• Clinical Research •

Postoperative recurrence after pediatric chalazion surgery: associated factors and the potential role of *Demodex* positivity

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Abstract

● **AIM:** To identify independent factors associated with postoperative recurrence after pediatric chalazion surgery, with attention to the potential role of *Demodex* positivity. Secondary objectives were to characterize this surgical population and investigate the associations of selected systemic blood parameters with chalazion requiring surgical intervention, postoperative recurrence, and *Demodex* positivity.

● **METHODS:** This retrospective study included a primary cohort analysis of 370 consecutive children who underwent chalazion surgery between October 2021 and December 2025 and a secondary case-control analysis of 216 children who underwent strabismus surgery over the same period. Demographic characteristics, lesion-related characteristics, use of an external skin approach, postoperative recurrence, *Demodex* status, and selected systemic blood parameters were retrospectively collected. Kaplan–Meier analysis and Cox proportional hazards regression were used to identify factors associated with postoperative recurrence. Secondary and exploratory logistic regression analyses evaluated factors associated with surgical chalazion and *Demodex* positivity, and investigated the associations of selected systemic blood parameters with chalazion requiring surgical intervention, postoperative recurrence, and *Demodex* positivity.

● **RESULTS:** Among the 370 children who underwent chalazion surgery, 64.9% were aged ≤3y, and postoperative recurrence occurred in 70 children (18.9%). Kaplan–Meier analysis estimated cumulative recurrence probabilities of 13.0% at 6mo and 19.3% at 12mo after surgery. In the full cohort, multivariable Cox regression identified younger age [adjusted hazard ratio (HR) per year, 0.77; 95% confidence interval (CI), 0.67–0.88; $P<0.001$] and cutaneous involvement (adjusted HR, 1.94; 95%CI, 1.12–3.33; $P=0.017$) as independently associated with postoperative recurrence. In the *Demodex*-examined subgroup ($n=183$), younger age (adjusted HR per year, 0.78; 95%CI, 0.67–0.92; $P=0.002$) and *Demodex* positivity (adjusted HR, 1.87; 95%CI, 1.03–3.37; $P=0.038$) were associated with recurrence. In secondary analyses, male sex was associated with surgical chalazion after adjustment for age [adjusted odds ratio (OR), 1.63; 95%CI, 1.10–2.40; $P=0.013$]. No independent clinical predictors of *Demodex* positivity were identified. Selected systemic blood parameters were not independently associated with the study outcomes.

● **CONCLUSION:** Younger age and cutaneous involvement are independently associated with postoperative recurrence after pediatric chalazion surgery. *Demodex* positivity is associated with postoperative recurrence in the examined subgroup, but this exploratory finding requires confirmation through prospective studies with systematic testing. Age and lesion-related characteristics may help inform postoperative follow-up.

● **KEYWORDS:** pediatric chalazion; surgery; postoperative recurrence; *Demodex*; risk factors
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INTRODUCTION

Chalazion is a prevalent eyelid disorder among children, characterized by chronic lipogranulomatous inflammation due to meibomian gland duct obstruction. Conservative treatment, such as warm compresses and eyelid hygiene, is effective in controlling some lesions; however, for chalazia that persist, recur, grow, or fail to respond to medical treatment, surgical excision remains necessary[1]. Chalazion excision constitutes approximately 26% of pediatric eyelid surgeries and is more commonly performed in preschool-aged children[2]. However, successful surgical removal does not guarantee a permanent cure; indeed, recurrence rates of almost 31.9% have been reported in pediatric literature[3]. Recurrence-related concerns, including repeated outpatient visits, prolonged treatment, or even further surgery, exert considerable psychological and financial strain on patients and their families. This highlights the need for a better understanding of risk factors that may predict recurrence.

Research on chalazion has investigated its epidemiology, lesion-related clinical characteristics, nutritional factors, *Demodex* infestation, and recurrence patterns[4-6]. However, evidence specifically addressing children who require surgical intervention remains limited. Surgical cases in pediatric patients, unlike conservative responders, generally have more refractory diseases and therefore a higher risk of postoperative recurrence. Thus, identifying factors predictive of recurrence in this population is of clinical importance.

Recently, both systemic inflammatory indices, including neutrophil-to-lymphocyte ratio (NLR), platelet-to-lymphocyte ratio (PLR), systemic immune-inflammation index (SII), systemic inflammation response index (SIRI), and pan-immune-inflammation value (PIV), and serum lipid parameters have garnered increasing attention in various ocular diseases, suggesting their potential involvement in disease development and progression[7-9]. However, pediatric chalazion is predominantly characterized by local pathological processes, including local meibomian gland duct obstruction and chronic inflammation, with alterations in the local eyelid margin microenvironment and *Demodex* positivity also implicated in its pathogenesis[10-12]. Moreover, younger age, multiple chalazia, and *Demodex* positivity have been suggested in previous cohort studies as risk factors for postoperative recurrence, although their independent contributions to postoperative recurrence remain incompletely defined[3,13]. Therefore, in the context of pediatric chalazion—a condition predominantly driven by local factors, whether systemic blood parameters improve prediction of development, postoperative recurrence or *Demodex* positivity in pediatric chalazion has not been established.

Therefore, the primary aim of this retrospective study was to identify factors independently associated with postoperative recurrence in children who underwent surgical treatment for chalazion, with attention to the potential role of *Demodex* positivity. Secondary aims were to characterize the clinical profile of children requiring chalazion surgery and explore the association of selected systemic blood parameters with chalazion requiring surgical treatment, postoperative recurrence, or *Demodex* positivity.

PARTICIPANTS AND METHODS

Ethical Approval The study was approved by the institutional ethics committee of Fujian Children's Hospital (approval No. 2026ETKLRK08009) and conducted in accordance with the Declaration of Helsinki. The requirement for informed consent was waived because of the retrospective study design. This study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.

Study Design and Participants This retrospective study included a primary cohort analysis of children who underwent chalazion surgery and a secondary case-control analysis using children who underwent strabismus surgery as controls. Additional exploratory analyses examined factors associated with *Demodex* positivity and the associations of selected systemic blood parameters with chalazion requiring surgical treatment, postoperative recurrence, and *Demodex* positivity.

A total of 486 children who underwent chalazion surgery at our institution between October 2021 and December 2025 were initially screened for eligibility. Of these, 116 were excluded according to the predefined inclusion and exclusion criteria, leaving 370 children in the primary cohort analysis. For the secondary case-control analysis, 221 children who underwent strabismus surgery during the same period were screened, of whom 5 were excluded according to the eligibility criteria, leaving 216 children as controls. Among the 370 children in the chalazion cohort, 183 underwent *Demodex* examination and were included in the *Demodex* subgroup analysis.

Inclusion and Exclusion Criteria Children were included in the chalazion group if they: 1) were clinically diagnosed with chalazion; 2) had a lesion of diameter ≥5 mm or a lesion that persisted despite standardized conservative treatment and subsequently required surgical intervention; 3) had at least 6mo of follow-up after surgery or documented recurrence within the

12-month observation period; and 4) had complete clinical and laboratory data.

Patients were excluded if they had: 1) hordeolum, eyelid tumors, eyelid trauma, or other eyelid lesions; 2) systemic infection or inflammatory disease, including respiratory infection or pneumonia, within 1mo before surgery, or C-reactive protein >10 mg/L; 3) severe immune-related, hematological, or metabolic disorders; or 4) incomplete clinical records or insufficient follow-up.

Children who underwent strabismus surgery at the same institution during the study period served as controls. Controls had no history of chalazion, eyelid margin disease, or meibomian gland disorders and had comparable preoperative ophthalmic evaluation.

Clinical Variables and Definitions Lesions were classified as single or multiple according to the number of chalazia present. Active inflammation was defined as localized inflammatory changes secondary to chalazion—marked by eyelid erythema and swelling, with or without pain or tenderness—and did not include acute infectious hordeolum. Cutaneous involvement was defined as extension beyond the tarsal plate to the overlying eyelid skin or subcutaneous tissue. Skin erosion was defined as a visible disruption of the overlying eyelid skin associated with the chalazion. Use of an external skin approach, alone or combined with a transconjunctival approach, was selected for lesions with cutaneous involvement, skin erosion, skin thinning, or adhesion to the overlying skin. The presence of cutaneous involvement alone did not mandate an external skin approach, and the final surgical approach was determined according to the overall lesion characteristics and the surgeon's judgment.

Postoperative recurrence was defined based on the following criteria: 1) Complete resolution of the primary lesion after initial surgery (no palpable nodule or localized chronic inflammation on postoperative examination); 2) Development of a new chalazion on the eyelid or recurrence at the original site; 3) Confirmed by clinical examination; 4) Occurrence within 12mo after surgery. The following were not considered recurrence: 1) Failure of the primary lesion to resolve after initial surgery; 2) Persistent palpable lesions; 3) Residual tissue at the surgical site.

Follow-up and Time-to-Event Definition The observation period was limited to 12mo after surgery. Time to recurrence was calculated from the date of surgery to the first documented postoperative recurrence. Children without documented recurrence were right-censored at their last available follow-up visit or at 12mo after surgery, whichever occurred first. Recurrences occurring beyond 12mo were not counted as events within the study observation period.

Laboratory Variables We measured peripheral blood eosinophil and basophil counts, as well as serum total cholesterol (TC) and low-density lipoprotein cholesterol (LDL-C), from routine preoperative blood tests.

Calculation of systemic inflammatory indices (NLR, PLR, SII, SIRI, and PIV) was based on neutrophil, lymphocyte, monocyte, and platelet counts. These cellular counts were not analyzed as independent variables. Separately, eosinophil and basophil counts were evaluated independently. Triglycerides and high-density lipoprotein cholesterol were not included in the analysis because collection of blood samples was performed under non-fasting conditions.

The systemic inflammatory indices were calculated as follows: NLR=neutrophil/lymphocyte; PLR=platelet/lymphocyte; SII=platelet×neutrophil/lymphocyte; SIRI=neutrophil×monocyte/lymphocyte; and PIV=platelet×neutrophil×monocyte/lymphocyte.

***Demodex* Examination** *Demodex* examination was performed in 183 of 370 children who underwent chalazion surgery. Immediately before surgery, bilateral eyelash sampling was performed for a total of 12 lashes per patient. Specifically, three lashes were obtained from each of the upper and lower eyelids, preferentially from areas adjacent to the lesion or eyelashes with cylindrical dandruff. Specimens were mounted in artificial cedarwood oil and examined under light microscopy (×100) by the same experienced ophthalmologist. *Demodex* positivity was defined as identification of any mite stage (egg, larva, nymph, or adult). This operational definition was intended to classify microscopic *Demodex* positivity rather than to establish clinically symptomatic ocular demodicosis.

Demodex examination was gradually incorporated into clinical practice during the study period and was not performed systematically in all eligible children. Because testing was not based on a prespecified sampling protocol, the examined subgroup may not have been representative of the entire surgical cohort. To assess potential selection bias, baseline clinical characteristics, postoperative recurrence, and follow-up duration were compared between children who underwent *Demodex* examination and those who did not. Analyses involving *Demodex* status were therefore restricted to the examined subgroup.

Statistical Analysis All statistical analyses were performed using Stata 17. Continuous variables were presented as median [interquartile range (IQR)] for descriptive purposes and were compared using the Mann-Whitney *U* test when group comparisons were performed. Categorical variables were presented as number (%) and compared using the Pearson χ^2 test. Postoperative recurrence was primarily analyzed using Kaplan–Meier survival analysis, log-rank tests, and Cox proportional hazards regression to account for varying follow-up durations.

The proportional hazards assumption was assessed using Schoenfeld residuals. Parsimonious multivariable Cox models were fitted in the full cohort (*n*=370) and the *Demodex*-examined subgroup (*n*=183). Covariates were selected based on clinical relevance and prior evidence rather than univariable *P*-value thresholds. To maintain model parsimony and minimize potential multicollinearity, clinically overlapping lesion-related characteristics were not included simultaneously. Cutaneous involvement was selected as a representative indicator of local lesion severity, whereas multiple lesions were considered an indicator of disease burden. The use of an external skin approach was excluded from the final multivariable Cox models because surgical approach was determined by baseline lesion characteristics. Binary logistic regression was also performed as a supplementary analysis of postoperative recurrence.

Secondary logistic regression analyses evaluated factors associated with chalazion requiring surgical treatment, and exploratory logistic regression models examined clinical factors associated with *Demodex* positivity and the associations of selected systemic blood parameters, including systemic inflammatory indices, serum lipid parameters, and eosinophil and basophil counts. These analyses were secondary to the primary time-to-event analyses. No adjustment for multiple comparisons was applied to exploratory analyses.

Baseline characteristics, postoperative recurrence, and follow-up duration were compared between children with and without *Demodex* examination to assess potential selection bias. All tests were two-sided, and $P<0.05$ was considered statistically significant.

RESULTS

Baseline Characteristics A total of 586 children were included in the study, comprising 370 children who underwent surgical treatment for chalazion and 216 children who underwent strabismus surgery as controls for the secondary occurrence analysis. Because the control group was older than the chalazion group [median (IQR), 5.00 (4.00–8.00) *vs* 3.00 (2.00–4.00)y, $P<0.001$], age was prespecified as an adjustment variable in subsequent occurrence analyses. Male patients accounted for 51.1% of the chalazion group, compared to 41.2% of the control group ($P=0.021$). Of the 370 children in the chalazion cohort, 240 (64.9%) were aged ≤3y and 130 (35.1%) were aged >3y. Baseline demographics are summarized in Table 1.

Table 1 Baseline characteristics of chalazion cohort and controls

n (%) or median (IQR)

Variable	Chalazion group (*n*=370)	Control group (*n*=216)
Age, y	3.00 (2.00–4.00)	5.00 (4.00–8.00)
Age ≤3y	240 (64.9)	-
Age >3y	130 (35.1)	-
Male sex	189 (51.1)	89 (41.2)

Dashes indicate data not presented. IQR: Interquartile range.

Primary Outcome: Postoperative Recurrence Among the 370 children in the chalazion cohort, postoperative recurrence occurred in 70 (18.9%). A subset of 183 patients underwent *Demodex* examination; among the subset, 45 patients experienced recurrence and 138 did not. *Demodex* positivity was observed in 26 of the 45 recurrent cases (57.8%), while the positivity rate was 37.7% (52/138) in the non-recurrent cases ($P=0.018$).

Kaplan–Meier analysis of postoperative recurrence Kaplan–Meier analysis was used to estimate the cumulative probability of postoperative recurrence over the 12-month postoperative period (Figure 1A). Kaplan–Meier analysis estimated cumulative recurrence probabilities of 13.0% [95% confidence interval (CI), 9.9%–16.8%] at 6mo and 19.3% (95%CI, 15.6%–23.7%) at 12mo after surgery. In the *Demodex*-examined subgroup (*n*=183), Kaplan–Meier curves showed lower recurrence-free survival among *Demodex*-positive children than among *Demodex*-negative children (log-rank $\chi^2=5.64$, $P=0.018$; Figure 1B).

Cox regression analyses of postoperative recurrence In age- and sex-adjusted Cox models, younger age was associated with a higher hazard ratio (HR) of postoperative recurrence after adjustment for sex (HR per year, 0.74; 95%CI, 0.65–0.84, $P<0.001$), whereas sex showed no significant association with recurrence after adjustment for age. After adjustment for age and sex, active inflammation (HR, 1.87; 95%CI, 1.09–3.20, $P=0.023$), cutaneous involvement (HR, 2.03; 95%CI, 1.19–3.47, $P=0.010$), and use of an external skin approach (HR, 1.93; 95%CI, 1.14–3.26, $P=0.015$) were each associated with postoperative recurrence. Multiple lesions and skin erosion were not significantly associated with recurrence in these models. In the *Demodex*-examined subgroup, *Demodex* positivity was associated with increased recurrence hazard after adjustment for age and sex (HR, 1.85; 95%CI, 1.02–3.38; $P=0.045$; Table 2).

Two parsimonious multivariable Cox proportional hazards models were developed. Model 1 included the full surgical cohort (*n*=370) and included age, sex, cutaneous involvement, and multiple lesions as covariates. Model 2 was restricted to children with available *Demodex* examination results (*n*=183) and included age, *Demodex* positivity, and cutaneous involvement.

In Model 1, younger age was associated with a higher hazard of postoperative recurrence (HR per year, 0.77; 95%CI, 0.67–0.88; $P<0.001$), corresponding to an approximately 23% reduction in the hazard of recurrence for each additional year of age. Cutaneous involvement was also associated with

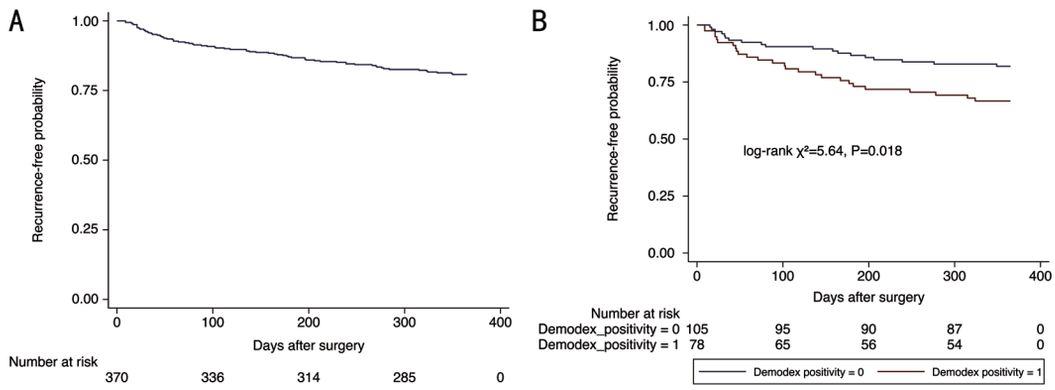


Figure 1 Kaplan–Meier estimates of recurrence-free survival after pediatric chalazion surgery A: Recurrence-free survival in the full cohort (*n*=370); B: Recurrence-free survival according to *Demodex* status in the examined subgroup (*n*=183; *Demodex*-positive, *n*=78; *Demodex*-negative, *n*=105). Differences between the *Demodex*-positive and *Demodex*-negative groups were assessed using the log-rank test. Numbers at risk are shown below the curves.

Table 2 Clinical characteristics and adjusted Cox regression analyses of postoperative recurrence *n* (%) or median (IQR)

Variable	Non-recurrence (*n*=300)	Recurrence (*n*=70)	Adjusted HR (95%CI)	*P*
Age (per year), median (IQR)	3.00 (2.00–4.00)	2.00 (1.00–3.00)	0.74 (0.65–0.84)	<0.001
Male sex	152 (50.7)	37 (52.9)	1.06 (0.66–1.70)	0.804
Multiple lesions	190 (63.3)	56 (80.0)	1.74 (0.96–3.15)	0.069
Active inflammation	169 (56.3)	52 (74.3)	1.87 (1.09–3.20)	0.023
Cutaneous involvement	152 (50.7)	51 (72.9)	2.03 (1.19–3.47)	0.010
Skin erosion	111 (37.0)	37 (52.9)	1.51 (0.94–2.42)	0.089
Use of an external skin approach	152 (50.7)	50 (71.4)	1.93 (1.14–3.26)	0.015
Demodex positivity (examined subgroup, *n*=183)	52/138 (37.7)	26/45 (57.8)	1.85 (1.02–3.38)	0.045

Age and sex estimates were obtained from the Cox model including both variables, and other variables were adjusted for both age and sex. *Demodex* examination was available for 183 children. HR: Hazard ratio; CI: Confidence interval; IQR: Interquartile range.

an increased recurrence hazard (HR, 1.94; 95%CI, 1.12–3.33; *P*=0.017), whereas sex and multiple lesions were not significantly associated with recurrence (Table 3).

In Model 2, younger age remained independently associated with a higher hazard of postoperative recurrence (HR per year, 0.78; 95%CI, 0.67–0.92; *P*=0.002). *Demodex* positivity was associated with an increased hazard of recurrence after adjustment for age and cutaneous involvement (HR, 1.87; 95%CI, 1.03–3.37; *P*=0.038). Cutaneous involvement showed a similar direction of association but did not reach statistical significance in this subgroup (HR, 1.79; 95%CI, 0.90–3.56; *P*=0.098; Table 3). *Demodex* findings are exploratory because testing was not systematic.

Among the 370 children in the surgical cohort, 183 (49.5%) underwent *Demodex* examination. Compared with untested children, those who underwent examination were younger [median (IQR), 2.00 (2.00–4.00) *vs* 3.00 (2.00–5.00)y; *P*=0.039] and had a higher observed recurrence proportion (24.6% *vs* 13.4%; *P*=0.006). The examined subgroup also differed in several clinical characteristics. These differences indicate potential selection bias in the *Demodex*-examined subgroup. Accordingly, associations involving *Demodex* positivity should be interpreted as exploratory and hypothesis-generating rather than generalizable to the entire surgical cohort.

Sensitivity analyses using alternative Cox model specifications showed associations between *Demodex* positivity and recurrence in the same direction, although statistical significance was not maintained in all models. In the Firth penalized logistic regression model adjusted for age and cutaneous involvement, *Demodex* positivity remained associated with postoperative recurrence [adjusted odds ratio (OR), 2.16; 95%CI, 1.07–4.36; *P*=0.032].

Secondary Analysis: Factors Associated with Chalazion Requiring Surgical Treatment Because of the marked age imbalance between the chalazion and control groups, the case-control analysis was prespecified as secondary. After adjustment for age, male sex was associated with higher odds of chalazion requiring surgery (adjusted OR, 1.63; 95%CI, 1.10–2.40; *P*=0.013). Selected systemic blood parameters were not associated with chalazion requiring surgery (Table 4).

Exploratory Analyses: *Demodex* Positivity and Selected Systemic Blood Parameters Exploratory analyses showed no significant associations between selected systemic blood parameters and chalazion requiring surgery, postoperative

Table 3 Multivariable Cox proportional hazards regression analyses of postoperative recurrence

Variable	Model 1: full cohort (*n*=370)		Model 2: *Demodex* subgroup (*n*=183)	
	Adjusted HR (95%CI)	*P*	Adjusted HR (95%CI)	*P*
Age (per year)	0.77 (0.67–0.88)	<0.001	0.78 (0.67–0.92)	0.002
Male sex	0.98 (0.61–1.58)	0.934	-	-
Cutaneous involvement	1.94 (1.12–3.33)	0.017	1.79 (0.90–3.56)	0.098
Multiple lesions	1.60 (0.88–2.92)	0.122	-	-
Demodex positivity	-	-	1.87 (1.03–3.37)	0.038

Dashes indicate variables not included in the corresponding model. No evidence of violation of the proportional hazards' assumption was observed in either multivariable Cox model (global Schoenfeld residual test: *P*=0.9103 and 0.9007, respectively). HR: Hazard ratio; CI: Confidence interval.

Table 4 Selected systemic blood parameters according to study outcomes

Variable	Chalazion *vs* strabismus, adjusted OR (95%CI)	*P*	Recurrence *vs* non-recurrence, adjusted OR (95%CI)	*P*	*Demodex* positive *vs* negative, adjusted OR (95%CI)	*P*
Eosinophil count, $\times10^9$/L	1.74 (0.90–3.34)	0.098	1.23 (0.40–3.84)	0.718	0.62 (0.16–2.49)	0.505
Basophil count, $\times10^9$/L	0.69 (0.16–2.96)	0.615	0.22 (0.04–1.10)	0.065	1.22 (0.10–14.39)	0.873
TC, mmol/L	0.77 (0.44–1.36)	0.368	1.34 (0.63–2.84)	0.445	2.04 (0.88–4.71)	0.096
LDL-C, mmol/L	1.09 (0.74–1.60)	0.676	1.34 (0.78–2.32)	0.294	0.95 (0.53–1.78)	0.932
NLR	0.83 (0.56–1.21)	0.324	1.12 (0.59–2.12)	0.747	0.94 (0.46–1.91)	0.859
PLR	1.00 (1.00–1.01)	0.711	1.00 (0.99–1.01)	0.634	1.00 (0.99–1.01)	0.788
SII	1.00 (1.00–1.00)	0.251	1.00 (1.00–1.00)	0.623	1.00 (1.00–1.00)	0.645
SIRI	0.72 (0.37–1.38)	0.308	1.05 (0.39–2.83)	0.926	0.86 (0.28–2.67)	0.784
PIV	1.00 (1.00–1.00)	0.260	1.00 (1.00–1.00)	0.815	1.00 (1.00–1.00)	0.486

Eosinophil and basophil counts are expressed in $\times10^9$/L. Each systemic blood parameter was evaluated in a separate logistic regression model adjusted for age and sex. No adjustment for multiple comparisons was applied. OR: Odds ratio; CI: Confidence interval; TC: Total cholesterol; LDL-C: Low-density lipoprotein cholesterol; NLR: Neutrophil-to-lymphocyte ratio; PLR: Platelet-to-lymphocyte ratio; SII: Systemic immune-inflammation index; SIRI: Systemic inflammation response index; PIV: Pan-immune-inflammation value.

Table 5 Clinical factors associated with *Demodex* positivity among tested children *n* (%) or median (IQR)

Variable	*Demodex*-negative (*n*=105)	*Demodex*-positive (*n*=78)	Crude OR (95%CI)	*P*	Age- and sex-adjusted OR (95%CI)	*P*
Age, per 1-year increase	3.00 (2.00–4.00)	2.00 (1.00–3.25)	0.90 (0.78–1.03)	0.135	0.90 (0.78–1.04)	0.136
Male sex	55 (52.4)	40 (51.3)	0.96 (0.53–1.72)	0.883	0.97 (0.54–1.76)	0.926
Multiple lesions	72 (68.6)	62 (79.5)	1.78 (0.89–3.53)	0.101	1.67 (0.83–3.36)	0.150
Active inflammation	70 (66.7)	50 (64.1)	0.89 (0.48–1.65)	0.720	0.83 (0.45–1.56)	0.571
Cutaneous involvement	66 (62.9)	47 (60.3)	0.90 (0.49–1.64)	0.718	0.81 (0.43–1.52)	0.511
Skin erosion	48 (45.7)	42 (53.8)	1.39 (0.77–2.49)	0.277	1.29 (0.70–2.37)	0.405
Use of an external skin approach	67 (63.8)	47 (60.3)	0.86 (0.47–1.57)	0.624	0.78 (0.42–1.46)	0.442
Recurrence	19 (18.1)	26 (33.3)	2.26 (1.14–4.49)	0.019	2.10 (1.04–4.23)	0.049

Age and sex estimates were obtained from the logistic regression model including both variables. OR: Odds ratio; CI: Confidence interval; IQR: Interquartile range.

recurrence, or *Demodex* positivity (Table 4). Although eosinophil count (*P*=0.098), basophil count (*P*=0.065), and TC (*P*=0.096) showed relatively small *P* values, none met the conventional significance threshold. Given the multiple comparisons performed without adjustment, these observations should be interpreted cautiously. Adjusted associations between selected systemic blood parameters and chalazion requiring surgical treatment are presented in Table 4.

Among the 183 children with available *Demodex* examination results, no demographic characteristics or clinical severity indicators were independently associated with *Demodex* positivity (Table 5). These exploratory findings should be interpreted cautiously because *Demodex* examination was not performed systematically.

DISCUSSION

Principal Findings and Factors Associated with Postoperative Recurrence This study highlights the importance of patient age and lesion-related characteristics in postoperative recurrence after pediatric chalazion surgery. The association between younger age and recurrence suggests that very young children may represent a clinically vulnerable group requiring closer postoperative attention, while the association with cutaneous involvement indicates that the extent of local tissue involvement may provide additional information beyond age alone. Importantly, our study extends previous research by examining postoperative recurrence in a pediatric surgical cohort using time-to-event analyses that account for differences in follow-up duration, rather than relying solely on binary recurrence outcomes. Furthermore, the exploratory analysis of *Demodex* positivity provides additional insight into a potential recurrence-associated factor in children undergoing surgical treatment. Although this association was generally consistent across alternative regression models, non-systematic *Demodex* testing and differences between examined and unexamined children limit its generalizability. Together, these findings support an age- and lesion-informed approach to postoperative assessment and identify *Demodex* positivity as a hypothesis for further prospective investigation.

Younger Age and Postoperative Recurrence The principal finding of this study was that younger age was independently associated with postoperative recurrence in the overall surgical cohort after multivariable adjustment. The association between younger age and postoperative recurrence is corroborated by a previous large pediatric surgical cohort study, in which younger age was significantly associated with chalazion recurrence after surgery[3]. Age-related differences have also been reported in other pediatric chalazion treatment outcomes. Yang *et al*[14] found higher rates of successful conservative treatment in younger children, whereas Samant *et al*[15] identified increasing age as a predictor of surgical intervention. These findings suggest that the association between age and clinical outcomes may vary according to the treatment modality and outcome assessed. The association between younger age and a higher risk of recurrence is biologically plausible. Age-related differences in meibomian gland function and ocular surface homeostasis could partly contribute to the greater susceptibility to recurrence observed at younger ages[16]. Moreover, it may be challenging for younger children to follow postoperative eyelid hygiene and conservative measures. Another contributing factor to chalazion persistence or recurrence may be age-related differences in ocular surface microbial ecology and local immune maturation[17-18]; however, these mechanisms warrant further exploration.

This finding may have noteworthy clinical implications. Younger patients, who are at higher risk of recurrence, may benefit from closer follow-up and stricter perioperative eyelid hygiene. Importantly, for younger children, it is particularly warranted to provide adequate preoperative counseling to parents or caregivers regarding the possibility of recurrence, the importance of postoperative eyelid care, and the potential need for further treatment. Such counseling may help establish realistic expectations regarding surgical outcomes and reduce misunderstandings or communication concerns if recurrence occurs. These measures are particularly relevant in young patients, as they may face both increased procedural burden and repeated exposure to general anesthesia in cases of recurrent disease requiring repeat surgery[3]. Furthermore, early detection of recurrence enables prompt conservative measures and may reduce the need for reoperation.

Clinical Relevance of Lesion-Severity Indicators and Postoperative Recurrence Active inflammation, cutaneous involvement, and the use of an external skin approach were associated with recurrence in age- and sex-adjusted analyses. After adjustment for clinically relevant covariates and consideration of overlapping lesion-related characteristics, cutaneous involvement remained associated with postoperative recurrence. Given its definition as extension beyond the tarsal plate to the overlying eyelid skin or subcutaneous tissue, cutaneous involvement may reflect a greater degree of local eyelid involvement and may serve as a clinically observable indicator associated with recurrence risk. A previous study by Huang *et al*[5] reported that cutaneous involvement and multiple lesions were associated with chalazion recurrence, supporting the potential clinical relevance of lesion-related characteristics in recurrence assessment, providing a literature-based rationale for considering these characteristics as indicators of local lesion severity and disease burden, respectively. Persistent peri-lesional inflammation has also been suggested to contribute to recurrence, although the underlying mechanisms remain incompletely understood[19-20]. In the present study, multiple lesions did not show an independent association with recurrence after adjustment for the examined covariates. Other lesion-related characteristics, including active inflammation and skin erosion, were not included in the final parsimonious models because of overlap among lesion-severity indicators and concerns regarding model complexity.

In clinical practice, active inflammation, cutaneous involvement, and skin erosion can be identified by visual inspection and are primarily used to assess lesion severity and guide surgical management[21]. Although these lesion-related characteristics may indicate greater lesion severity, our findings suggest the associations with recurrence do not establish their predictive performance, and these characteristics should not be used alone for recurrence risk estimation. Instead, lesion

severity may help determine whether an external skin approach is required and may facilitate preoperative counseling of parents regarding the surgical approach and its potential cosmetic impact. The use of an external skin approach was not considered an independent preoperative predictor because it represents a clinician-directed treatment decision influenced by baseline lesion characteristics. Therefore, including surgical approach as a predictor may introduce treatment-selection bias.

***Demodex* Positivity and Postoperative Recurrence** Within the *Demodex*-examined subgroup, *Demodex* positivity was associated with higher hazard of postoperative recurrence after multivariable adjustment. However, because testing was performed in a clinically selected subset, the present finding cannot establish *Demodex* positivity as an independent risk factor in the overall surgical population.

Importantly, the present study defined *Demodex* positivity as identification of any mite stage, rather than clinically diagnosed ocular demodicosis or symptomatic *Demodex* infestation. This distinction is important because microscopic detection of *Demodex* does not necessarily indicate clinically significant infestation[22].

Our findings are consistent with previous studies reporting associations between *Demodex* and chalazion development or recurrence[5,13,23]. However, terminology and diagnostic criteria for ocular *Demodex* have varied across studies. Some studies have primarily assessed the microscopic presence of *Demodex*, whereas others have used quantitative mite-density thresholds or clinical criteria to define infestation or ocular demodicosis. Huang *et al*[5], similar to our approach, defined *Demodex* positivity by the detection of at least one mite, while also discussing higher mite-count thresholds proposed for clinically meaningful infestation. Notably, a universally accepted threshold for clinically significant *Demodex* infestation in children has not been established. Our finding that microscopic *Demodex* positivity was independently associated with postoperative recurrence therefore suggests that the association between *Demodex* and recurrence may not be restricted to children with a high mite burden or clinically apparent ocular demodicosis. It also raises the possibility that adopting higher quantitative thresholds alone may overlook microscopically positive children in whom *Demodex* positivity status still carries information relevant to recurrence risk.

Several mechanisms may account for this association. Colonizing eyelash follicles and the peri-meibomian gland area, *Demodex* mites may cause mechanical irritation, local microbial environment changes, and chronic inflammatory responses[24]. In addition to immune responses triggered by mite-derived antigens and metabolic products, bacteria may also be carried by *Demodex mites*[25]—both may result in persistent meibomian gland obstruction and granulomatous inflammation. These mechanisms, though incompletely understood, provide biological plausibility for our findings. Importantly, it should be acknowledged that microscopic detection of *Demodex* alone does not establish that the mites directly cause postoperative recurrence or represent a causal factor. However, *Demodex* examination was not systematically performed in all eligible children, as microscopy was introduced later during the study period and examination was therefore available for only 183 patients. This, together with the influence of clinical practice patterns, may have introduced selection bias.

Future prospective studies should validate the association between *Demodex* positivity and postoperative recurrence and clarify whether mite burden provides additional prognostic value.

In the secondary exploratory analysis, we analyzed characteristics associated with *Demodex* positivity. No independent associations were identified with age, sex, lesion multiplicity, cutaneous involvement, active inflammation, skin erosion, or use of an external skin approach, suggesting that routine demographic and lesion-severity indicators seem insufficient to reliably identify *Demodex*-positive children.

Demodex colonization has been linked to several host- and environment-related factors, including meibomian gland dysfunction, household hygiene, and systemic metabolic conditions such as diabetes mellitus[24,26-27]. However, we were unable to evaluate their roles, as these variables were not routinely recorded in our retrospective cohort. Prospective studies incorporating environmental, behavioral, and host-related characteristics may help better define the determinants of *Demodex* positivity in children with chalazion.

Clinical Characteristics of the Surgical Cohort and Secondary Case-Control Analysis Children requiring chalazion surgery were predominantly preschool-aged, with 64.9% aged ≤3y. This distribution is consistent with previous epidemiological and surgical cohort studies in children[2,4,28] and further characterizes the population requiring surgical treatment. These findings highlight the clinical relevance of age in pediatric chalazion surgery. However, this does not imply that younger age itself increases disease risk, as the strabismus controls were substantially older. Younger children may nevertheless be more likely to progress to surgery, potentially because of immature meibomian gland function and limited cooperation with warm compresses, eyelid hygiene, and lid massage.

After adjustment for age, male sex was associated with chalazion requiring surgery. This secondary finding may help explain progression to surgery, not susceptibility to chalazion. However, the age mismatch between groups may induce residual confounding; thus, the observed association should

be interpreted with caution. The association between sex and chalazion remains controversial in the literature. Some studies have reported a female predominance in chalazion diagnosis, whereas others have observed that male patients are more prone to surgical intervention[29].

Prospective research, in which controls are age-matched, is needed to assess whether male sex predisposes children to surgery-requiring chalazion.

Exploratory Findings Regarding Systemic Blood Parameters No independent associations were observed between serum TC or LDL-C, peripheral eosinophil or basophil counts, or systemic inflammatory indices (NLR, PLR, SII, SIRI, and PIV) and pediatric chalazion requiring surgery, postoperative recurrence, or *Demodex* positivity. These negative findings suggest that routine systemic blood parameters provide limited incremental value for recurrence risk stratification. These findings also align with the predominantly localized nature of chalazion pathogenesis, where local factors—meibomian gland obstruction, chronic lipogranulomatous inflammation, and the local eyelid microenvironment—outweigh systemic inflammatory or metabolic status[27,30]. This predominantly local disease process may help explain the limited associations observed for systemic inflammatory and metabolic parameters in our study.

This study has several strengths. First, it focused specifically on children requiring surgical treatment, a clinically important subgroup that is underrepresented in previous studies. Second, the analytical hierarchy was prespecified, with postoperative recurrence as the primary outcome and case-control, *Demodex*, and selected systemic blood parameters treated as secondary or exploratory. Third, demographic characteristics, lesion-related characteristics, *Demodex* status, and selected systemic blood parameters were evaluated within the same clinical dataset. Finally, potential overlap among lesion severity indicators was considered during model specification to improve model parsimony and interpretability.

This study has several limitations. First, its retrospective single-center design may have introduced selection bias, and external validation is required. Therefore, the generalizability of the observed associations to other pediatric populations remains uncertain. Second, the chalazion and strabismus groups were not age-matched; therefore, the findings from secondary case-control analyses remain susceptible to residual confounding despite statistical adjustment. Third, *Demodex* examination was performed only in a subset of children and was not systematically applied. The examined subgroup differed from the untested group in several characteristics; therefore, the association between *Demodex* positivity and postoperative recurrence should be considered exploratory and hypothesis-generating rather than definitive evidence applicable to the entire surgical cohort. Fourth, follow-up was limited to 6–12mo, which may have resulted in incomplete assessment of late recurrence. Prospective studies with standardized follow-up schedules are needed to confirm these findings. Finally, postoperative eyelid hygiene, allergic history, environmental exposures, and other potentially relevant factors were not systematically recorded. Exploratory analyses of systemic blood parameters were not adjusted for multiple comparisons; therefore, these findings should be interpreted cautiously.

Younger age and cutaneous involvement were independently associated with postoperative recurrence after pediatric chalazion surgery. In the *Demodex*-examined subgroup, *Demodex* positivity showed an exploratory association with recurrence; however, this finding requires confirmation in prospective studies with systematic testing. Time-to-event analyses further supported these associations while accounting for variable follow-up duration. Although cutaneous involvement was independently associated with recurrence, individual lesion characteristics alone may have limited value for predicting postoperative recurrence. Secondary analyses suggested an association between male sex and surgically treated chalazion, whereas selected systemic blood parameters showed no consistent associations in exploratory analyses. These findings highlight the need for prospective studies with standardized perioperative management and systematic assessment of potential risk factors.

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