest that postoperative nutrient management helps reduce the incidence of macular edema and improve visual function recovery.

Macular edema is a common complication after cataract surgery [24], with a complex pathogenesis involving inflammation, disruption of the blood-retinal barrier, increased vascular permeability, and other mechanisms [20, 25]. Adequate nutritional support during the postoperative period is particularly crucial for tissue repair and complications prevention. Lutein, as an antioxidant, can effectively protect the macula from oxidative stress and is essential for maintaining visual function. α -linolenic acid improves microcirculation, alleviates ocular

inflammation, and aids in the rapid recovery of ocular tissues. Vitamin A and E play key roles in maintaining retinal integrity and providing antioxidant protection: vitamin A is an essential component of retinal photoreceptor pigments, while vitamin E reduces inflammation and protects ocular cells from free radical damage. Zinc gluconate promotes tissue repair and accelerates wound healing, whereas β -carotene serves as an antioxidant, protecting the retina from phototoxic injury and supporting visual health. These nutrients, provided as once-daily oral compound taken with meals, which provide convenient and steady nutritional support, thereby fostering postoperative recovery and reducing complication rates.

The study results also demonstrate that postoperative astigmatism values in the study group were lower than those in the control group, suggesting that nutrient management may help reduce postoperative astigmatism. Postoperative astigmatism is related to factors

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Table 2. Comparison of primary outcome measures between the two groups (Incidence of Macular Edema at week 12, Visual Field Mean Deviation at week 12)

Indicator	Study Group (n=60)	Control Group (n=60)	X ² /t	P	
Incidence of Macular Edema (%)	1 (1.67)	6 (10.00)	3.793	0.051	
VFMD	Before surgery	9.58±1.60	9.55±1.44	0.120	0.905
	12 weeks after surgery	6.54±1.54*	7.16±1.82*	2.014	0.046

Note: VFMD, Visual Field Mean Deviation. Compared with before surgery, *P<0.05.

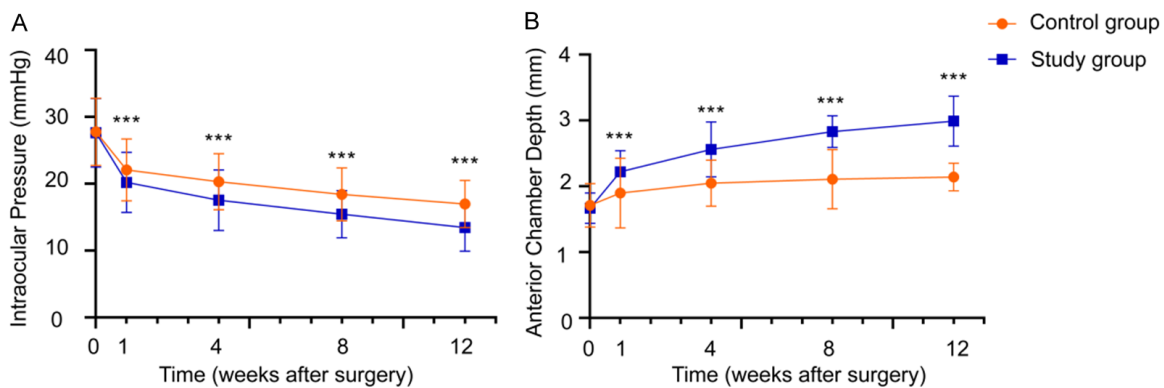


Figure 3. Comparison of IOP (A) and ACD (B) between the two groups over the period of 12 weeks after treatment. Note: IOP, Intraocular Pressure; ACD, Anterior Chamber Depth. Compared to control group, ***P<0.001.

Table 3. Comparison of ocular structural and functional indicators between the two groups

Indicator	Time	Study Group (n=60)	Control Group (n=60)	t	P
Retinal Nerve Fiber Layer (μm)	Before surgery	83.54±10.54	82.15±10.19	0.734	0.464
	12 weeks after surgery	72.49±15.52*	73.05±14.52*	0.204	0.839
Endothelial Cell Density (cells/mm ²)	Before surgery	2512±412.66	2508.15±433.87	0.05	0.96
	12 weeks after surgery	2484.48±400.54*	2492.81±467.84*	0.105	0.917
Corneal Astigmatism (D)	Before surgery	1.07±0.25	1.06±0.23	0.228	0.838
	12 weeks after surgery	0.61±0.12*	1.02±0.25*	11.452	<0.001

Note: Compared with before surgery, *P<0.05.

such as surgical incisions and alterations in corneal morphology. Adequate nutritional intake may enhance the repair capacity of ocular tissues and accelerate corneal wound healing. Previous research by Christen et al. [26] reported associations between β-carotene, vitamins C and E, and cataract risk, consistent with the findings of the present study. Nutrients, such as vitamin C, support collagen synthesis, promote proliferation of corneal epithelial cells, facilitate stromal repair, and help maintain normal corneal curvature and morphology. Additionally, appropriate nutrient supplementation can attenuate postoperative inflammatory responses, preventing further inflammation-related damage to corneal tissues and stabilizing corneal morphology, thereby reducing post-

operative astigmatism. Specific nutrients with anti-inflammatory properties, such as α-linolenic acid and vitamin E, can regulate inflammatory responses and also alleviate macular edema, contributing to improved overall surgical outcome.

Previous studies by Zhuang et al. [27] have also shown that vitamin E intake may reduce the incidence of cataracts, supporting the findings of this study. Additionally, maintaining stable IOP is also an important goal of postoperative nutrient management [28]. Elevated IOP is a recognized risk factor for macular edema, and appropriate nutritional intake can help regulate IOP. In this study, supplementation with vitamin A and zinc gluconate supported retinal function

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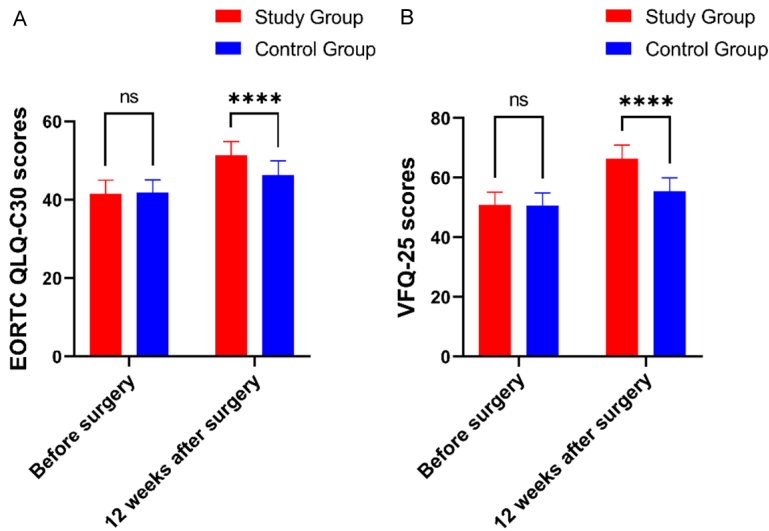


Figure 4. Comparison of patient-reported outcomes at 12 weeks postoperative in study and control groups. A. Comparison of EORTC QLQ-C30 scores before the operation and 12 weeks after the operation; B. Comparison of VFQ-25 scores before the operation and 12 weeks after the operation. Note: EORTC QLQ-C30, European Organization for Research and Treatment of Cancer Quality of Life Questionnaire Core 30; Satisfaction (VFQ-25), Visual Function Questionnaire-25. Compared to control group, **** $P < 0.0001$; ns, not significant.

and tissue repair, while β -carotene provided additional protection, together helping to reduce macular edema associated with increased IOP [29, 30]. Additionally, improving the overall metabolic status of ocular tissues is another key effect of nutrient management. A favorable metabolic environment facilitates waste removal, nutrient absorption, and maintenance of normal physiological functions, thereby promoting visual function recovery. Furthermore, phacoemulsification assisted by postoperative nutrient management appears to be safe [31]. Proper selected nutrients (e.g., vitamins, antioxidants) primarily function through physiological pathways - enhancing tissue repair and reducing inflammation - rather than interfering with surgical procedures or introducing external risks. When nutrient selection and dosage are guided by clinical evidence, and patients have no relevant metabolic disorders, safety is generally acceptable [32]. These results further confirm that postoperative nutrient management does not pose additional risks of adverse reactions under standard application.

The study results indicated that, postoperatively, the study group had lower PSQI and VAS scores, as well as reduced IL-6 and TNF- α levels, compared with the control group, while the

EORTC QLQ-C30 and VFQ-25 scores were significantly higher. These improvements can largely be attributed to the postoperative nutrient management administered in the study group. Antioxidants such as lutein and β -carotene may reduce ocular oxidative damage, protect the macula and retina, and facilitate visual function recovery, consequently lowering VAS scores. Previous research by Camacho-Barcia et al. [33] demonstrated a clear association between dietary vitamin intake and improved outcomes following cataract surgery, aligning closely with the findings of our study. α -linolenic acid enhances ocular microcirculation and exerts anti-inflammatory effects, while vitamin E further reduces inflammation, thereby decreasing the levels

of inflammatory cytokines such as IL-6 and TNF- α . Additionally, zinc gluconate enhances tissue repair, accelerates postoperative physical recovery, and ultimately improves patients' overall quality of life, explaining the higher EORTC QLQ-C30 scores observed [34]. Effective postoperative recovery and reduced discomfort naturally enhance patient satisfaction. Overall, the study group demonstrated superior outcomes in terms of sleep quality, pain management, inflammatory response, quality of life, and patient satisfaction.

As mentioned, our findings are consistent with several recent studies, although discrepancies or inconsistencies among various reports still exist. For example, the large-scale DREAM study published in the *New England Journal of Medicine*, which evaluated omega-3 supplementation for chronic dry eye disease, did not demonstrate clear symptomatic benefits [35]. Such differences may result from variations in baseline health conditions and nutritional profiles of study populations, differences in formulation and timing of the interventions, and outcome measures used during follow-up. Additionally, low-dose, single-vitamin supplementation over extended periods often yields limited effects, whereas intensive short-term interven-

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Table 4. Comparison of PSQI, VAS and inflammatory cytokines at 12 - week postoperatively

Indicator	Time	Study Group (n=60)	Control Group (n=60)	t	P
Pittsburgh Sleep Quality Index	Before surgery	6.59±1.25	6.62±1.18	-0.136	0.892
	12 weeks after surgery	2.12±0.79*	3.84±0.88*	11.266	<0.05
Visual Analog Scale	Before surgery	5.03±0.45	5.07±0.52	-0.377	0.707
	5 days after surgery	1.03±0.09*	1.97±0.36*	19.622	<0.001
IL-6 (pg/mL)	Before surgery	5.59±1.32	6.02±1.51	-0.270	0.787
	12 weeks after surgery	5.21±1.08*	6.14±1.37*	4.129	<0.05
TNF-α (pg/mL)	Before surgery	20.27±3.07	20.23±3.01	0.072	0.943
	12 weeks after surgery	18.29±3.55*	20.16±3.28*	2.997	<0.05

Note: IL-6, Interleukin-6; TNF-α, Tumor Necrosis Factor-alpha. Compared to before surgery, *P<0.05.

Table 5. Comparison of incidence of adverse reactions between the two groups

Group	Iris Injury	Corneal Edema	Hyphema	Capsular opacity	elevated intraocular pressure	Total Incidence Rate (%)	χ ²	P
Study Group (n=60)	1 (1.67)	2 (3.33)	1 (1.67)	1 (1.67)	1 (1.67)	6 (10.00)	3.84	0.05
Control Group (n=60)	0 (0.00)	6 (10.00)	1 (1.67)	4 (6.67)	3 (5.00)	14 (23.33)		

tions combining multiple nutrients may generate more pronounced clinical benefits through synergistic interactions [36, 37]. Compared to these studies, our investigation employed a comprehensive postoperative nutritional regimen - including antioxidants such as lutein and β-carotene, α-linolenic acid, vitamin E, and zinc gluconate - and comprehensively assessed multiple aspects of postoperative recovery. This approach demonstrated clear advantages in the intervention group, underscoring the potential clinical value of integrated nutrient management for optimizing perioperative care in cataract patients.

Despite the encouraging results, this study has some limitations. First, as a retrospective study, it remained susceptible to residual confounding despite the use of PSM to balance baseline characteristics. Second, the sample size of this study was relatively small, which may limit the generalizability of the findings. Future research should include prospective, multicenter, large-sample clinical trials to further validate these results. Additionally, this study primarily focused on the effects of postoperative nutrient management on macular edema, visual function recovery, astigmatism, and sleep quality, without delving deep into the underlying mechanisms. Future research could use molecular and cellular techniques to explore the underlying mechanisms, providing a more solid theoretical basis for its clinical application.

Conclusion

Phacoemulsification assisted by postoperative nutrient management demonstrated significant advantages in reducing the incidence of postoperative macular edema and accelerating visual function recovery in patients with age-related cataracts.

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Disclosure of conflict of interest

None.

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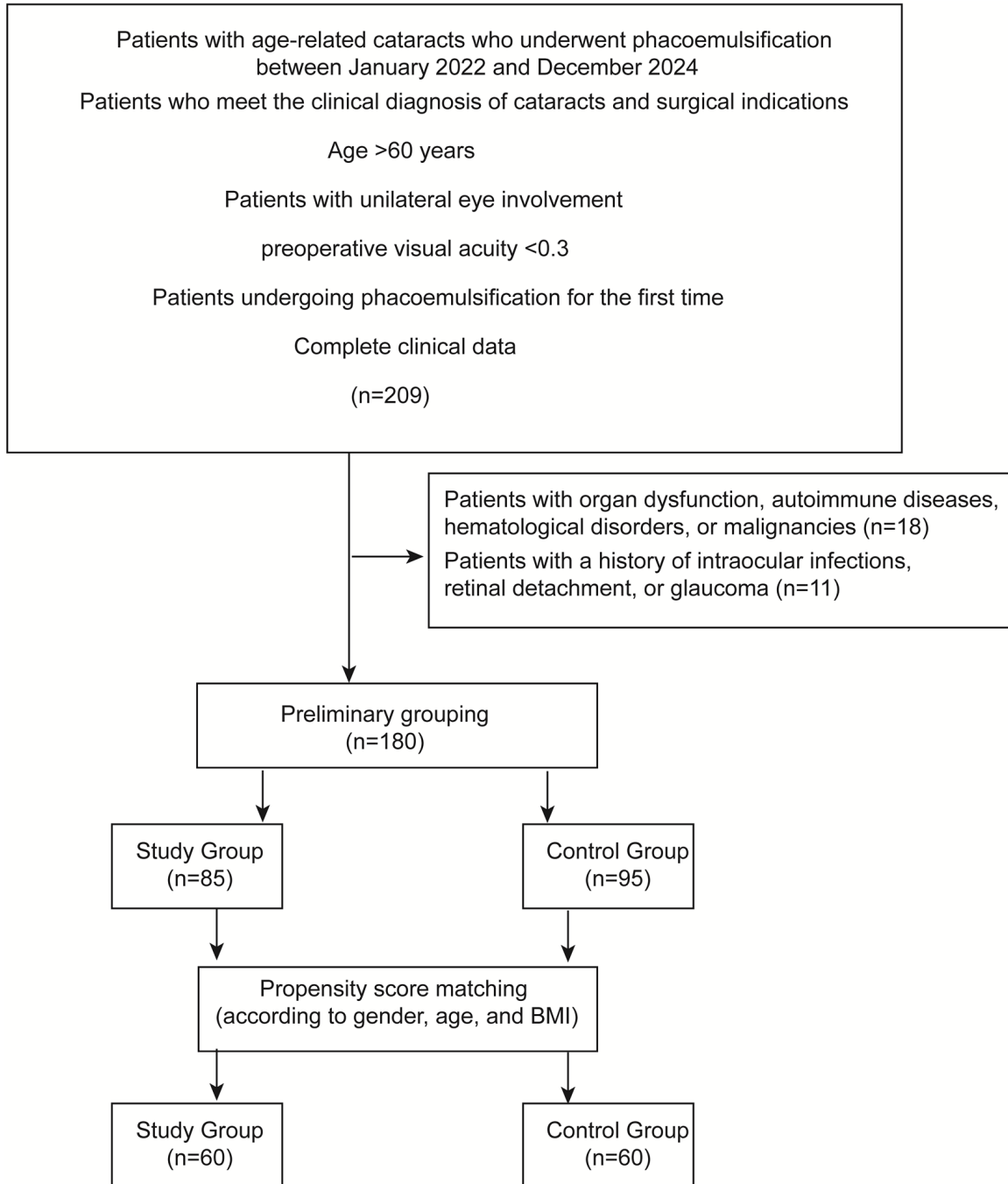
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Supplementary Figure 1. Flowchart of patient selection and grouping.