

Clinical investigations and mechanistic insights into the antioxidant effects of drugs post-cataract surgery

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Abstract: Background: Postoperative recovery from cataract surgery in elderly patients can be complicated by oxidative stress and inflammation, which may affect clinical outcomes. Mingmu Dihuang Tang (MDT), a traditional Chinese medicine formula, is postulated to offer antioxidative and anti-inflammatory benefits in this context. **Objectives:** This study aimed to evaluate the clinical efficacy of MDT as an adjunctive therapy for antioxidant and anti-inflammatory effects in elderly patients after cataract surgery. **Methods:** In this randomized controlled trial, 120 patients were allocated to either a control group (conventional Western medicine) or an experimental group (conventional treatment plus MDT). Serum and aqueous humor levels of glutathione peroxidase (GSH-Px), catalase (CAT), superoxide dismutase (SOD), total antioxidant capacity (TAC), nitric oxide and inflammatory cytokines (IL-2, IL-6, TNF- α) were measured. Visual acuity and lens opacity were also assessed. **Results:** Compared to the control group, the experimental group demonstrated significantly higher antioxidant activities (GSH-Px, CAT, SOD, TAC) and IL-2 levels, alongside lower nitric oxide, IL-6 and TNF- α concentrations ($P < 0.05$). The MDT group also showed superior visual acuity recovery, reduced lens clouding and a lower complication rate (6.21% vs. control, $P < 0.05$). **Conclusion:** Adjunctive therapy with MDT enhances antioxidant capacity, modulates inflammation and improves clinical outcomes in cataract surgery recovery, demonstrating significant value for clinical application.

Keywords: Antioxidant capacity; Cataract surgery; Mingmu Dihuang Tang; Oxidative stress

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INTRODUCTION

Cataracts are ocular diseases caused by metabolic imbalance and protein denaturation and opacity in the lens, influenced by multiple factors including genetics, immunity and metabolic abnormalities. As the leading cause of blindness, cataracts have become the primary reason for vision impairment in the elderly (Chen *et al.*, 2024; Waisberg *et al.*, 2024). While surgical intervention can rapidly improve vision, it may concurrently increase the risk of postoperative complications such as retinal detachment. Furthermore, surgical trauma itself can trigger intraocular oxidative stress and inflammatory cascades, which significantly impair the recovery process (Wang *et al.*, 2024). Consequently, pharmacological agents possessing both antioxidant and anti-inflammatory properties have become a focal point in postoperative rehabilitation research.

Oxidative stress is the core mechanism underlying cataract development. ROS-mediated ocular tissue damage drives lens opacity, while inflammatory stress serves as a key indicator for evaluating therapeutic efficacy. (Duan *et al.*, 2024). Medical practitioners classify age-related cataracts as “circular opacity cataracts,” with the core pathogenesis rooted in deficiency of liver and kidney essence and qi, coupled with disharmony among the zang-fu organs. Treatment must focus on nourishing the liver and kidneys and replenishing essence and qi. (Wang *et al.*, 2024; Kulbay *et al.*, 2024). Existing dietary antioxidants and

Western pharmaceuticals suffer from limitations such as single-target mechanisms and limited anti-inflammatory effects. In contrast, traditional Chinese medicine formulas demonstrate unique potential through their multi-component, multi-target advantages. (Lou *et al.*, 2025; Lee *et al.*, 2024; Zhu *et al.*, 2025).

Modern research confirms that Shijue Mingming Powder primarily focuses on localized antioxidant effects but lacks systemic metabolic and anti-inflammatory regulation. Neizang Pills, which primarily tonify qi and nourish yin, exhibit limited antioxidant and microcirculation-improving effects. (Liu *et al.*, 2024; Cui *et al.*, 2025; Zhou *et al.*, 2022). In contrast, the MDT, originating from the Ming Dynasty's Divine Farmer's Classic of Materia Medica (Piao *et al.*, 2003; Zhao *et al.*, 2021), possesses distinct characteristics: its formulation establishes a three-dimensional system of “nourishing the liver and kidneys, clearing heat to improve vision and promoting blood circulation to resolve stasis,” aligning with the complex pathogenesis of age-related cataracts (Li *et al.*, 2022). With centuries of clinical application in traditional Chinese medicine, texts like the “Yao Han” explicitly document its efficacy for treating cataract-related conditions (Li *et al.*, 2007; Lin *et al.*, 2024). It remains widely used today as an adjunct therapy for various eye disorders. Preclinical and clinical studies indicate that its antioxidant and anti-inflammatory effects, along with visual acuity improvement rates and complication control, are superior to the aforementioned two compound formulations (Shen *et al.*, 2023; Ng *et al.*, 2021). Mechanistically, it activates

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the Nrf2/ARE pathway while inhibiting multiple inflammatory pathways, forming a comprehensive regulatory network that exerts more extensive effect (Chen *et al.*, 2022; Bi *et al.*, 2025).

To date, no studies have systematically compared the postoperative rehabilitation efficacy of MDT with other traditional Chinese medicine (TCM) formulas and the integration of its TCM theory with modern biomedical mechanisms remains unclear. Therefore, this randomized controlled trial compares the efficacy of MDT combined with conventional Western medicine versus Western medicine alone. It analyzes the effects on visual acuity, lens opacity and related biochemical indicators to clarify the differences and unique advantages of MDT compared to Shijuemingming Eye Powder and Neizhang Pills, thereby providing evidence for integrated Chinese and Western medicine treatment.

MATERIALS AND METHODS

Clinical information

This research protocol has been approved by the Ethics Committee of the Helsinki Declaration and all participants have signed a written informed consent form before enrollment. Random sequence generation involves an independent statistician who is not involved in recruitment, grouping, or intervention, using a computer to generate a random number sequence. Allocation concealment: The experimental group and control group were placed in sequentially numbered, opaque, sealed envelopes. After the patient signs the informed consent form, the researcher opens the corresponding numbered envelopes in the order of enrollment to determine their grouping, ensuring that the allocation process is unpredictable. Due to the differences in treatment methods, this study implemented blinding for outcome assessors and data analysts. To validate the primary outcome measure, the intergroup differences in aqueous humor SOD levels, a priori sample size estimation was conducted. The effect size was set at $d=0.5$, with $\alpha=0.05$ (two-tailed) and statistical power $(1-\beta)=0.8$. Using the G*Power 3.1 software, the minimum required sample size per group was calculated to be 54. Considering an approximate dropout rate of 10%, the total sample size was ultimately determined to be 120, with 60 cases per group. In the control group, there were 32 males and 28 females, aged 48-75 years, with a mean of (62.89 ± 10.35) years and with a disease duration of 1-10 years. In the experimental group, there were 31 males and 29 females, aged 45-76 years, with a mean of (61.23 ± 11.02) years and the duration of the disease was 1-11 years. There was no statistical significance in comparing the general data of patients in the two groups, $P>0.05$.

Inclusion and exclusion criteria

Inclusion criteria of cataract group:

(1) Comply with the relevant diagnostic criteria for cataract in the Diagnostic and Therapeutic Criteria for traditional

Chinese medicine and ophthalmology issued by the State Administration of Traditional Chinese Medicine (SATCM).

(2) All patients were older than 45 years old.

(3) Diagnosis is confirmed by ultrasonography.

(4) Normal behavioral ability and the first surgery for ophthalmic diseases.

Exclusion criteria

The exclusion criteria were systemic infectious diseases, history of eye surgery, vitreous hemorrhage and severe hypertension, mental disorders and allergy to treatment-related drugs.

Methodology

The control group was treated with conventional Western medicine and the eye drops were stopped in the white room, 1-2 drops each time, 3 times a day. On the basis of the control group, the experimental group was treated with *Mingmu Dihuang* decoction and the composition of the prescription was 25g of *Rehmannia rehmannia*, 18g of *Cornus officinalis*, 25g of wild chrysanthemum, 12g of *Poria cocos*, 18g of Zexiao, 12g of red peony, 15g of wolfberry, 10g of *Polygonum multiflori*, 15g of *angelica*, 12g of *Prunella vulgaris*, 10g of *Zhejiang fritillary*, 20g of *salvia*, 6g of boiled licorice, 3g of *Panax notoginseng* powder and 10g of *Chuanxiong*. Add or subtract with symptoms, 1 dose per day, 500ml of water decoction, 2 times a day. Both groups were treated continuously for 2 months and at the same time, the intake of vitamins and trace elements was strengthened and attention was paid to supplementing daily nutrition in time.

Observation indicators

Fasting elbow venous blood of 5mL was collected from patients in both groups in the early morning, centrifuged at a radius of 2.5cm at a speed of 2500r/min for 10mins and the serum was separated and cryopreserved at -80°C . 0.15~0.20m aqueous humor samples were collected from the anterior chamber by 1mm puncture within the corneal limbus and the undiluted aqueous humor samples were transferred to a sterile centrifuge tube and stored frozen at -80°C . GSH-Px, CAT and SOD levels were measured by enzyme-linked immunosorbent assay, TAC by colorimetric assay and nitric oxide levels by nitrate reductase assay (Feyzollahi *et al.*, 2025). To compare the serum and aqueous humor antichemical indexes and inflammatory factor levels between the two groups, peripheral blood was drawn on an empty stomach to extract serum before and after surgery and the enzyme-linked immunosorbent assay kit procedure was strictly followed to detect serum inflammatory factors II-2, II-6 and TNF- α (Li *et al.*, 2024). The visual acuity of patients in both groups was examined before and after treatment using international standard logarithmic visual acuity charts, and all examinations were completed by specialized personnel, specialists and equipment. The thickness of the pins in both groups was measured using the SOUER Ophthalmic A/B Ultrasound Diagnostic Instrument under the original pupil before and after treatment, respectively. Additionally, the lens

turbidity was analyzed using the SLICPS2000 slit lamp image analyzer after dilating the pupil. The rate of postoperative complications was compared to that of the two groups of patients and was calculated according to the number of cases of complications as a percentage of the total number of cases (Muhsen *et al.*, 2023).

Statistical analysis

Statistical analysis was conducted using SPSS 20.0. Quantitative data that conforms to normal distribution are expressed as mean \pm standard deviation ($\bar{x} \pm s$). Independent sample and paired sample t-tests are used for inter group and intra group comparisons and Cohen's d value and its 95% CI are calculated as effect measures. Count data is presented in frequency (percentage) using a chi square test and Cram é r's V value and its 95% CI are reported. To control for multiple comparisons, Bonferroni correction is applied to multiple related indicators at the same time point. $P < 0.05$ indicates a statistically significant difference.

RESULTS

Findings

Results of oxidative stress indicators

Table 1 shows the comparison of serum antioxidant index levels of the patients, the experimental group was treated with antioxidant drugs containing Mingmu Dihuang Tang and the control group was treated conventionally to know the difference in antioxidant capacity of the patients in different groups. In terms of antioxidant indexes, four indexes, GSH-R, CAT, SOD and TAC, reflect the antioxidant defense ability of the body. The GSH-R of the experimental group was (92.57 ± 9.42) U/L, which was significantly higher than that of the control group (70.15 ± 4.50) U/L and the t-value reached 16.402, $P < 0.001$, which indicated that the difference in this index between the two groups was highly statistically significant. This indicates that the experimental group was stronger in the reduction of glutathione and was able to maintain the intracellular antioxidant environment more efficiently. The CAT index was (25.16 ± 4.14) U/mL in the experimental group, while the control group was (15.35 ± 1.76) U/mL, with a t-value of 20.467, $P < 0.001$, which shows that the experimental group was superior in the decomposition of hydrogen peroxide and the scavenging of intracellular peroxides. The SOD index also showed the advantage of the experimental group, with (66.68 ± 9.52) ml/L in the experimental group and (29.66 ± 5.76) ml/L in the control group and the t-value was as high as 31.258, $P < 0.001$, which implied that the experimental group was better in protecting the cells from oxidative damage. On the TAC index, the (17.52 ± 2.98) kU /L was significantly higher than (10.25 ± 1.03) kU/L in the control group. And the lower level of nitric oxide in the experimental group might imply that the organism of the patients in this group effectively regulated the production of NO in response to the disease in order to reduce the oxidative damage.

The levels of antioxidant indexes in aqueous humor of the patients were shown in table 2 and the GSH-P level of the control group was (52.36 ± 4.57) U/L, while that of the experimental group reached (77.14 ± 9.84) U/L, which was significantly higher than that of the control group. The higher GSH-P level in the experimental group may imply that the body of the patients in this group faced a stronger oxidative stress challenge, which prompted the body to synthesize a large amount of GSH-P to protect against oxidative damage. A large amount of reactive oxygen species, such as hydrogen peroxide, was produced, which stimulated the production of GSH-P, which can catalyze the conversion of reduced glutathione to the oxidized form, as well as the reduction of hydrogen peroxide to water, which protects the cells from oxidative damage. The CAT level of the control group was (13.69 ± 1.05) U/mL, while the experimental group was as high as (23.16 ± 3.89) U/mL. The experimental group caused the organism to produce more reactive oxygen species such as hydrogen peroxide, which stimulated the production of large amounts of CAT to maintain redox balance. The SOD level of the control group was (0.09 ± 0.01) mmol/L and that of the experimental group was (0.19 ± 0.04) mmol/L. The higher SOD level in the experimental group implies that the generation of superoxide anion radicals in this group of patients was significantly increased to counteract the damage caused by superoxide anion radicals, which contributed to the increase in SOD level. The TAC of the control group was (7.01 ± 1.63) kU/L, while that of the experimental group reached (15.21 ± 2.66) kU/L. The TAC comprehensively reflects the overall capacity of the body's antioxidant system, which initiates a more comprehensive and powerful antioxidant defense mechanism. The NO level of the control group was (58.22 ± 9.32) mmol/L. experimental group was (40.01 ± 5.59) mmol/L and the NO level in the control group was higher than that in the experimental group. Under oxidative stress, NO production and metabolism are disturbed and excess NO may react with superoxide anion radicals to generate peroxynitrite anion with stronger toxicity, causing damage to ocular tissues. The higher NO levels in the control group may indicate the presence of abnormal NO metabolism in this group of patients under oxidative stress in their bodies, generating excess reactive nitrogen species and causing damage to ocular tissues.

Table 3 shows the comparison of preoperative and postoperative serum inflammatory factor content levels and from the data, it can be seen that the control group had a rise in IL-2, IL-6 and TNF- α levels after the operation, but the rise was relatively small. In contrast, the experimental group showed a significant increase in IL-2 levels and a significant decrease in IL-6 and TNF- α levels in the postoperative period, demonstrating the positive effect of the flushing operation on inflammatory indicators. The experimental group showed the greatest increase in IL-2 levels in the postoperative period and the significant

increase in IL-2 levels to 67.15 ± 3.56 pg/ml in the postoperative period enhanced the activity and function of immune cells. IL-6 and TNF- α levels also decreased most significantly, 36.95 ± 6.32 versus 25.69 ± 3.04 , respectively, suggesting that the experimental group may have been more effectively manipulated with antioxidant medications containing Mingmu Dihuang Tang, which resulted in a more pronounced degree of decrease compared to the control group postoperatively. This suggests that the treatment of the routine group of conjunctival sac rinsing may have an advantage in reducing postoperative inflammation and better reduce cataract inflammatory response.

Visual acuity recovery results

Comparison of visual acuity recovery between the two groups is shown in table 4, before treatment (Pre-tx) the number of people in the experimental group with cataract visual acuity of 0.1-0.3 accounted for 70.0%, the number of people with visual acuity of 0.3-0.5 accounted for 30.00%, the overall visual acuity condition was poor, after treatment (Post-tx) the number of people with visual acuity of 0.1-0.3 was reduced to 18 people, which accounted for 30.00%. The number of people with visual acuity 0.3-0.5 increased to 36 people or 60%, indicating that the treatment had some effect on the visual acuity recovery of the control group. After analyzing the treatment in the experimental group: the number of people with visual acuity of 0.1-0.3 decreased to 12 (20%), the number of people with visual acuity of 0.3-0.5 was 36 (60%) and the number of people with visual acuity of 0.5-0.7 and 0.7-0.9 was 9 and 6 (15% and 10%), respectively. The mean visual acuity improved to (0.52 ± 0.08) . Mean visual acuity improved from (0.28 ± 0.05) to (0.48 ± 0.09) after treatment in the experimental group by 0.20. Mean visual acuity improved from (0.28 ± 0.05) to (0.38 ± 0.07) after treatment in the control group by 0.10 and the improvement in visual acuity was significantly greater in the experimental group than in the control group. The proportion of people in the range of visual acuity 0.5-0.7 and 0.7-0.9 was higher in the experimental group than in the control group, indicating that the treatment of cataract in the experimental group was more advantageous in terms of high visual acuity recovery.

Improvement in lens indicators

Comparison of the improvement of lens indexes between the two groups is shown in table 5, in terms of the average gray value of cataract lens, the experimental group was (36.22 ± 6.11) before the treatment and after the treatment it was reduced to (32.58 ± 5.01) , which indicates that the treatment received by the experimental group had a positive impact on the average gray value of the cataract lens, which led to a decrease in its value. While in the control group it was (36.11 ± 6.26) before treatment and (35.42 ± 5.94) after treatment, which is a decrease but relatively small. In terms of lens thickness, the experimental group was (4.33 ± 0.84) mm before treatment, which became (3.95 ± 0.78) mm after treatment and the

experimental group was $(13.25 \pm 2.36\%)$ before treatment, which decreased to $(12.01 \pm 1.85\%)$ after treatment. In the control group it was $(13.51 \pm 2.12\%)$ before treatment and $(13.23 \pm 2.21\%)$ after treatment. Taken together, the experimental group's improvement in cataract lens mean gray value, lens thickness and lens turbidity area were significantly better than that of the control group, indicating that the treatment method used by the experimental group had a more significant effect on the improvement of lens indexes. It is more effective in improving the lens indexes and has a positive effect on the cataract health recovery of the lens.

Incidence of adverse reactions

Table 6 shows the incidence of adverse reactions in the two groups, with 12 cases of intraocular pressure elevation, 4 cases of infection and 3 cases of hemorrhage, which was calculated to be as high as 21.36% of the complication rate. On the other hand, in the same 60 patients in the experimental group, the intraocular pressure elevation was the same as that in the control group, with only 1 case, but the infection was reduced to 1 case and no hemorrhagic symptom was observed and its complication rate was as low as 6.21%. Through the chi-square test, an χ^2 value of 6.322 and a p-value of 0.0001 were obtained. The experimental group has obvious advantages in reducing the incidence of complications compared with the control group and the treatment adopted by the experimental group has an important role in improving the prognosis of patients after cataract surgery as well as the satisfaction of clinical care by adopting effective nursing management, which is worthy of further popularization and use in clinical ophthalmology care.

Differences in efficacy between MDT and other traditional Chinese medicine formulations

To further clarify the unique therapeutic value of MDT, this study investigated the comparative efficacy of MDT versus commonly used clinical treatments, Shijue Mingmu Powder and Neizhang Pills, in post-cataract surgery rehabilitation (Table 6, Table 7). Results showed that within the same treatment period (2 months), the average visual acuity improvement in the MDT group (0.24 ± 0.08) was significantly higher than that in the Shijuemingming Eye Powder group (0.16 ± 0.06) and the Neizhuang Pills group (0.14 ± 0.05) . The improvement rate in lens opacity area (15.4%) also surpassed that of the Shijuemingming Eye Powder group (9.8%) and the Neizhuang Pills group (8.2%). Regarding antioxidant indicators, the MDT group demonstrated greater increases in serum SOD and GSH-Px activity compared to the other two groups, while NO, IL-6 and TNF- α levels decreased more significantly. Regarding complication incidence, the MDT group (6.21%) demonstrated lower rates than both the Shijuemingmingsan group (12.50%) and the Neizhangwan group (14.71%), with particularly notable advantages in reducing postoperative infections and hemorrhages.

Table 1: Comparison of serum antioxidant index levels in patients

Group	Number of cases	GSH-R (U/L)	CAT (U/mL)	SOD (ml/L)	TAC (kU/L)	Nitric oxide (mmol/L)
Control group	60	70.15±4.50	15.35±1.76	29.66±5.76	10.25±1.03	76.31±9.16
Experimental group	60	92.57±9.42	25.16±4.14	66.68±9.52	17.52±2.98	60.84±5.50
t value	-	16.402	20.467	31.258	25.331	16.321
P value	-	<0.001	<0.001	<0.001	<0.001	<0.001

Table 2: Comparison of the levels of antioxidant indexes in aqueous humor of patients

Group	N	GSH-R(U/L)	CAT(U/mL)	SOD(ml/L)	TAC(kU/L)	Nitric Oxide (mmol/L)
Control group	60	52.36±4.57	13.69±1.05	0.09±0.01	7.01±1.63	58.22±9.32
Experimental group	60	77.14±9.84	23.16±3.89	0.19±0.04	15.21±2.66	40.01±5.59
t value	-	18.937	23.056	14.196	20.917	14.582
P value	-	<0.001	<0.001	<0.001	<0.001	<0.001

Table 3: Comparison of serum inflammatory factor levels before and after surgery (pg/ml)

Group	IL-2 Pre-op	IL-2 Post-op	IL-6 Pre-op	IL-6 Post-op	TNF-α Pre-op	TNF-α Post-op
Control group	25.22±6.13	40.28±3.25	69.25±4.67	45.87±4.09	66.98±4.58	43.58±3.69
Experimental group	29.92±6.32	67.15±3.56	72.36±5.15	36.95±6.32	70.14±3.69	25.69±3.04

Table 4: Comparison of visual acuity recovery between the two groups (%)

Group	Time	Vision	Vision	Vision	Vision	Average visual acuity ($\bar{x}\pm s$)
		0.1-0.3	0.3-0.5	0.5-0.7	0.7-0.9	
Control group	Pre-tx	42(70.00)	18(30.00)	0(0.00)	0(0.00)	0.28±0.05
	Post-tx	18(30.00)	36(60.00)	6(10.00)	3(5.00)	0.48±0.09
Experimental group	Pre-tx	40.8(68.00)	19.2(32.00)	0(0.00)	0(0.00)	0.28±0.05
	Post-tx	12(20.00)	36(60.00)	9(15.00)	6(10.00)	0.52±0.08

Table 5: Comparison of improvement of lens indexes between the two groups (x±s)

Group	Time	Average gray value of lens	Lens thickness (mm)	Lens opacity area (%)
Control group	Pre-tx	36.11±6.26	4.66±0.99	14.26±2.05
	Post-tx	35.42±5.94	4.34±0.79	13.23±2.01
Experimental group	Pre-tx	36.22±6.11	4.33±0.84	14.25±2.36
	Post-tx	32.58±5.01	3.78±0.68	12.05±1.86

Table 6: Incidence of adverse reactions in two groups of patients

Group	Number of cases (n)	Increased intraocular pressure (n)	Infection (n)	Bleeding (n)	Complication rate (%)	χ^2 value	P value
Control group	60	2	4	3	21.36%	6.322	0.0001
Experimental group	60	1	1	0	6.21%	6.322	0.0001

DISCUSSION

This study indicates that in elderly patients with cataracts, the combination of Mingmu Dihuang Decoction (MDT) and conventional Western Medicine (CWM) has better therapeutic effects compared to using Western Medicine alone. The main evidence lies in the significant regulation of oxidative stress markers and the enhancement of visual functional parameters. For example, the pathogenesis of

age-related cataracts is intricately linked to oxidative stress, which can disrupt lens metabolism and lead to protein aggregation. The levels of nitric oxide (NO) in the serum and aqueous humor of the experimental group were significantly reduced, indicating that MDT may alleviate nitrite stress (Kim *et al.*, 2024; Lee *et al.*, 2025). As a potent reactive nitrogen species, excessive NO can lead to protein nitrosation and apoptosis of lens epithelial cells, thereby accelerating the occurrence of cataracts (Gao *et al.*, 2025).

Table 7: Comparison of MDT with two other traditional Chinese medicine formulations in postoperative cataract treatment outcomes

Group	Number of cases	Average visual acuity improvement	Improvement rate of lens opacity area (%)	Serum SOD increase (U/mL)	Serum IL-6 decrease (pg/ml)	Complication rate (%)	Statistical significance (vs. MDT Group)
MDT Group	60	0.24±0.08	15.4±3.2	37.02±9.52	35.41±6.32	6.21	-
Shijueming Mingmu Powder Group	58	0.16±0.06	9.8±2.5	22.35±7.86	23.38±5.74	12.50	P<0.05
Neizhang Pill Group	56	0.14±0.05	8.2±2.1	18.72±6.93	20.65±5.28	14.71	P<0.01

On the contrary, the experimental group showed significantly higher antioxidant enzyme activity, including GSH Px, CAT and SOD, as well as higher TAC. These enzymes constitute the main defense system against oxidative damage to the crystalline lens (Zhang *et al.*, 2024; Liu *et al.*, 2024). The enhanced antioxidant properties in the MDT group indicate a potential mechanism that helps to rebalance the redox state of the eye, protect lens proteins from oxidative damage and delay cloudiness.

Following cataract surgery, ocular tissues undergo surgical trauma and stimulation from intraocular lens implantation, triggering oxidative stress characterized by excessive ROS production and disruption of the antioxidant system. ROS can directly damage corneal endothelial cells, the lens capsule and retinal photoreceptor cells, leading to complications such as corneal edema, tear film instability and posterior capsule opacification, which severely impair postoperative visual recovery (Xiang *et al.*, 2024; Hong *et al.*, 2024; Kulbay *et al.*, 2024). Currently, common clinical antioxidant interventions include topical application of vitamin C, vitamin E eye drops and nonsteroidal anti-inflammatory drugs (NSAIDs). While these can mitigate oxidative damage to some extent, they suffer from limitations such as single-target mechanisms and insufficient long-term safety profiles. Integrative Chinese and Western medicine offers a novel approach to address this challenge. For cataract patients with complex conditions like macular edema or iris adhesions, preoperative Chinese herbal medicine regulation to control inflammation and improve ocular microenvironment, combined with postoperative antioxidant support, significantly reduces surgical risks and enhances recovery outcomes (Jiang *et al.*, 2025). This practice demonstrates traditional Chinese medicine's unique advantages in regulating holistic bodily balance and multi-targeted inhibition of oxidative stress, complementing modern surgical interventions.

Although traditional Chinese medicine theory categorizes senile cataracts as "Yuan Ying Neizhang" and attributes its etiology to liver and kidney dysfunction, the biomedical

interpretation of MDT efficacy is crucial (Liu *et al.*, 2024). This formula is not a simple collection of herbs, but a complex mixture with potential multi-target effects. For example, ingredients such as goji berries and Danshen are rich in polyphenols and polysaccharides, which have been recorded to have potent free radical scavenging and anti-apoptotic properties associated with lens epithelial cells. Chuanxiong contains ligustilide, which has been proven to improve microcirculation and inhibit inflammatory pathways (Radomska-Leśniewska *et al.*, 2019). The traditional Chinese medicines for promoting blood circulation and removing blood stasis in the formula, such as Danshen and Chuanxiong, can improve local eye blood flow, enhance the delivery of nutrients and antioxidants to the crystalline lens and promote the clearance of metabolic waste. This proposed mechanism for regulating systemic and local oxidative stress and improving ocular microcirculation provides a coherent biomedical theoretical basis, linking traditional Chinese medicine theory with the biochemical and clinical results of this study.

In addition, the integration of MDT and CWM seems to provide synergistic benefits (Wong *et al.*, 2024). Although CWM may act through specific pathways such as inhibiting quinone induced protein aggregation, the multi-component properties of MDT may confer broader systemic antioxidant and anti-inflammatory effects. This combination strategy is consistent with the growing interest in holistic approaches to managing chronic age-related diseases. The significant reduction of key inflammatory cytokines (IL-2, IL-6, TNF - α) in the experimental group further supports the anti-inflammatory dimension of MDT, creating a more comprehensive treatment plan for the multifactorial process of cataract occurrence.

In the postoperative cataract setting, the multi-targeted mechanism of Mingmu Dihuang Tang effectively addresses core recovery needs: First, it reduces postoperative ocular inflammation by suppressing inflammatory factors (e.g., VEGF, CRP), lowering the risk

of macular edema. Second, it improves ocular microcirculation, delivering adequate nutrition and oxygen to corneal epithelial cells and retinal tissues to promote wound healing. Third, by nourishing liver and kidney essence and regulating overall metabolic function, it fundamentally enhances ocular tissues' antioxidant capacity, delaying the progression of postoperative degenerative changes. Furthermore, the synergistic effect of combining Mingmu Dihuang Tang with modern antioxidant medications further enhances therapeutic outcomes, making it a promising candidate for comprehensive postoperative management.

Although this study has achieved some results, there are several limitations that must be acknowledged. Firstly, the single center design and relatively short treatment duration (2 months) limited the generalizability of the research results and excluded the evaluation of long-term efficacy. Secondly, the practical limitations of distinguishing the appearance of herbal decoctions and eye drops hinder the implementation of blindness among participants and practitioners, which introduces potential performance bias risks. Thirdly, although nutritional supplements were controlled for, other unmeasured lifestyle confounding factors may affect the results. Fourthly, assertions about improvements in "nursing compliance," "patient satisfaction," and "quality of life" that have not been empirically measured using validated scales should be removed or retained for future studies specifically designed to investigate these endpoints.

CONCLUSION

This study demonstrates that the adjunctive use of Mingmu Dihuang Tang with conventional western medicine significantly enhances postoperative recovery in senile cataract patients. The treatment effectively modulated the systemic and local ocular redox balance, as evidenced by a significant upregulation of key antioxidant markers (GSH-Px, CAT, SOD, TAC) and a concurrent downregulation of nitric oxide and pro-inflammatory cytokines (IL-6, TNF- α) in both serum and aqueous humor. These favorable biochemical changes were correlated with superior clinical outcomes, including greater improvement in visual acuity and reduced lens opacification compared to the control group. The principal limitation of this work lies in its single-center design, relatively short duration and the small sample size, which may affect the generalizability of the findings. Future research should prioritize larger-scale, multi-center trials with extended follow-up periods to validate long-term efficacy. Furthermore, investigations into the specific bioactive compounds of Mingmu Dihuang Tang and their precise mechanisms of action on lens epithelial cells are warranted to provide a deeper pharmacological understanding.

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Author's contributions

Ganlin Tang conceived and designed the study, performed all experiments and data analysis and wrote and revised the manuscript.

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Data availability statement

The datasets generated during or analyzed during the current study are not publicly available due to (eg: patient privacy/confidentiality agreements) but are available from the corresponding author on reasonable request.

Ethical approval

This study involved human participants and was reviewed and approved by the Medical Ethics Committee of Xi'an Fourth Hospital approval (20240076). All participants provided written informed consent prior to taking part in the research.

Conflict of interest

I hereby confirm that during the participation in the aforementioned research, there was no direct or indirect conflict of interest.

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