Clinical Impact of a Novel Light-Transmitting Ocular Dressing in Children After Bilateral Strabismus Surgery: A Prospective Quasi-Experimental Study

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AIM: Nontransparent ocular dressings used after bilateral strabismus surgery deprive children of visual input, often provoking crying, causing premature dressing removal, and increasing caregiver burden. This study evaluated the effectiveness of a self-developed, novel light-transmitting ocular dressing in improving postoperative experience and alleviating caregiver burden.

METHODS: This prospective quasi-experimental study enrolled 120 children (3–14 years) who underwent bilateral strabismus surgery from August to December 2024. Participants were alternately assigned according to admission week to either a light-transmitting dressing group ($n = 60$) or a conventional nontransparent dressing group ($n = 60$). Outcomes included postoperative comfort (visual analogue scale [VAS]), crying/agitation level, caregiver burden (Zarit Caregiver Burden Interview), and unplanned dressing-change rate. Multivariate linear regression was used to evaluate the independent effect of dressing type after adjustment for demographic and surgical covariates.

RESULTS: Compared with those in the nontransparent group, children in the light-transmitting group reported significantly better postoperative comfort (VAS: 1.57 ± 0.81 vs 3.58 ± 1.34, $p < 0.001$) and were more likely to remain calm and cooperative (76.67% vs 33.33%). Caregiver burden scores were significantly lower (30.30 ± 3.12 vs 36.51 ± 4.20, $p < 0.001$), and the unplanned dressing-change rate was reduced (3.33% vs 18.33%, $p < 0.01$). After adjustment for demographic and surgical variables (procedure type, number of muscles operated, and operative duration), dressing type remained an independent predictor of comfort ($\beta = -2.04$, $p < 0.001$) and caregiver burden ($\beta = -6.36$, $p < 0.001$). Caregiver education level was balanced between groups and was an independent predictor of caregiver burden ($\beta = -0.80$, $p = 0.03$).

CONCLUSIONS: The light-transmitting ocular dressing effectively improves comfort after bilateral strabismus surgery in children, reduces crying/agitation and caregiver burden, and lowers the need for unplanned dressing changes. By preserving postoperative visual input, this design offers an effective nonpharmacological strategy to mitigate postoperative psychological stress in children and warrants broader clinical adoption.

Clinical Trial Registration: China Clinical Trial Registry (ChiCTR2600117638).

Keywords: light-transmitting ocular dressing; strabismus surgery; postoperative comfort; pediatric patients; crying/agitation; caregiver burden

Introduction

Strabismus—defined as ocular misalignment—is among the most common pediatric ophthalmic disorders [1]. In China, the reported prevalence of childhood strabismus ranges from 2.5% to 5.0% [2–4]. Strabismus can lead to reduced visual acuity and amblyopia and may result in permanent visual dysfunction, substantially affecting children's psychosocial development and quality of life [5,6]. Surgery is the primary clinical treatment, and strabismus is one of the ophthalmic conditions for which bilateral surgery is relatively common [7,8].

After strabismus surgery, the operated eye is routinely covered with a sterile ocular dressing to maintain cleanliness, prevent rubbing, and absorb secretions [9]. Conventional dressings, typically composed of multiple layers of gauze, fully occlude the eye and block light transmission. For children undergoing bilateral surgery, the sudden onset of darkness can trigger anxiety, fear, and a loss of control [10]. Such psychological stress often manifests as intense crying, agitation, and attempts to remove the dressing [11]. These behaviors may compromise wound healing and pro-

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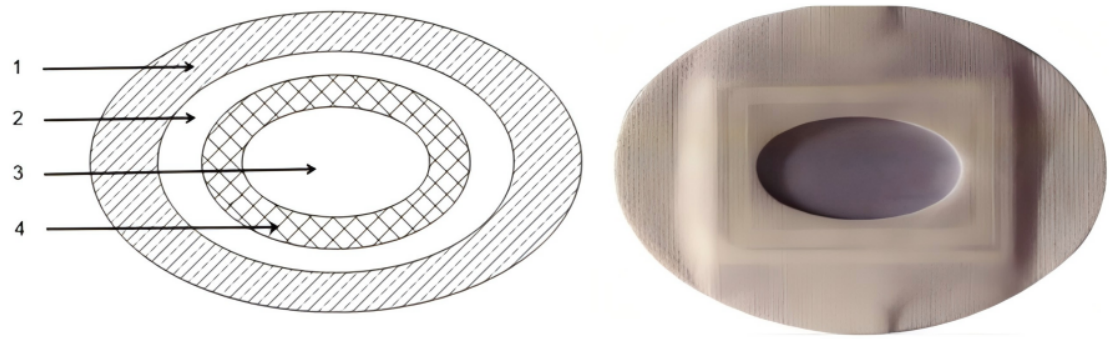

Fig. 1. Schematic and photograph of the light-transmitting ocular dressing. The dressing is composed of: (1) adhesive backing, (2) absorbent cotton gauze, (3) transparent resin sheet, and (4) junction between gauze and resin. The left figure is reproduced from the author's own patent (China National Patent No. ZL201721326324.X), granted in 2019. The author holds the copyright in these materials.

long recovery, and they are a major source of negative medical experience. At the same time, caregivers must continuously manage the child's intense emotions and behaviors, incurring substantial psychological and physical burden. This predicament conflicts with the core principles of family-centered pediatric care, which seek to optimize safety and comfort. Therefore, an innovative solution is urgently needed—one that provides reliable physical protection while also addressing the psychosocial needs of children and their families.

This study investigated a patented (China National Patent No. ZL201721326324.X) novel light-transmitting ocular dressing comprising four components: (1) an adhesive backing to secure the dressing around the orbit; (2) an absorbent cotton-gauze layer positioned between the adhesive backing and resin sheet to absorb ocular secretions; (3) a transparent resin sheet that permits vision while shielding against foreign bodies; and (4) a junction connecting the resin sheet and gauze layer to stabilize the window (Fig. 1). The dressing was translated into a clinical application in 2023 and officially implemented in the study institution in 2024. Its core innovation is a transparent viewing window that preserves basic postoperative visual input [12]. We hypothesized that this design could mitigate psychological stress induced by complete visual deprivation. Prior research demonstrated the favorable feasibility of this dressing design in adults after bilateral surgery [13], but its effectiveness in children remains uncertain. Given children's greater reliance on visual reassurance, we focused on whether the light-transmitting dressing can improve postoperative comfort, attenuate distress behaviors (e.g., crying), and reduce caregiver burden, thereby providing a strong, family-centered nonpharmacological option for postoperative pediatric ophthalmic care.

Methods

Participants

In this prospective quasi-experimental study, the sample size was calculated based on pilot data (n = 20) collected by our team in July 2024. Using dressing comfort as the primary indicator, the pilot yielded scores of 1.80 ± 0.90 vs 3.20 ± 1.40 between groups. With α = 0.05 and β = 0.10, PASS 15.0 (NCSS, LLC, Kaysville, UT, USA) was utilized to estimate the required sample size. Allowing for a 20% attrition rate, we planned to enroll 120 children (60 per group). We consecutively screened 150 children undergoing bilateral strabismus surgery between August and December 2024 and assigned them to either a light-transmitting dressing group or a nontransparent dressing group alternately in accordance with admission week: children admitted in odd-numbered weeks were assigned to the light-transmitting dressing group, whereas those admitted in even-numbered weeks were assigned to the conventional nontransparent dressing group. Of the 150 children screened, 30 were excluded for the following reasons: communication barriers preventing expression of subjective feelings (n = 8), change of accompanying caregiver during the perioperative period (n = 7), guardian refusal (n = 6), conversion to unilateral surgery or change in surgical plan (n = 5), and severe intraoperative complications (n = 4). Subsequently, the remaining 120 eligible children were allocated to groups on an alternating basis according to the week of admission; all children completed the planned follow-up and were included in the final analysis (60 children per group). The study flow is shown in Fig. 2. Inclusion criteria were as follows: (1) age 3–14 years; (2) clinically diagnosed strabismus and first-time bilateral strabismus surgery; (3) clear consciousness and ability to express subjective feelings; (4) surgery performed under general anesthesia by the same primary surgeon; and (5) written informed consent from a guardian; the accompanying caregiver was not changed during hospitalization. Exclusion criteria were as follows: (1) communication barriers preventing expression of subjective feelings; (2) allergy to medical gauze materials; (3) other ocular or craniofacial surgery within the past 3 months; (4) change of accompanying caregiver during the perioperative period; and (5) guardian refusal. Withdrawal criteria were as follows: (1) conversion to unilateral surgery or change in the surgi-

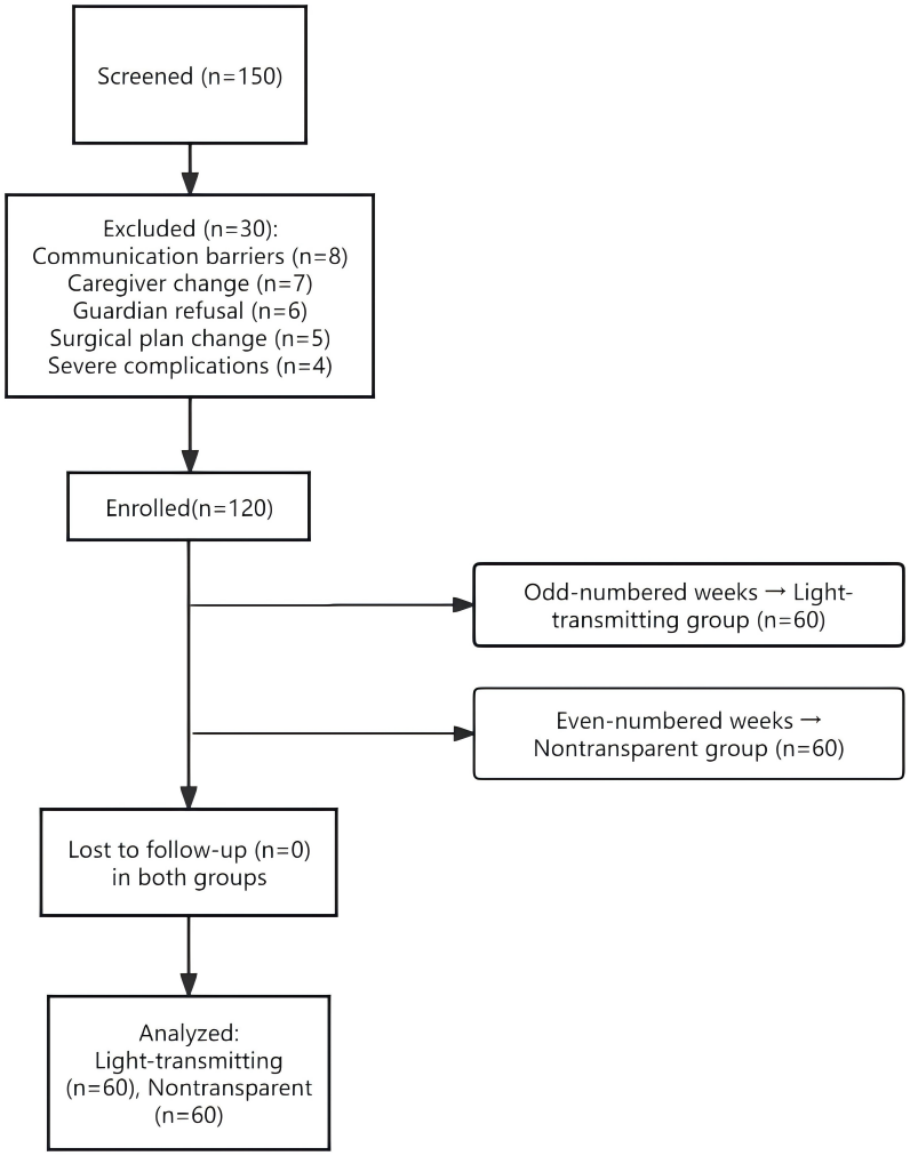

Fig. 2. Flow diagram depicting participant grouping in this study.

cal plan; (2) severe intraoperative complications (e.g., anaphylactic shock); and (3) participant or guardian request to withdraw during the observation period. Caregiver characteristics (age, sex, education level, and relationship to the child) were collected as baseline variables because they may influence caregiver burden scores. This trial was registered with the Chinese Clinical Trial Registry (registration number: ChiCTR2600117638, https://www.chictr.org.cn/showproj.html?proj=307067).

Procedures

All surgeries were performed by a single surgeon (YHJ) in a day-surgery setting. Both groups were discharged within 24 hours after surgery. Surgical complexity indicators—including procedure type (rectus recession/resection and/or oblique muscle surgery), number of muscles involved, and operative duration—were recorded for all participants. After surgery, disposable self-adhesive dressings were applied, with model C9 used in the light-transmitting group and model T7 in the non-transparent group. Except for the viewing-window design, the two types of dressings had identical physical parameters (backing material, adhesive strength, and gauze absorbency) and were manufactured by the same company (Weihai Jierui Medical Products Co., Ltd.) (Fig. 3). At noon on postoperative day 1, the attending physician performed a routine dressing change and comprehensively assessed the operated eyes. Based on the assessment, the physician determined whether continued protective occlusion was necessary. After postoperative dressing change, neither group continued occlusion, and both were subjected to standard postoperative anti-inflammatory eyedrop therapy. Due to the visible differences between the two dressings, blinding of participants, caregivers, and outcome assessors was not feasible. To minimize observer bias

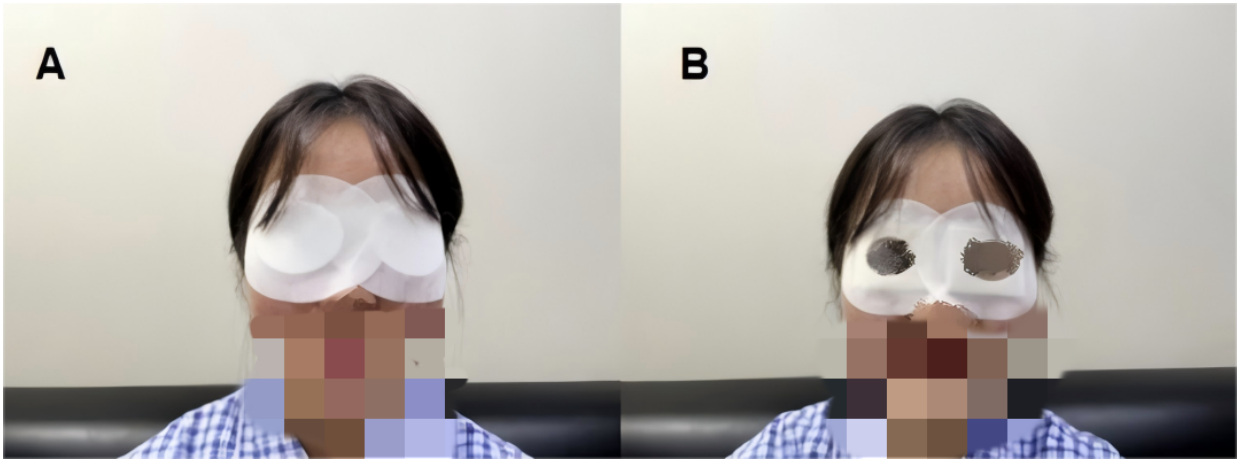

Fig. 3. Postoperative occlusion using a nontransparent ocular dressing (A) or a light-transmitting ocular dressing (B).

despite this limitation, the following measures were implemented: (1) all responsible nurses received uniform training and followed standardized assessment scripts for all outcome measures; (2) the research coordinator responsible for participant grouping did not participate in subsequent recruitment or outcome assessment; (3) to avoid cross-contamination, postoperative dressing changes for the two groups were conducted in separate areas of the ward; and (4) an objective endpoint (frequency and reasons for unplanned dressing changes) was included to support the subjective findings.

Outcome Measures

Data were collected using a prespecified, standardized workflow. To ensure consistency across subjective assessments, all responsible nurses received uniform training before study initiation.

(1) Dressing comfort: At 6 hours after returning to the ward, the responsible nurse assessed ocular discomfort related to the dressing using a visual analogue scale (VAS). The VAS was used specifically to measure the subjective sensation of irritation, foreign body sensation, pressure, or pain localized to the operated eye area caused by the dressing. A 10-point line (0–10) was used, where 0 indicates comfortable and 10 indicates extremely uncomfortable/intolerable [13]. For children aged ≤5 years or those with difficulty understanding the VAS, a combined assessment using the VAS and the Wong–Baker FACES Pain Rating Scale was applied in accordance with the following steps: First, the child was shown the Wong–Baker FACES scale, which consists of six faces ranging from a smiling face (0 = no discomfort) to a crying face (10 = worst discomfort), and asked to point to the face that best represented their current feeling. The nurse then presented a VAS graphic that included the same six facial icons positioned at the corresponding points along the 0–10 continuum (0, 2, 4, 6, 8, and 10). Based on the child's selection, the nurse helped determine a specific numeric score within the corresponding interval. To minimize subjectivity, the numeric score was assigned based on the child's direct indication on the 0–10 line under standardized guidance. The final score (0–10) was then recorded. The use of VAS for assessing dressing-related comfort is supported by previous studies. Burucu *et al.* [14] employed VAS with a 0–10 scale to evaluate the comfort level of catheter fixation in chemotherapy patients who used different catheter dressings, and demonstrated that dressing type significantly influenced comfort scores regardless of pain. For the combined approach in young children, a validation study by Gong *et al.* [15] demonstrated that the Wong–Baker FACES scale correlates well with the Echelle Douleur Inconfort Nouveau-Ne scale (EDIN scale, neonatal pain and discomfort scale) in assessing comfort among children with acute fever ($r = 0.742$, $p < 0.001$), concluding that it can be used for comfort evaluation in children aged 0–5 years.

(2) Caregiver burden: Before the routine dressing change at noon on postoperative day 1, the responsible nurse followed a standardized assessment script and guided family members to complete the Chinese version of the Zarit Caregiver Burden Interview (ZBI) questionnaire. Caregivers were instructed to respond based on their experiences during the first 24 hours post-surgery, focusing on items relevant to acute caregiving such as time demands, emotional stress, and physical exhaustion. The original ZBI was developed by Zarit *et al.* [16] in 1985 and includes 22 items scored on a 5-point scale (0–4): 0 = never, 1 = rarely, 2 = sometimes, 3 = often, and 4 = nearly always. Total scores are interpreted as 0–19 (none or minimal burden), 20–39 (mild burden), 40–59 (moderate burden), and ≥60 (severe burden). The Chinese version has demonstrated good reliability and validity in prior evaluation (Cronbach's alpha = 0.87) [17,18].

(3) Crying/agitation level: Immediately after the child returned from the post-anesthesia care unit and the responsible nurse completed handover with the post-anesthesia care unit (PACU) nurse, postoperative crying/agitation was assessed using a self-developed graded scale. The scale

was developed based on a comprehensive literature review [9,12] and expert consensus involving three senior pediatric anesthesiologists and two pediatric ophthalmic nurses. All responsible nurses received uniform training on the scale before study initiation and followed a standardized assessment script to ensure consistency across raters. Assessments were repeated every two hours for a total of three times, and the highest level was recorded. The scale has four levels: Level 0, no distress (calm and cooperative, normal communication or sleep, no crying or irritability); Level 1, mild transient distress (brief crying or body twisting $\leq$1 minute, rapidly relieved by verbal comfort or gentle touch); Level 2, moderate persistent distress (continuous crying or restlessness requiring active soothing such as holding the child or distraction, gradually calming within 10 minutes); and Level 3, severe intense distress (persistent intense crying, screaming, scratching at the dressing, or strong physical resistance lasting >10 minutes, not relieved by routine soothing). Assessments were performed by the responsible nurse. Given the exploratory nature of this self-developed scale without formal psychometric validation, this indicator is considered a supportive rather than a definitive endpoint.

(4) Unplanned dressing changes and reasons: A routine dressing change was performed at noon on postoperative day 1. We recorded the frequency and reasons for unplanned dressing changes between return to the ward and routine change. Reasons included: (i) dressing removal by the child; (ii) extensive bleeding/exudate soaking the dressing; and (iii) skin itching or allergic reactions. Records were completed by the responsible nurse.

(5) Considerations for objectivity: Although the primary outcomes (comfort, crying/agitation, and burden) involve subjective assessment, we included the number of unplanned dressing changes as a key objective clinical endpoint to strengthen clinical relevance. This endpoint directly reflects the need for additional medical interventions triggered by dressing-related discomfort (e.g., scratching).

Statistical Analysis

All analyses were performed using SPSS version 20.0 (IBM Corp., Armonk, NY, USA). Normality of continuous variables was assessed using the Shapiro–Wilk test. Normally distributed variables were presented as mean $\pm$ standard deviation and compared using independent-samples t tests (t values reported). Non-normally distributed variables were expressed as medians with interquartile ranges [median (IQR)] and compared using the Mann–Whitney U test (Z values reported). Categorical variables were expressed as counts and percentages and compared using the χ^2 test when expected cell frequencies met the Cochran's rule (all expected counts $\geq$5); otherwise, Fisher's exact test was applied. For multicategorical variables with a natural order (child school grade, operative duration, number of muscles operated, and surgical procedure), these variables were entered as ordinal variables after assigning numerical scores according to their rank order: child school grade (kindergarten = 1, primary school = 2, middle school = 3); operative duration (<30 min = 1, 30–45 min = 2, >45 min = 3); number of muscles operated (2 muscles = 1, 3 muscles = 2, $\geq$4 muscles = 3); surgical procedure (bilateral rectus recession/resection = 1, combined recession and resection = 2, including oblique muscle surgery = 3). Model diagnostics were performed to assess the assumptions of linear regression. Multicollinearity was evaluated using variance inflation factors (VIF), with values below 10 considered acceptable. The distribution of residuals was examined via Quantile-Quantile (Q-Q) plots and the Shapiro–Wilk test, and homoscedasticity was assessed by plotting residuals against predicted values.

To evaluate the independent impact of dressing type on the primary outcomes, we constructed multivariate linear regression models with caregiver burden score and comfort score as dependent variables [19]. In addition to group assignment, we considered differences in surgical operations as potential confounders of postoperative stress and therefore adjusted for surgical covariates, including procedure type (categorized by the primary operation), number of muscles operated, and operative duration. Demographic covariates were also included: child age, sex, and school grade, as well as caregiver age, sex, education level, and relationship to the child. Both child age and school grade were included in the regression models because they capture distinct aspects of child development: age reflects biological maturation, while school grade reflects social and cognitive development, which may independently influence postoperative stress responses. Statistical significance was set at $p < 0.05$.

Results

Participant Characteristics

Demographic characteristics of children and caregivers, as well as surgical covariates, were comparable between groups, with no statistically significant differences observed (all $p > 0.05$), except for caregiver age ($p = 0.002$). Details are shown in Table 1.

Postoperative Outcomes

As shown in Table 2, children in the light-transmitting group reported significantly better comfort (1.57 $\pm$ 0.81 vs 3.58 $\pm$ 1.34, $t = -9.95$, $p < 0.001$), were more likely to remain calm (76.67% at Level 0 vs 33.33%, $Z = -4.77$, $p < 0.001$), and had lower caregiver burden scores (30.30 $\pm$ 3.12 vs 36.51 $\pm$ 4.20, $t = -9.18$, $p < 0.001$) compared to those in the nontransparent group.

Unplanned Dressing Changes and Reasons

Routine dressing change was performed as scheduled in 58 children (96.67%) in the light-transmitting group and 49 children (81.67%) in the non-transparent group. In

Table 1. Baseline characteristics of study participants.

Characteristic	Light-transmitting group (n = 60)	Nontransparent group (n = 60)	Test statistic	p value
Child characteristics				
Sex, n (%)			$\chi^2 = 0.30$	0.58
Male	30 (50.00)	27 (45.00)		
Female	30 (50.00)	33 (55.00)		
Age (years), mean ± SD	7.93 ± 2.59	8.10 ± 2.71	$t = -0.34$	0.73
School grade, n (%)			$\chi^2 = 0.80$	0.67
Kindergarten	10 (16.67)	13 (21.67)		
Primary school	44 (73.33)	43 (71.67)		
Middle school	6 (10.00)	4 (6.67)		
Caregiver characteristics				
Sex, n (%)			$\chi^2 = 0.60$	0.44
Male	22 (36.67)	18 (30.00)		
Female	38 (63.33)	42 (70.00)		
Age (years), mean ± SD	41.08 ± 7.81	37.38 ± 4.85	$t = 3.12$	0.002
Education level, n (%)			Fisher's exact test	0.53
Primary school or below	2 (3.33)	2 (3.33)		
Middle school	9 (15.00)	14 (23.33)		
High school	24 (40.00)	26 (43.33)		
University/College	21 (35.00)	13 (21.67)		
Postgraduate	4 (6.67)	5 (8.33)		
Relationship to child, n (%)			$\chi^2 = 2.23$	0.14
Parent/Guardian	42 (70.00)	49 (81.67)		
Relative	18 (30.00)	11 (18.33)		
Surgical characteristics				
Surgical procedure, n (%)			Fisher's exact test	0.85
Bilateral rectus recession or resection	18 (30.00)	18 (30.00)		
Combined recession and resection	38 (63.33)	40 (66.67)		
Including oblique muscle surgery	4 (6.67)	2 (3.33)		
Number of muscles operated, n (%)			$\chi^2 = 1.44$	0.49
2	16 (26.67)	20 (33.33)		
3	34 (56.67)	34 (56.67)		
≥4	10 (16.67)	6 (10.00)		
Operative duration, n (%)			$\chi^2 = 0.50$	0.78
<30 min	34 (56.67)	34 (56.67)		
30–45 min	20 (33.33)	22 (36.67)		
>45 min	6 (10.00)	4 (6.67)		

Notes: Caregiver characteristics were included as baseline variables because they may influence caregiver burden scores.

the light-transmitting group, two children (3.33%) required unplanned dressing changes, compared with 11 children (18.33%) in the nontransparent group. There was a statistically significant difference in the incidence of unplanned dressing changes between the two groups ($p < 0.01$) (Table 3). In the non-transparent group, most unplanned changes were due to children removing the dressing themselves (n = 6, 10.0%), whereas no such cases occurred in the light-transmitting group. Other reasons included dressing oozing/exudation (light-transmitting: n = 2; nontransparent: n = 4) and skin allergy (light-transmitting: n = 0; nontransparent: n = 1).

Postoperative Healthcare Utilization and Economic Analysis

Wound healing was uneventful in both groups, with no surgical-site infection or delayed healing. All children underwent day surgery with a 1-day hospital stay, and total hospitalization costs did not differ significantly. However, given the marked difference in unplanned dressing-change rates, the light-transmitting dressing demonstrated clear health-economic benefits. A preliminary cost analysis was performed based on direct material costs associated with unplanned dressing changes. The unplanned dressing-change rate was 3.33% (2/60) in the light-transmitting group versus 18.33% (11/60) in the nontransparent dressing group, an absolute reduction of 15%. Based on the difference in unplanned dressing-change rates and the unit

Table 2. Comparison of postoperative comfort, levels of crying/restlessness and caregiver burden between the two groups.

Group	*n*	Comfort score (mean ± SD)	Crying/agitation level				Caregiver burden score
			Level 0	Level 1	Level 2	Level 3	
Light-transmitting group	60	1.57 ± 0.81	46 (76.67)	11 (18.33)	2 (3.33)	1 (1.67)	30.30 ± 3.12
Nontransparent group	60	3.58 ± 1.34	20 (33.33)	27 (45.00)	7 (11.67)	6 (10.00)	36.51 ± 4.20
Test statistic		$t = -9.95$	$Z = -4.77$				$t = -9.18$
p value		<0.001	<0.001				<0.001

Notes: Comfort score and caregiver burden score were compared using an independent *t*-test (*t* values reported); crying/agitation level was compared using the Mann–Whitney *U* test (*Z* value reported).

Table 3. Reasons for unplanned dressing changes between the light-transmitting and non-transparent dressing groups.

Factor	Light-transmitting group ($n = 60$)	Nontransparent group ($n = 60$)
Removal by children themselves	0 (0.00)	6 (10.00)
Oozing of blood or fluid from the dressings	2 (3.33)	4 (6.67)
Allergic skin reaction	0 (0.00)	1 (1.67)

Notes: Data are presented as n (%). There was a statistically significant difference in the incidence of unplanned dressing changes between the two groups ($\chi^2 = 6.988$, $p < 0.01$).

Table 4a. Multivariate linear regression analysis of factors influencing postoperative comfort score.

Variable	*B* (95% CI)	*t*	*p*
Child age	–0.06 (–0.19, 0.06)	–1.00	0.32
Child sex	–0.10 (–0.52, 0.33)	–0.44	0.66
Child's school grade	0.25 (–0.39, 0.89)	0.76	0.45
Group	–2.04 (–2.46, –1.62)	–9.66	**<0.001**
Surgical procedure	0.215 (–0.30, 0.73)	0.83	0.41
Number of muscles operated	–0.01 (–0.43, 0.45)	–0.04	0.97
Operative duration	–0.15 (–0.46, 0.17)	–0.91	0.36

Notes: The bold value indicates statistical significance ($p < 0.05$). Reference categories for categorical variables: child sex (male), child's school grade (kindergarten). Group coding: light-transmitting dressing = 1, nontransparent dressing = 0. All variance inflation factors (VIF) were below 3 (range: 1.1–2.5), indicating no concerning multicollinearity. Model $R^2 = 0.46$.

Table 4b. Multivariate linear regression analysis of factors influencing caregiver burden score.

Variable	*B* (95% CI)	*t*	*p*
Caregiver age	0.02 (–0.09, 0.12)	0.35	0.72
Caregiver sex	–1.21 (–2.41, 0.02)	–2.02	0.05
Caregiver education level	–0.80 (–1.53, –0.06)	–2.15	**0.03**
Relationship to child	1.30 (–0.31, 2.91)	1.60	0.11
Group	–6.36 (–7.76, –4.97)	–9.03	**<0.001**
Surgical procedure	–0.30 (–1.89, 1.29)	–0.37	0.71
Number of muscles operated	0.80 (–0.54, 2.14)	1.18	0.24
Operative duration	0.81 (–0.22, 1.84)	1.56	0.12

Notes: Bold values indicate statistical significance ($p < 0.05$). Reference categories for categorical variables: caregiver sex (male), caregiver education level (primary school or below), relationship to child (parent/guardian). Group coding: light-transmitting dressing = 1, nontransparent dressing = 0. All variance inflation factors (VIF) were below 3 (range: 1.1–2.5), indicating no concerning multicollinearity. Model $R^2 = 0.49$.

cost of the dressing, the average direct material cost saving per child in the light-transmitting group was calculated as the product of the rate difference and dressing unit price, amounting to approximately ¥8 (roughly 1.17 USD based on the exchange rate of 1 USD = 6.8157 CNY).

Multivariate Linear Regression Analysis of Postoperative Comfort and Caregiver Burden

Multivariate linear regression was performed to ensure independence of these associations, with adjustment for demographic and surgical covariates. Variable selection was based on clinical relevance and prior literature. Given that the final model includes 120 participants and 8 predictor variables, this sample size is considered appropriate for exploratory multivariate linear regression analysis. After adjustment, dressing type remained an independent determinant of caregiver burden ($\beta = -6.36$, 95% CI: (–7.76, –4.97), $p < 0.001$) and comfort score ($\beta = -2.04$, 95% CI: (–2.46, –1.62), $p < 0.001$). In the caregiver burden model, the caregiver's level of education was also significantly associated with the caregiver burden score ($\beta = -0.80$, 95% CI: (−1.53, −0.06), $p = 0.03$). None of the included surgical variables were statistically significant (all $p > 0.05$). The final models explained 46% of the variance in comfort ($R^2 = 0.46$, Table 4a) and 49% of the variance in caregiver burden ($R^2 = 0.49$, Table 4b). Model diagnostics confirmed that all variance inflation factors (VIF) were below 3 (ranging from 1.1 to 2.5), indicating no concerning multicollinearity.

Discussion

In this prospective quasi-experimental study, we systematically evaluated the clinical utility of a light-transmitting ocular dressing in children after bilateral strabismus surgery. Compared with a conventional nontransparent dressing,

the light-transmitting dressing significantly improved children's subjective comfort, reduced crying/agitation and caregiver burden, and decreased the frequency of unplanned dressing changes, highlighting clear clinical advantages.

Although baseline characteristics were well balanced between the two groups, multivariate linear regression models were constructed to rigorously control for potential marginal confounders (e.g., caregiver age) and to examine the independent effect of dressing type. In addition to demographic covariates, the models simultaneously adjusted—for the first time in this context—for surgical variables, including procedure type, number of muscles operated, and operative duration. The results confirmed that, after adjustment, dressing type remained the most robust independent predictor of both postoperative comfort (β = –2.04, $p < 0.001$) and caregiver burden (β = –6.36, $p < 0.001$). The models explained 46% and 49% of the variance in comfort and burden, respectively. Importantly, none of the surgical variables reached statistical significance, suggesting that the benefit of preserving visual input outweighs differences in surgical complexity. This supports our central premise: alleviating "visual deprivation"—a key psychological stressor—confers stable benefits across different surgical complexities.

The regression models also identified caregiver education level as an independent determinant of burden (β = –0.80, $p = 0.03$), with higher education associated with lower perceived burden—possibly reflecting stronger coping capacity [20]. This finding may help clinicians identify at-risk caregivers and tailor support accordingly. The nonsignificant effects of child-related covariates (e.g., age, sex) further support the broad applicability of the light-transmitting dressing across pediatric subgroups [13].

The mechanism underlying these benefits is likely multifactorial. In addition to the psychological benefit of preserving visual input, the physical characteristics of the light-transmitting dressing may also play a role. Conventional nontransparent dressings are thick and opaque, potentially creating a sensation akin to "sudden blindness" and contributing to pressure, heat, and physical discomfort [21]. In contrast, the light-transmitting dressing incorporates a thin transparent resin window that preserves visual input while maintaining hygiene and preventing rubbing, thereby reducing sensory shock and negative emotions associated with darkness [9]. This interpretation is supported by a growing body of evidence linking postoperative visual deprivation to anxiety and agitation in children [22,23]. In our data, 76.67% of children in the light-transmitting group remained fully calm and cooperative, compared with 33.33% in the nontransparent group; moderate-to-severe crying/agitation occurred in only 5% vs 21.67%, respectively. The viewing window allows children to perceive their surroundings and caregivers' facial expressions, reducing the sense of loss of control. Moreover, visual access enables caregivers to use distraction techniques (e.g., comfort objects, videos), potentially reducing sympathetic arousal and crying intensity [12]. Certainly, the physiological advantages of light-transmitting dressings may synergize with visual function preservation, thereby enhancing overall comfort. Future studies could further employ objective measurement methods such as skin temperature or pressure sensors to investigate the relative contributions of visual and tactile factors.

The reduction in caregiver burden likely reflects a positive feedback cycle: calmer children allow caregivers to transition from reactive soothing to active emotional support through eye contact and interactive play. This more positive caregiving experience directly reduces subjective burden and exemplifies the bidirectional benefits of family-centered nursing interventions [24]. From a practical perspective, the light-transmitting dressing reduced unplanned dressing changes through its design. Without a viewing window, conventional dressings make early detection of bleeding or exudation difficult; combined with scratching due to discomfort, dressings may loosen or become contaminated, necessitating additional replacement. The transparent window allows nursing staff to rapidly inspect the operated eye when discomfort is reported, enabling timely management. The smooth resin surface may also reduce friction and itching around the periocular skin. Fewer unplanned changes reduce consumable use, staff workload, and potential cross-infection risk.

Our findings are consistent with those of Zhang *et al*. [9], who evaluated a rigid light-transmitting eye shield and reported reduced emergence agitation after bilateral strabismus surgery. Collectively, these findings underscore the importance of preserving postoperative vision. However, our design advances this concept by addressing limitations of prior devices: the previously reported shield relied on external tape fixation, had a rigid texture, and lacked absorbency. In contrast, our integrated dressing combines a compliant resin window for comfort, a self-adhesive backing for reliable fixation, and an internal absorbent layer for secretion management. Together, these features translate the principle of transparency into measurable clinical gains—improved comfort, reduced caregiver burden, and fewer unplanned adjustments—offering a more comprehensive postoperative nursing solution.

Lin *et al*. [10] previously attempted to mitigate visual deprivation-induced distress through "visual preconditioning", in which preoperative occlusion was used to familiarize children with the sensation of eye covering. While potentially effective, this approach requires additional preoperative intervention and does not address the immediate postoperative experience. In contrast, our light-transmitting dressing provides a more direct solution by restoring continuous visual input immediately after surgery, preventing visual deprivation at its source and integrating seamlessly into routine clinical care.

Limitations and Future Directions

This single-center prospective quasi-experimental study has several limitations. First, since the two types of dressings differ visibly in appearance, blinding outcome assessors was not feasible, which may introduce measurement bias. To mitigate this risk, we: (1) used highly standardized instruments and procedures (e.g., standardized scripts for VAS and ZBI); (2) incorporated an objective endpoint (frequency and reasons for unplanned dressing changes) as supportive evidence; and (3) applied dual data entry with cross-checking to ensure accuracy. Nevertheless, the lack of blinding may still have influenced subjective ratings such as comfort and caregiver burden. Second, participants were assigned based on alternating admission weeks rather than through true randomization. Although an imbalance in caregiver age was observed between groups at baseline, this variable was adjusted for in the multivariate regression model and showed no significant association with the outcome, suggesting that its confounding effect was minimal. Third, our primary outcomes relied mainly on subjective scales. We acknowledge that comfort is a multidimensional concept encompassing physiological, psychological, and social domains, and our VAS assessment focused primarily on the physical or ocular dimension of comfort related to dressing. Although the use of VAS for measuring dressing comfort is supported by previous literature [15], future studies may incorporate multidimensional comfort scales for a more comprehensive evaluation. Fourth, we did not collect other objective physiological indicators (e.g., heart rate, analgesic use) that could have provided additional support for the subjective findings. Future studies should consider incorporating such parameters. Fifth, this was a single-center study with a relatively modest sample size restricted to children aged 3–14 years undergoing bilateral strabismus surgery. Therefore, generalizability to other age groups, unilateral surgeries, or different healthcare settings should be undertaken with caution. Sixth, the economic analysis presented is preliminary, based on direct material cost savings from reduced unplanned dressing changes. It does not account for nursing time, indirect costs, or potential long-term benefits. A formal cost-effectiveness analysis is thus needed in future multicenter trials. Seventh, the Zarit Caregiver Burden Interview (ZBI) questionnaire used in this study was originally designed for long-term caregiving contexts. Caregivers in the present study were instructed to describe their experiences during the first 24 hours post-surgery, but we should acknowledge that items in this questionnaire may not fully capture the unique aspects of acute postoperative caregiving, even though the Chinese version of the ZBI has been validated in various caregiving settings [17,18]. Future studies should consider developing or validating instruments specifically designed for short-term perioperative caregiver burden assessment. Eighth, the crying/agitation scale used in this study was developed based on a literature review and expert consensus, and all nurses received standardized training in its applications. However, the reproducibility of the crying/agitation outcome is probably limited since inter-rater reliability or test-retest reliability of the scale has never been formally evaluated. We recommend that future research validate the scale's psychometric properties and, where possible, incorporate objective physiological parameters (e.g., heart rate, analgesic use) to complement subjective behavioral assessments. Finally, the observation period was limited to the first postoperative day, and we did not assess long-term outcomes such as wound healing, scar formation, or psychological sequelae. An extended follow-up would provide a more comprehensive evaluation. Future multicenter, large-sample randomized controlled trials are warranted to validate effectiveness and safety across surgical types, age groups, and special populations (e.g., children with autism spectrum disorder or intellectual disability). In addition, wearable sensing technologies could be leveraged to monitor temperature, humidity, and pressure under the dressing in real time to support individualized postoperative care. Finally, given the observed association between caregiver education and burden, clinical practice may consider more targeted instruction and support for caregivers with lower educational attainment. Despite these limitations, the consistent and robust differences between groups across multiple endpoints—including both subjective and objective measures—support the clinical value of the light-transmitting dressing. Furthermore, the present study was limited to children aged 3–14 years without neurodevelopmental disorders; therefore, our findings may not be generalizable to special populations such as children with autism spectrum disorder or intellectual disability. Future studies involving these populations will need to address additional ethical and methodological challenges, including obtaining appropriate informed consent and adapting outcome measures for these individuals.

Conclusions

In summary, the light-transmitting ocular dressing preserves the protective functions of conventional dressings while meeting children's need for binocular visual input. Multivariate analyses indicate that it independently and significantly improves postoperative experience, reduces the impact of temporary binocular visual deprivation on children's self-care ability, and alleviates the dual burden on families and the healthcare system. These findings support its clinical scalability and promise for broader implementation.

Availability of Data and Materials

The data that support the findings of this study are available from the corresponding authors upon reasonable request.

Author Contributions

WS: Conceptualization, Writing—original draft; YL: Conceptualization, Writing—review & editing; YS: Software, Formal analysis; HY: Formal analysis; RHZ: Formal analysis; JH: Investigation; YHJ: Investigation; ZFM: Formal analysis, Writing—review & editing. All authors contributed to the critical revision of the manuscript for important intellectual content. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

The study protocol was reviewed and approved by the Institutional Ethics Committee of the Beijing Tongren Hospital (Approval No. TREC2024-KY092). Prior to participation, all legal guardians were fully informed about the study objectives, procedures, potential risks, and their rights, and written informed consent was obtained after they had achieved a complete understanding of the study. For children aged 8 years and older, age-appropriate explanations of the study were provided in plain language, and their assent was obtained with guardian permission. All ethical procedures were strictly adhered to the core principles of the Declaration of Helsinki and conformed to current ethical standards and consensus guidelines for pediatric clinical research.

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Conflict of Interest

The authors declare no conflict of interest.

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