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FROM THE PRESIDENT'S DESK

Uttar Pradesh State Ophthalmological Society

Dear readers,

Dr. Shashank Kumar

I am happy to present you all the 2nd issue of UP Journal of Ophthalmology. It is indeed an honour that now the official journal of UP State Ophthalmological Society is Indexed in Elsevier EMBASE. All articles from year 2020 will be indexed and the authors will get benefit of the same. I am happy to share that we are getting articles more than our requirements and the evaluators/ reviewers are doing a great job in finalising best articles for you all.

My Editorial team is also very hard working and trying their best to choose a bouquet of meaningful articles for the readers.

All the best!

Warm regards,

Dr. Shashank Kumar
President
UP State Ophthalmological Society

UP Journal of Ophthalmology

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Research Article

Study of the Result Profile of Lacrimal Probing in Children

Bhavana Choudhary*, R. C. Gupta, Lokesh Kumar Singh, Alka Gupta, Shraddha Bhardwaj

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Abstract

Objectives: To evaluate the outcome profile of lacrimal probing in children with congenital nasolacrimal duct obstruction (CNLDO) and to assess the relationship between age, number of probing sittings, and procedural success.

Methods: This prospective observational study was conducted in the Department of Ophthalmology, LLRM Medical College, Meerut, from May 2024 to April 2025. A total of 295 children (433 eyes) aged 9 to 60 months diagnosed with CNLDO were included. Patients were divided into three age groups: Group A (9–18 months), Group B (19–36 months), and Group C (37–60 months). Conservative treatment with lacrimal sac massage was advised initially in younger children, while persistent cases underwent nasolacrimal duct probing under aseptic precautions. Outcomes were assessed on the basis of resolution of watering and discharge during follow-up.

Results: Among 295 patients, 153 (51.87%) were males and 142 (48.12%) were females. Unilateral involvement was observed in 157 patients (53.28%), while 138 patients (46.71%) had bilateral disease. Conservative management with lacrimal sac massage showed improvement in 195 of 250 eyes (77.90%) in the 9 to 18 months age group. Primary probing was performed in 238 eyes and was successful in 162 eyes (68.20%). Repeat probing demonstrated comparatively lower success rates, particularly in older children. The overall success rate of probing was 92.17% among eyes completing follow-up.

Conclusion: CNLDO can be effectively managed with early diagnosis and timely intervention. Lacrimal sac massage is beneficial in younger children, while probing remains a safe and effective treatment for persistent cases. Earlier intervention is associated with higher success rates and reduced need for repeated procedures.

Keywords: Congenital nasolacrimal duct obstruction, Lacrimal probing, Epiphora, Pediatric ophthalmology.

Introduction

Congenital nasolacrimal duct obstruction (CNLDO) is one of the most frequently encountered lacrimal drainage abnormalities in infants and young children and represents a common cause of persistent epiphora during early childhood. The condition usually occurs due to incomplete canalization of the nasolacrimal duct, most commonly at the level of the distal valve of Hasner. Failure of ductal opening results in impaired tear drainage, leading to retention of tears and secondary mucous discharge.[1,2] The incidence of CNLDO has been reported to range between 6% and 20% among newborns, although many cases undergo spontaneous resolution during the first year of life as the lacrimal drainage system matures.[3,4]

Embryologically, the lacrimal drainage system develops from a solid cord of ectodermal cells situated between the lateral nasal and maxillary processes. Canalization begins centrally and progresses both proximally and distally, with the distal nasolacrimal duct being the final portion to canalize. Incomplete opening at the valve of Hasner is considered the most common anatomical cause of congenital obstruction.[5] Persistent membrane formation, narrow duct lumen, bony abnormalities, and inflammation-related fibrosis have also been implicated in resistant or complex cases.[6]

Clinically, children with CNLDO commonly present with excessive watering, crusting of eyelashes, recurrent mucopurulent discharge, and increased tear meniscus

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height. Symptoms are often unilateral but may be bilateral in a significant proportion of patients. Reflux of mucous material on pressure over the lacrimal sac area is considered a characteristic clinical sign and helps differentiate CNLDO from other causes of childhood epiphora.[7] Persistent obstruction may predispose affected children to recurrent conjunctivitis, acute dacryocystitis, preseptal cellulitis, and periocular skin excoriation due to chronic irritation.[8]

The diagnosis of CNLDO is primarily clinical and is based on detailed history and ocular examination. Ancillary investigations such as fluorescein dye disappearance test, lacrimal irrigation, and probing may be useful in selected cases to confirm the site and severity of obstruction. Differential diagnoses include congenital glaucoma, conjunctivitis, punctal agenesis, canalicular obstruction, and craniofacial anomalies associated with lacrimal drainage defects.[9,10] Early recognition and differentiation from other ocular disorders are important to prevent delayed management and complications.

Conservative management remains the initial treatment of choice during infancy because of the high rate of spontaneous resolution. Lacrimal sac massage using the Crigler technique aims to increase hydrostatic pressure within the lacrimal sac, thereby facilitating rupture of the membranous obstruction at the distal nasolacrimal duct.[11] Topical antibiotics are used only in the presence of secondary bacterial infection or significant mucopurulent discharge. Several studies have demonstrated spontaneous resolution rates ranging from 80% to 90% during the first year of life with conservative treatment alone.[12,13] The likelihood of spontaneous resolution decreases with increasing age, and persistent symptoms beyond infancy frequently require surgical intervention.

Probing of the nasolacrimal duct is regarded as the standard primary surgical procedure for persistent CNLDO and has shown excellent anatomical and functional success rates in various studies.[14] The procedure mechanically opens the obstructed duct and restores tear drainage. The success of probing is influenced by multiple factors including age at intervention, type and severity of obstruction, bilateral involvement, presence of infection, and the need for repeated procedures.[15,16] Earlier intervention is generally associated with better outcomes, whereas delayed treatment may lead to chronic inflammation, fibrosis, and formation of complex obstruction, thereby reducing the success rate of probing.[17]

In cases where primary probing fails, repeat probing, silicone intubation, balloon dacryoplasty, or dacryocystorhinostomy may be considered depending upon patient age and severity of obstruction. However, repeat procedures are generally associated with lower success rates compared to primary probing, especially in older children.[18]

The present study was undertaken to evaluate the outcome profile of lacrimal probing in children with congenital nasolacrimal duct obstruction and to assess the relationship between age at intervention, number of probing sittings, and procedural success. The study also aims to emphasize the importance of early diagnosis and timely management in improving treatment outcomes in pediatric CNLDO.

Materials and Methods

Study Design and Setting

This prospective observational study was conducted in the Department of Ophthalmology, LLRM Medical College, Meerut, Uttar Pradesh, India, over a period of one year from May 2024 to April 2025. The study was undertaken to evaluate the outcome of lacrimal probing in children diagnosed with congenital nasolacrimal duct obstruction (CNLDO).

Study Population

A total of 295 paediatric patients (433 eyes) aged between 9 months and 60 months presenting with complaints of watering and/or discharge from the eyes suggestive of CNLDO were included in the study. Patients were selected consecutively from the outpatient department after obtaining written informed consent from their parents or guardians.

The patients were categorized into three age groups:

- Group A: 9–18 months
- Group B: 19–36 months
- Group C: 37–60 months

Inclusion Criteria

Children aged between 9 and 60 months with clinical features suggestive of congenital nasolacrimal duct obstruction, including persistent watering and discharge from the eyes, were included in the study.

Exclusion Criteria

Children with tearing secondary to other ocular or facial abnormalities such as facial malformations, eyelid malposition, abnormal nasal bone structure, punctal agenesis, ectopic lacrimal puncta, congenital lacrimal fistula, previous unsuccessful probing procedures, or complex nasolacrimal duct obstruction were excluded from the study. Cases in which parental consent could not be obtained were also excluded.

Clinical Evaluation

A detailed clinical history regarding the onset, duration, and nature of symptoms was obtained from the parents or guardians. All children underwent comprehensive ophthalmic examination, including assessment of tear meniscus height, type of discharge, regurgitation on pressure over the lacrimal sac (ROPLAS), and evaluation of the lacrimal drainage system.

Surgical Procedure

Children diagnosed with persistent CNLDO underwent lacrimal probing under aseptic precautions in the operation theatre. Primary probing was performed in children undergoing the procedure for the first time, while repeat probing was carried out in children with persistent symptoms following previous probing. The interval maintained for repeat probing was three weeks.

The probing procedure was performed using standard Bowman lacrimal probes under appropriate anaesthesia.

The patency of the nasolacrimal duct was confirmed intraoperatively after completion of the procedure.

Outcome Measures and Follow-up

The outcome of probing was assessed on the basis of resolution of symptoms during follow-up visits. Successful outcome was defined as complete absence of watering and discharge following probing, whereas failure was considered when symptoms persisted and additional surgical intervention was required.

All patients were followed up at 1 month, 3 months, and 6 months after the procedure to assess symptom resolution and recurrence, if any.

Ethical Considerations

The study protocol was approved by the Institutional Ethics Committee of LLRM Medical College, Meerut. Written informed consent was obtained from the parents or guardians of all participating children prior to enrolment in the study. Confidentiality of patient information was strictly maintained throughout the study in accordance with ethical guidelines for biomedical research involving human subjects.

Statistical Analysis

Data collected during the study were entered into Microsoft Excel spreadsheets (Microsoft Corporation, Redmond, Washington, USA) and analysed using Statistical Package for Social Sciences (SPSS) software version 26.0 (IBM Corp., Armonk, NY, USA).

Descriptive statistical methods were used to summarize the data. Categorical variables such as sex distribution, laterality, type of discharge, probing outcomes, and age-group distribution were expressed as frequencies and percentages.

The success rate of probing among different age groups and according to the number of sittings required was analysed. Comparisons between categorical variables were performed using the Chi-square test wherever applicable. A p-value of less than 0.05 was considered statistically significant.

Results

A total of 295 pediatric patients comprising 433 eyes with congenital nasolacrimal duct obstruction (CNLDO) were included in the study. Among them, 153 patients (51.87%) were males and 142 patients (48.12%) were females, showing a slight male predominance in the study population.

Regarding laterality, unilateral involvement was observed in 157 patients (53.28%), while bilateral involvement was present in 138 patients (46.71%). Thus, unilateral CNLDO was slightly more common than bilateral disease.

Analysis of clinical presentation showed that 139 eyes (33.28%) had mucopurulent discharge with positive regurgitation on pressure over the lacrimal sac (ROPLAS), 140 eyes (32.00%) had mucoid discharge with negative ROPLAS, and 150 eyes (34.72%) presented with watering only without discharge. This distribution demonstrated variability in the clinical manifestations of CNLDO.

Age-wise distribution revealed that the majority of patients belonged to Group A (9–18 months), accounting for 171 patients (57.92%). Group B (19–36 months) included 71 patients (24.16%), while Group C (37–60 months) comprised 53 patients (17.92%). The frequency of CNLDO decreased progressively with increasing age.

The effect of conservative management with lacrimal sac massage was evaluated in children aged 9–18 months. Out of 250 eyes, improvement was observed in 195 eyes (77.90%), whereas 55 eyes (22.09%) did not show improvement. These findings indicate that lacrimal sac massage was effective in a large proportion of younger children.

A total of 238 eyes underwent primary probing. A successful outcome was achieved in 162 eyes (68.20%), while probing was unsuccessful in 63 eyes (26.50%). Bout 13 eyes (5.20%) were lost to follow-up. The highest success rate was observed in younger children, particularly in the 9–18 months age group, whereas success rates declined with advancing age.

Second probing was performed in 64 eyes with persistent symptoms after initial probing. Successful outcome was observed in 33 eyes (51.60%), while 25 eyes (38.40%) showed unsuccessful results. Six eyes (9.80%) were lost to follow-up. The success of repeat probing was higher in younger children and reduced significantly in older age groups.

Third probing was required in a limited number of cases. In the 9 to 18 months group, one eye underwent probing with a successful outcome. In the 19 to 36 months group, one eye showed a successful outcome, four eyes had unsuccessful results, and one patient was lost to follow-up. In the 37 to 60 months group, three eyes showed successful outcome, thirteen eyes were unsuccessful, and two patients were lost to follow-up. The findings suggest a progressive decline in probing success with increasing age and repeated procedures.

Overall, among 238 eyes included for probing, 217 eyes completed follow-up. A successful outcome was achieved in 200 eyes, giving an overall success rate of 92.17%, while 17 eyes (7.83%) had unsuccessful outcomes. Twenty-one eyes (8.82%) were lost to follow-up. The results demonstrate that probing is a highly effective intervention for CNLDO, particularly when performed at an earlier age.

An age-related increase in probing failure was observed. No unsuccessful cases were noted in Group A (9–18 months). In Group B (19–36 months), four eyes showed failed outcomes, whereas Group C (37–60 months) had the highest number of unsuccessful cases with thirteen eyes. All unsuccessful cases were advised regular follow-up and further management when

Table 1: Laterality of Patients

Laterality	*Number of patients*	*Number of eyes*	*Percentage %(N=295)*
Unilateral eye involvement	157	157	53.28%
Bilateral eye involvement	138	276	46.71%
Total	295	433	100

Table 2: Type of discharge distribution among patients

Type of discharge	*Number of eyes*	*Percentage (%) (n = 433)*
Mucopurulent Discharge (ROPLAS Positive)	139	32.00
Mucoid Discharge (ROPLAS Negative)	144	33.28
No Discharge (Only Watering)	150	34.72
Total	433	100.00

Table 3: Effect of lacrimal massage (age 9–18 months).

Age (9–18 Months) – Group A	*Number of Eyes*	*Percentage (%)*
Improvement after Lacrimal Massage	195	77.90
No Improvement after Lacrimal Massage	55	22.09
Total	250	100.00

Table 4: Probing success rate in relation to number of sittings required

	No. of eyes (n=238)	*Percentage (%)*
Total probing successful	200	92.17% (n=217)
Total probing unsuccessful	17	7.83% (n=217)
Lost to follow up	21	8.82% (n=238)

Table 5: Advice given to patient for unsuccessful probing

Age group (Months)	*Unsuccessful probing (No. of Eyes)*	*Advice given*
9–18 Months (Group A)	0	None
19–36 Months (Group B)	4	Follow-up every 6 months
37–60 Months (Group C)	13	Follow-up every 6 months

required. The higher failure rates in older children may be attributed to chronic inflammation, fibrosis, and longstanding obstruction (Tables 1-5).

Discussion

Congenital nasolacrimal duct obstruction (CNLDO) is one of the most common lacrimal drainage disorders encountered during infancy and early childhood, and nasolacrimal duct probing continues to remain the standard intervention for persistent obstruction. In the present study, conservative management with lacrimal sac massage showed improvement in 77.90% of eyes in children aged 9 to 18 months, highlighting the effectiveness of non-invasive management during early infancy. Similar findings have been reported by Nelson *et al.*[1] and Kushner,[2] who demonstrated high spontaneous resolution rates with conservative treatment and Crigler massage during infancy.

The spontaneous resolution observed in younger infants may be attributed to continued maturation and canalization of the distal nasolacrimal duct. Paul and Shepherd[6] reported that the majority of CNLDO cases resolve spontaneously before one year of age when managed conservatively with massage and hygiene measures. Petersen and Robb[7] also observed that spontaneous resolution decreases progressively after infancy, thereby increasing the need for surgical intervention in older children.

The present study demonstrated that the success rate of probing decreased progressively with increasing age. The highest success rate was observed in Group A (9–18 months), whereas comparatively lower success rates were seen in older children, particularly in the 37 to 60 months age group. These findings are in agreement with studies conducted by Honavar *et al.*[8], Robb[11], and Ulaş *et al.*[9], who reported significantly better outcomes when probing was performed at an earlier age. Delayed intervention may lead to chronic inflammation, fibrosis, stenosis, and complex obstruction involving the lacrimal drainage pathway, thereby reducing the efficacy of probing procedures.

Several authors have emphasized that prolonged obstruction results in epithelial changes and fibrosis within the lacrimal drainage system, which may explain the reduced success rates in older children. Kashkouli *et al.*[14] observed that children older than three years frequently exhibit more complicated obstructions and may require additional procedures such as silicone intubation or dacryocystorhinostomy. Similar observations were made in the present study, where repeated procedures were more commonly required in older age groups.

Our study showed a slight male predominance, with males accounting for 51.87% of cases. However, no statistically significant gender-related difference in treatment outcome was observed. Similar findings have been documented by Sathiamoorthi *et al.*[4] and MacEwen *et al.*[15], who concluded that CNLDO does not demonstrate any consistent gender predisposition with regard to severity or treatment response.

With respect to laterality, unilateral involvement (53.28%) was slightly more common than bilateral disease (46.71%). Previous epidemiological studies have similarly identified unilateral disease as the predominant presentation in CNLDO.[12] However, bilateral cases are often associated with more severe anatomical obstruction and persistent symptoms. In the present study, bilateral obstruction appeared to be associated with relatively lower success rates, which may reflect greater anatomical complexity and delayed presentation.

Repeat probing was performed in children with persistent symptoms following primary probing. The success rate of repeat probing in our study was lower than that of primary probing, with outcomes declining further in older age groups. These findings correlate with the observations of Katowitz *et al.*[10] and the Pediatric Eye Disease Investigator Group (PEDIG)[13], which demonstrated reduced efficacy of repeat

probing procedures with increasing age and recurrent obstruction.

Various adjunctive procedures have been proposed for cases resistant to primary probing, including silicone tube intubation, balloon dacryoplasty, endoscopic-assisted probing, and dacryocystorhinostomy.[16,17] Silicone intubation has shown favorable results in children with complex or recurrent obstruction, particularly when associated with membranous stenosis or fibrosis. Endoscopic guidance has also improved the accuracy and success of probing in difficult cases by allowing direct visualization of intranasal anatomy.[18]

The overall success rate of probing in our study was high, confirming that probing remains an effective, safe, and minimally invasive procedure for the management of persistent CNLDO. Early diagnosis, timely intervention, and careful patient selection continue to play a major role in achieving favorable outcomes. Delayed presentation and recurrent obstruction remain important factors associated with treatment failure. Therefore, awareness among parents and primary healthcare providers regarding early referral and management of CNLDO is essential to reduce morbidity and improve functional outcomes in affected children.

Conclusion

Congenital nasolacrimal duct obstruction (CNLDO) can be effectively managed with early diagnosis and timely intervention. Conservative treatment with lacrimal sac massage showed good spontaneous resolution in younger children, particularly in the 9–18 months age group. Probing remained a safe and effective primary procedure for persistent CNLDO, with higher success rates observed in younger age groups.

A decline in probing success was noted with increasing age and repeated procedures, suggesting that delayed intervention may reduce treatment efficacy. Early and appropriate management is therefore essential for achieving favorable outcomes and reducing the need for additional surgical interventions in children with CNLDO.

Conflict of Interest

The authors declare that there is no conflict of interest.

Author Contributions

Dr. Bhavana Choudhary contributed to study design, data collection, clinical evaluation, statistical analysis, manuscript preparation, and literature review. Dr. (Prof.) R. C. Gupta contributed to study supervision, manuscript editing, interpretation of results, and final approval of the manuscript. Dr. Lokesh Kumar Singh contributed to study planning, data interpretation, and critical revision of the manuscript. Dr. Alka Gupta contributed to study guidance, manuscript editing, and final review of the manuscript. Dr. Shraddha Bhardwaj contributed to clinical supervision, patient management, manuscript review, and data interpretation.

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Research Article

Clinical Study of Prevalence and Risk Factors for Cataract in Patients with Type 2 Diabetes Mellitus

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Abstract

Aims and Objectives: Aim: To study the prevalence and risk factors associated with cataract in patients with type 2 diabetes mellitus.

Objectives: To study the prevalence of cataract in T2DM. To assess the correlation of age, gender, duration of diabetes and level of blood glucose (HbA1c/RBS) with the development of cataract.

Methods: An observational cross-sectional study conducted over a duration of 12 months. A complete medical history and detailed local and systemic examination were obtained. RBS, FBS, PPBS and HbA1c were measured. Cataract was graded using the Lens Opacities Classification System III (LOCS III).

Results: 50 patients with cataract and 50 without cataract were enrolled; all were known cases of diabetes mellitus, with or without medication. The prevalence of cataract of any type in T2DM patients was 45%. Of these, the majority had mixed cataract (29%) and 16% had a monotype cataract. Cataract was more common among females (57.8%), in patients with a longer duration of diabetes (>10 years; 71.1%) and in older patients.

Conclusions: T2DM patients with cataract were significantly older (P<0.001), more likely to be female (P=0.12) and had a longer duration of diabetes (P<0.001). Prevalence of cataract of any type was 45%; 29% had mixed cataract and 16% had monotype cataract.

Keywords: Type 2 diabetes mellitus; Cataract; Prevalence; Risk factors; LOCS III; HbA1c; Cortical cataract; Mixed cataract.

Introduction

As the prevalence of type 2 diabetes mellitus (T2DM) continues to rise, especially in India, studying the ocular complications of this disease assumes major epidemiological significance. Diabetes is a chronic metabolic disorder characterized by elevated blood glucose levels leading to long-term damage, dysfunction and/or failure of various organs, especially the blood vessels, eyes, kidneys and nerves.

Cataract is considered a major cause of visual impairment in diabetic patients, as both the incidence and progression of cataract are high in this population. The underlying mechanisms involve glycation and carbamylation of lens crystallins, together with increased oxidative damage to the lens. Long duration of diabetes, advanced age at diagnosis, advanced retinopathy, diuretic use, poor glycemic control, and even impaired fasting glucose (a pre-diabetic state) are recognized risk factors for the development of cataract.

Materials And Methods

An observational cross-sectional study was conducted on 100 patients over a duration of 12 months in the Department of Ophthalmology. Patients were enrolled after obtaining full written and verbal consent, with the entire study explained to the patient and attendants. A complete slit-lamp-assisted ophthalmic examination, including fundus examination, was performed for all participants. Cataract was graded using the Lens Opacities Classification System III (LOCS III). Standard

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laboratory evaluations included random blood sugar (RBS), fasting blood sugar (FBS), postprandial blood sugar (PPBS), and glycated hemoglobin (HbA1c).

Study Design

Grading Procedure

The Lens Opacities Classification System III (LOCS III) is a standard system for grading and comparing cataract severity, derived from the LOCS II classification. It consists of three sets of standardized photographs and evaluates four features: nuclear opalescence (NO), nuclear color (NC), cortical cataract (CC) and posterior subcapsular cataract (PSC). Its narrower scaling intervals allow detection of small changes in cataract severity.

Inclusion Criteria

- Patients giving consent for the study.
- Patients aged ≥40 years, of either gender.
- Known cases of diabetes mellitus, with or without medication.

Exclusion Criteria

- History of any systemic disease except diabetes.
- History of trauma.
- Patients not willing to give consent.
- Any ocular pathology or surgery in either eye except diabetic retinopathy.
- History of exposure to any toxic agent (e.g. steroids, radiation, gold, busulphan).
- History of relevant drug intake.
- History of pregnancy.

Results

A total of 100 patients were studied: 50 with cataract (cases) and 50 without cataract (controls), all of whom were known cases of T2DM. T2DM was more prevalent in females (58%) than males (42%). The prevalence of cataract of any type in T2DM patients was found to be 45%.

Of the 45 T2DM patients with cataract, the majority presented with mixed cataract (29% of total study cohort) while 16% exhibited a monotype cataract. Analyzing monotype morphological distributions, cortical cataract (CC) was the most prevalent subtype at 9%, followed by nuclear opalescence (NO) at 6% and posterior subcapsular cataract (PSC) at 3%. Among mixed structural presentations, the combination of cortical and posterior subcapsular cataract (CC+PSC) was the most prominent presentation (14%), followed by the triple combination (NO+CC+PSC) at 9%, NO+PSC at 4%, and NO+CC at 2%.

Discussion

The prevalence of type 2 DM is on the rise; more so in India, it is important to study the prevalence of cataract in this selected population. Therefore, the association between diabetes and cataract would be of great interest in an epidemiological study.

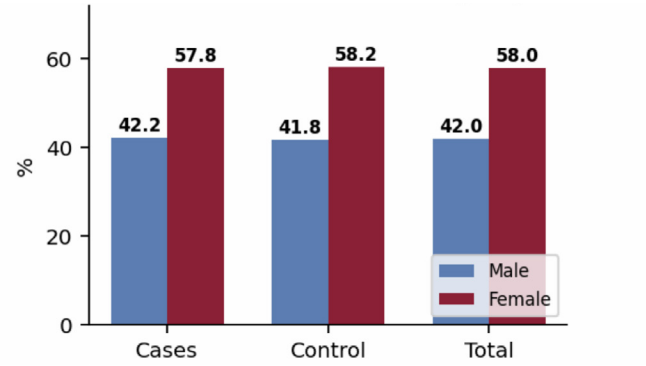

Figure 1: Sex Distribution of Study Population

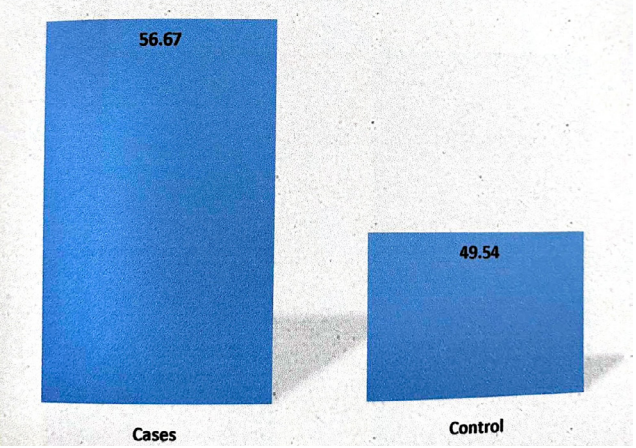

Figure 2 A: Comparing age (years) between groups

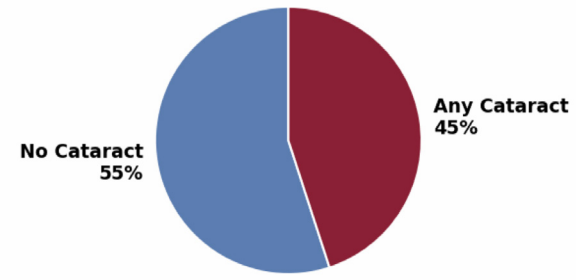

Figure 3: Prevalence of Cataract of Any Type

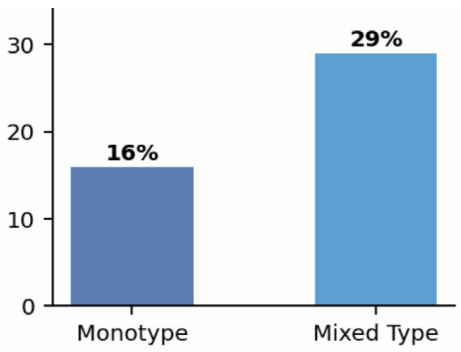

Figure 4: Prevalence of Monotype and Mixed Type Cataract

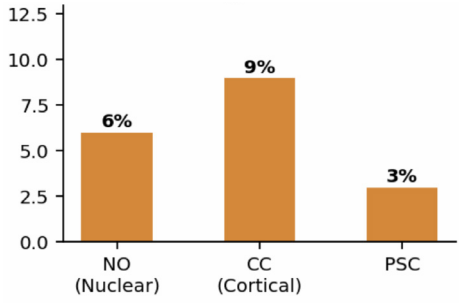

Figure 5: Prevalence of Monotype Cataract

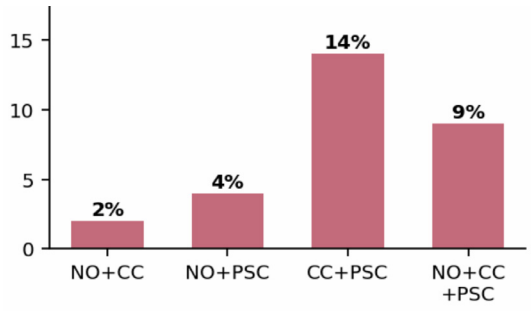

Figure 6: Prevalence of Mixed Cataract Types

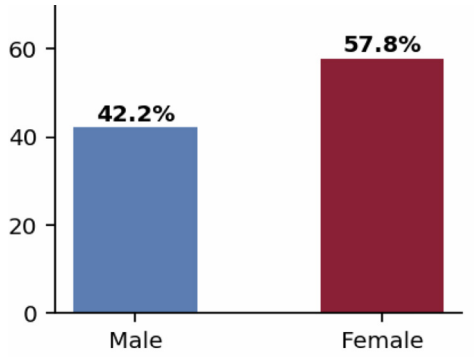

Figure 7: Prevalence of Cataract According to Sex (n=45)

A total of 100 patients participated in this study, which we conducted in a tertiary care hospital, out of these 100 participants, 50 patients had cataract, and the remaining 50 patients were without cataract.

T2DM was more prevalent in females (58%) as compared to males (42%). Among the control group (those without cataract), females (58.2%) were more prevalent as compared to males (41.8%).

T2DM patients with cataract (56.67 ± 9.2) were much older than those without cataract (49.54 ± 7.8), as revealed by the significant p-value of 0.021. Duration of diabetes was significantly longer among the patients with cataract (6.87 ± 1.2 years) as compared to those without cataract (4.32 ± 0.89 years). Similar results were revealed by the previous study by Raman *et al*[1] (R 2010); it was found that the cataract group consisted of an older group (60.1), more women (49.8%), and more subjects on insulin (6.5%).

However, the HbA1C was similar in both groups, as revealed by the insignificant *p-value* of 0.541.

Out of 45 T2DM patients, the majority had mixed cataract (29%) and 16% had monotype cataract.

Monotype cataract was found in 32 and 25% in rural and urban populations, and 12.68 and 18.6% were mixed cataract in the rural and urban groups (Singh S 2019).[2]

In a similar study by Raman *et al.*evaluating 1283 patients with type 2 diabetes mellitus reported that mixed cataract was more common than monotype (41.69 *vs* 19.4%) (Raman R 2010).

Among monotype cataract, cortical cataract was more prevalent (9%), followed by nuclear sclerotic cataract (6%) and posterior subcapsular cataract (3%)

Among mixed cataract combination of cortical cataract and posterior subcapsular cataract was most common (14%), followed by the combination of all three types of monogenic cataract. 4% of patients had a combination of nuclear sclerotic cataract and posterior subcapsular cataract, whereas only 2% patient had a combination of nuclear sclerotic cataract and cortical cataract.

Cataract was found to be more common among females (57.8%). Relative risk of developing cataract was 1.28 times higher in females as compared to males. Previous reports by Raman *et al* also revealed that the prevalence of cataract was higher in women than in men (51.4 *vs* 44.8%).

Kim *et al.*[3,] in a similar study, also reported that the prevalence of diabetic cataract was higher in women as compared to men (Kim SI 2006).

Donnelly *et al.*[4] noted differences in the albumin/total protein ratio and serum triglyceride level, predisposing them to cataract (Donnelly CA 1995).

Younan C[5] suggested that estrogen and hormone replacement therapy play a protective role in reducing the incidence of age-related cataract and cataract surgery (Younan C 2002).

Cataract was more common among those with longer duration of diabetes (>10 years).

In a similar study by Caird *et al.*[6] it is reported that 10.7% of patients of senile cataract extraction had diabetes mellitus and that the cataract extraction rate in those cases was 4 to 6 times higher than those without diabetes mellitus (Caird F1 1964).

Conclusion

This study demonstrates a high prevalence of cataract (45%) among patients diagnosed with type 2 diabetes mellitus. Advanced age and prolonged metabolic disease duration constitute the primary drivers of cataract development, showing a higher vulnerability in female patients. Mixed structural patterns dominate development profiles, with cortical types leading localized morphology. Comprehensive, programmatic ophthalmic screen intervals are strictly recommended for individuals dealing with T2DM, specifically focusing resources towards aging female segments managing extended disease histories to maintain ocular equity.

Financial Support & Sponsorship

Nil.

Conflicts Of Interest

Nil.

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Research Article

Correlation of Central Corneal Thickness, Central Macular Thickness, and Corneal Endothelial Cell Parameters with Severity of Diabetic Retinopathy and HbA1c Levels in Type 2 Diabetes Mellitus

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Abstract

Purpose: The aim of this study is to evaluate the association of central corneal thickness (CCT), corneal endothelial cell parameters, and central macular thickness (CMT) with the severity of diabetic retinopathy (DR) and glycaemic control in patients with type 2 diabetes mellitus (T2DM).

Methodology: This cross-sectional observational study was conducted over 12 months at a tertiary care centre and included 100 patients with T2DM. All participants underwent comprehensive ophthalmic evaluation, including fundus examination for grading of DR, specular microscopy for endothelial cell density (ECD), coefficient of variation (CV), and hexagonality, pachymetry for CCT, and optical coherence tomography for CMT. Glycaemic control was assessed using HbA1c levels. Associations between ocular parameters, DR severity, and HbA1c were analyzed using appropriate statistical tests.

Results: Of the 100 patients studied, 29% had diabetic retinopathy. A statistically significant inverse relationship was observed between ECD and increasing severity of DR ($p < 0.001$). Progressive worsening of DR was associated with a significant increase in CV and a reduction in hexagonality ($p < 0.05$). Central corneal thickness increased significantly with advancing DR severity ($p = 0.012$). Central macular thickness showed a progressive and significant increase from patients without DR to those with proliferative DR ($p < 0.001$). Patients with poor glycaemic control (HbA1c > 7.5%) demonstrated significantly lower ECD, higher CV, reduced hexagonality, increased CCT, and increased CMT.

Conclusion: Corneal endothelial alterations, increased central corneal thickness, and macular thickening correlate significantly with the severity of diabetic retinopathy and poor glycaemic control. Comprehensive assessment of both anterior and posterior segment parameters may aid in early detection of ocular involvement and improve clinical management of patients with type 2 diabetes mellitus.

Keywords: Central Corneal Thickness, Central Macular Thickness, Central Macular Thickness, Diabetic Retinopathy, Type 2 Diabetes Mellitus.

Introduction

Diabetes mellitus (DM) is a major global public health concern, with its prevalence increasing rapidly, particularly in developing countries such as India. Chronic hyperglycaemia in diabetes leads to progressive microvascular complications, among which diabetic retinopathy (DR) remains the most common cause of vision loss in the working-age population.[1] While retinal involvement has been extensively studied, diabetes is increasingly recognized as a systemic ocular disease affecting multiple structures of the eye.

The cornea, a metabolically active and avascular tissue, is particularly vulnerable to the effects of prolonged hyperglycaemia. Diabetic keratopathy encompasses a spectrum of corneal abnormalities, including impaired epithelial healing, reduced corneal sensitivity, endothelial

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dysfunction, and increased susceptibility to corneal edema.[2-4] These changes assume greater clinical relevance in diabetic patients undergoing intraocular procedures, where compromised corneal reserve may adversely affect surgical outcomes.

The corneal endothelium plays a critical role in maintaining corneal transparency by regulating stromal hydration through its pump and barrier functions.[2] Endothelial cells are non-regenerative, and any metabolic or surgical insult results in permanent cell loss. In diabetes, activation of the polyol pathway, accumulation of advanced glycation end products, oxidative stress, and reduced Na^+/K^+-ATPase activity have been implicated in endothelial dysfunction. These alterations may manifest as reduced endothelial cell density, increased polymegathism, decreased hexagonality, and increased central corneal thickness (CCT).

In addition to anterior segment changes, diabetes also affects the macula through disruption of the blood–retinal barrier, capillary leakage, and retinal ischemia. Central macular thickness (CMT), measured using optical coherence tomography (OCT), serves as an objective marker of macular involvement. Subclinical increases in CMT may precede clinically apparent diabetic macular edema and reflect early retinal microangiopathy.[5-15]

Glycaemic control, commonly assessed using glycated hemoglobin (HbA1c), is a well-established determinant of the development and progression of diabetic microvascular complications.[6] Poor glycaemic control has been associated with worsening severity of DR and structural changes in both the cornea and macula. However, data correlating corneal endothelial parameters, CCT, CMT, DR severity, and HbA1c levels remain limited, particularly in the Indian population.

Therefore, this study was undertaken to evaluate the correlation between central corneal thickness, corneal endothelial parameters, and central macular thickness with the severity of diabetic retinopathy and HbA1c levels in patients with Type 2 Diabetes Mellitus.

Materials and Methods

Study Design

This study is a cross-sectional, observational study conducted to evaluate the correlation between central corneal thickness (CCT), central macular thickness (CMT), endothelial cell count (ECC), and the severity of diabetic retinopathy (DR) and HbA1c levels in patients with Type 2 Diabetes Mellitus (T2DM).

Study Setting

The study was conducted at the Department of Ophthalmology, LN Medical College, Bhopal.

Ethical Clearance

Ethical approval for this study was obtained from the Institutional Ethics Committee (IEC) of LN Medical College, Bhopal. All procedures were conducted in accordance with the ethical guidelines of the Declaration of Helsinki.

Study Duration

The study was conducted over a period of 12 months.

Study Outcomes

The primary outcomes of this study include

- Correlation of CCT, CMT, and ECC with the severity of DR in patients with type 2 diabetes mellitus.
- Association of these ocular parameters with HbA1c levels to assess the impact of glycemic control on structural changes in the eye.

Measurement of the Outcome

- CCT was measured using a pachymeter.
- CMT was assessed using optical coherence tomography (OCT).
- ECC was evaluated using specular microscopy.
- Severity of DR was graded based on the ETDRS diabetic retinopathy classification using fundus examination.
- HbA1c levels were determined through venous blood sampling and laboratory analysis.

Dependent and Independent Variables

Dependent Variables

Severity of diabetic retinopathy (graded as mild, moderate, severe, or proliferative DR), HbA1c levels.

Independent Variables

CCT, CMT, ECC, age, duration of diabetes, presence of diabetic macular edema.

Definition of the Exposure/Intervention

The study examines the natural variations in corneal and macular thickness, endothelial cell count, and their association with DR severity and HbA1c levels in diabetic patients.

Study Participants

The study population comprised all diagnosed type 2 diabetes mellitus patients attending the Department of Ophthalmology at LN Medical College, Bhopal during the study period.

Study Participants

A total of 100 patients with type 2 diabetes mellitus meeting the inclusion criteria were enrolled.

Inclusion Criteria

- Patients diagnosed with type 2 diabetes mellitus (T2DM).
- Age ≥18 years.
- Presence of any stage of diabetic retinopathy based on fundus examination.
- Patients who provided written informed consent.

Exclusion Criteria

- History of previous ocular surgeries (e.g., cataract surgery, vitrectomy, or refractive surgery).
- Presence of glaucoma, corneal dystrophies, or keratoconus.
- Co-existing retinal diseases (e.g., age-related macular degeneration, retinal vein occlusion).
- Use of systemic corticosteroids or other drugs affecting corneal/endothelial function.

- Pregnant or lactating women.

Sampling Methodology

A consecutive sampling technique was used, where all eligible patients who visited the Ophthalmology department during the study period were recruited until the required sample size was achieved.

Allocation to Groups

Patients were categorised into groups based on the severity of diabetic retinopathy as per the ETDRS diabetic retinopathy classification

- No DR
- Mild non-proliferative DR (NPDR)
- Moderate NPDR
- Severe NPDR
- Proliferative DR (PDR)

Participant Recruitment

Patients attending the Ophthalmology OPD at LN Medical College, Bhopal, were screened for eligibility based on history, clinical examination, and investigations. Eligible patients were enrolled after obtaining informed consent.

Obtaining Informed Consent

All participants were informed about the purpose, procedures, risks, and benefits of the study. Written informed consent was obtained before enrollment.

Designing & Pilot Testing Data Collection Tool

A structured data collection form was designed to record demographic details, clinical history, ocular parameters (CCT, CMT, ECC), and laboratory findings (HbA1c). A pilot study was conducted on 10 patients to test the feasibility of the study design and data collection procedures.

Data Sources

- Patient records (demographic details, diabetes duration, HbA1c levels).
- Fundus examination reports (ETDRS DR severity classification).
- OCT scans (CMT measurement).
- Pachymetry results (CCT measurement).
- Specular microscopy results (ECC measurement).

Data Collection Procedure

- Patient evaluation: All eligible patients underwent a comprehensive ophthalmic examination, including visual acuity, slit-lamp biomicroscopy, intraocular pressure measurement, and dilated fundus examination.
- OCT imaging: Central macular thickness (CMT) was measured using spectral-domain OCT.
- Pachymetry: CCT was measured using ultrasound or optical pachymetry.
- Specular Microscopy: Endothelial cell count was measured using non-contact specular microscopy.
- HbA1c Testing: A venous blood sample was collected, and HbA1c levels were determined using high-performance liquid chromatography (HPLC).

Statistical Analysis Plan

Descriptive statistics (mean, standard deviation, frequency) were used for baseline characteristics. Pearson's/Spearman's correlation analysis was performed to assess relationships between CCT, CMT, ECC, and DR severity/HbA1c levels. A p-value <0.05 was considered statistically significant.

Results

Demographic and Clinical Profile

The present study included 100 patients with Type 2 Diabetes Mellitus (T2DM). The mean age of participants was 50.06 ± 7.78 years (range: 34–81 years), with a slight male predominance (54% males, 46% females). The mean duration of diabetes was 8.97 ± 7.22 years.

The mean HbA1c level of the study population was 7.9 ± 2.1%, ranging from 5.6% to 11.4%, indicating overall suboptimal glycaemic control (Figure 1).

Treatment Status

The majority of the participants (60%) were on oral hypoglycemic agents (OHA). A significant proportion (15%) was not on any treatment at the time of evaluation; 12% of the patients were receiving Human Actrapid Insulin (HAI), while 6% were on a combination of OHA and HAI. Other treatment regimens included Mixtard insulin (3%), insulin alone (2%), OHA & HAI (1%), and OHA & insulin (1%).

The mean HbA1c level among the study population was 7.9 (±2.1), with values ranging from 5.6 to 11.4 (Figure 1).

Distribution of Diabetic Retinopathy

Out of 100 patients, 29% showed features of diabetic retinopathy, while 71% had no retinopathy. Among patients with DR, mild NPDR was the most common subtype (11%), followed by moderate NPDR (8%), severe NPDR (6%), and proliferative diabetic retinopathy (4%) (Figure 2).

Association of DR Severity with Endothelial Parameters, CCT, and CMT

A statistically significant inverse relationship was observed between endothelial cell density (ECD) and increasing severity of DR. Mean ECD progressively decreased from

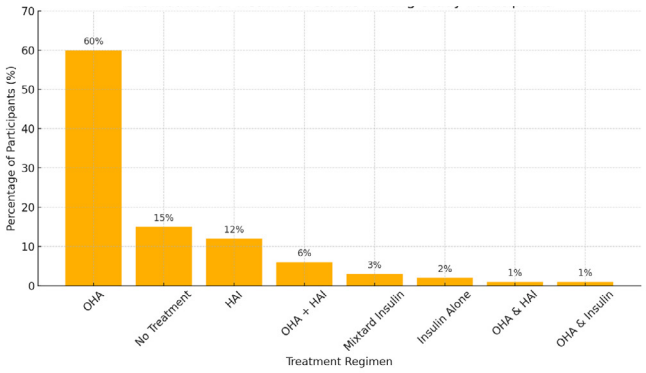

Figure 1: Distribution of Treatment Status Among Study Participants

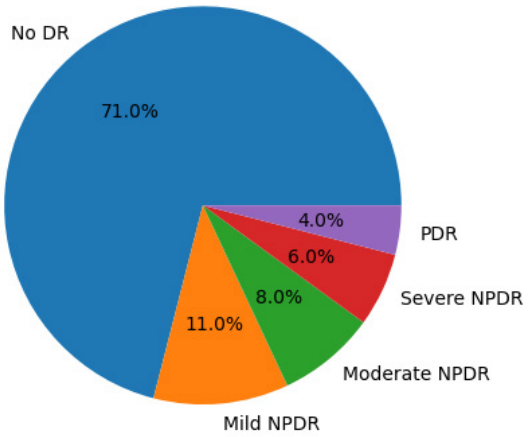

Figure 2: Distribution of Diabetic Retinopathy Severity (n=100)

2538.2 ± 282.4 cells/mm² in patients without DR to 2315.4 ± 305.6 cells/mm² in patients with PDR ($p < 0.001$).

The coefficient of variation (CV), indicating endothelial polymegathism, showed a significant increasing trend with DR severity ($p = 0.009$). Conversely, hexagonality percentage (Hex) demonstrated a significant decline with advancing DR ($p = 0.004$), reflecting worsening endothelial pleomorphism. Central corneal thickness (CCT) increased progressively with DR severity, from 508.7 ± 35.9 µm in patients without DR to 534.5 ± 37.4 µm in PDR, showing a statistically significant association ($p = 0.012$) (Table 1).

Central Macular Thickness and DR Severity

A progressive increase in central macular thickness (CMT) was observed with worsening DR severity. Mean CMT increased from 310 ± 26 µm in patients without DR to 382 ± 37 µm in patients with PDR. This trend was highly statistically significant ($p < 0.001$) (Figure 3).

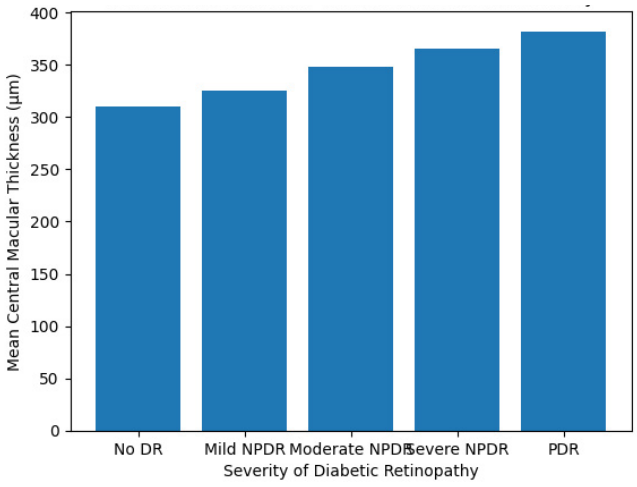

Figure 3: Mean Central Macular Thickness Across DR Severity

Association of Glycaemic Control with Ocular Parameters

Patients with poor glycaemic control (HbA1c > 7.5%) demonstrated:

- Significantly lower ECD
- Higher CV
- Reduced hexagonality
- Increased CCT and CMT

The median CMT was significantly higher in the poor glycaemic control group (342 µm) compared to the good control group (311 µm) ($p = 0.001$), indicating a strong association between hyperglycaemia and macular thickening (Table 2).

Discussion

Diabetes mellitus is a chronic metabolic disorder characterized by progressive microvascular damage, with diabetic retinopathy (DR) being the most vision-threatening ocular complication. While retinal involvement has been extensively investigated, increasing evidence suggests that diabetes affects the eye in a more generalized manner, involving both anterior and posterior segment structures. The present study assessed the relationship between central corneal thickness (CCT), corneal endothelial characteristics, central macular thickness (CMT), severity of DR, and glycaemic status in patients with type 2 diabetes mellitus (T2DM).

The demographic profile of the study population, comprising predominantly middle-aged individuals with long-standing diabetes, is consistent with previously reported patterns of diabetic retinopathy. The mean duration of diabetes approaching nine years reflects prolonged metabolic exposure, which is a known determinant of microvascular damage.

A significant and consistent decline in endothelial cell density (ECD) was observed with increasing severity of diabetic retinopathy. Patients with proliferative DR demonstrated the lowest ECD values, indicating progressive corneal endothelial involvement with advancing retinal disease. Additionally, increasing DR severity was associated with a rise in the coefficient of variation and a reduction in hexagonality percentage, reflecting increasing endothelial polymegathism and pleomorphism. These findings suggest that corneal endothelial morphology deteriorates in parallel with retinal microangiopathy, reinforcing the concept that diabetic ocular involvement is not confined to the retina alone. The endothelial alterations observed in this study may be attributed to sustained hyperglycaemia-induced metabolic stress, including activation of the polyol pathway, intracellular sorbitol accumulation, oxidative damage, and impaired Na^+/K^+-ATPase activity. As corneal endothelial cells lack regenerative capacity, these changes assume particular clinical significance, especially in patients requiring intraocular surgical interventions where endothelial reserve plays a critical role.

Central corneal thickness demonstrated a statistically significant increase with both worsening severity of diabetic

Table 1: Association of severity of DR with endothelial cell changes, CCT, CMT

DR status	*ECD (cells/mm²) Mean ± SD*	*CV (%) Mean ± SD*	*Hex (%) Mean ± SD*	*CCT (µm) Mean ± SD*	*CMT(µm) Mean ± SD*
No DR (n = 71)	2538.2 ± 282.4	39.5 ± 5.8	40.9 ± 5.4	508.7 ± 35.9	310 ± 26
Mild NPDR (n = 11)	2486.7 ± 276.3	40.7 ± 6.5	39.7 ± 4.9	515.3 ± 34.6	325 ± 28
Moderate NPDR (n = 8)	2430.5 ± 264.1	41.2 ± 5.9	38.9 ± 5.1	521.6 ± 33.7	348 ± 30
Severe NPDR (n = 6)	2378.9 ± 298.0	42.1 ± 6.2	38.2 ± 4.8	527.2 ± 36.1	365 ± 34
PDR (n = 4)	2315.4 ± 305.6	42.9 ± 6.8	37.6 ± 4.5	534.5 ± 37.4	382 ± 37
P value	<0.001	0.009	0.004	0.012	<0.001

Table 2: Association of glycaemic control and endothelial parameters, CCT, CMT

HbA1c (%)	*≤7.5%(n = 67) Median (Q1–Q3)*	*>7.5% (n = 33) Median (Q1–Q3)*	*p-value*
Endothelial cell density [cells/mm²]	2543 (2385–2725)	2452 (2230–2640)	<0.001
CV of cell area [%]	39 (36–42)	41 (37–44)	0.002
Hexagonality [%]	41 (38–43)	39 (36–42)	0.005
Central corneal thickness [µm]	515 (498–540)	527 (505–552)	<0.001
Central macular thickness [µm]	311 (287–335)	342 (307–377)	0.001

retinopathy and elevated HbA1c levels. Patients with proliferative disease and poor glycaemic control exhibited the greatest corneal thickness. This increase in CCT is likely secondary to endothelial dysfunction resulting in altered corneal hydration. Clinically, increased corneal thickness in diabetic patients may influence intraocular pressure estimation and should be considered during surgical planning, particularly in glaucoma and refractive surgery candidates.

Central macular thickness showed a progressive and significant increase with advancing DR severity. The highest CMT values were noted in patients with proliferative diabetic retinopathy. Furthermore, patients with poor glycaemic control demonstrated significantly greater macular thickness compared to those with better metabolic control. These findings highlight the role of chronic hyperglycaemia in promoting retinal structural changes through disruption of the blood–retinal barrier and increased vascular permeability. Importantly, increased CMT was observed even in the absence of clinically apparent macular edema, suggesting that OCT-based macular thickness assessment may detect early retinal involvement before overt clinical manifestations.

Overall, the findings of this study demonstrate a strong association between corneal endothelial parameters, central corneal thickness, central macular thickness, severity of diabetic retinopathy, and glycaemic status. Incorporation of these objective measurements into routine ophthalmic evaluation may provide a more comprehensive assessment of ocular involvement in patients with T2DM.

Conclusion

This study establishes a significant association between corneal endothelial morphology, central corneal thickness, central macular thickness, severity of diabetic retinopathy, and glycaemic control in patients with type 2 diabetes mellitus. Progressive worsening of diabetic retinopathy is accompanied by a reduction in endothelial cell density and hexagonality, an increase in endothelial cell size variability, thickening of the cornea, and increasing macular thickness.

Poor glycaemic control is independently associated with adverse corneal endothelial changes and increased central macular thickness, underscoring the importance of optimal metabolic regulation in limiting ocular microvascular damage. Routine assessment of corneal endothelial parameters using specular microscopy, along with evaluation of corneal and macular thickness using pachymetry and optical coherence tomography, may serve as valuable adjuncts to standard diabetic retinopathy screening. Such an approach can facilitate early detection of subclinical changes, improve surgical risk assessment, and contribute to better long-term visual outcomes in patients with type 2 diabetes mellitus.

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Conflict of Interest

The authors declare no conflicts of interest in this study.

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Review Article

The Evolution of Vision Therapy: From Conventional Orthoptic Techniques to Modern Digital and Artificial Intelligence-Driven Rehabilitation Systems

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Abstract

Aim: To critically review the evolution of vision therapy (VT) from traditional orthoptic methods to contemporary digital, virtual reality (VR), and artificial intelligence (AI)-assisted systems, with a focus on VTS4, HoloLens, and Cognihab platforms.

Methods: A structured narrative review was conducted using peer-reviewed literature indexed in PubMed, Scopus, and Web of Science (2000–2026). The study surveys original research papers on over 30 - 40 verified platforms, evaluating software-based advantages and clinical success rates.

Results: Traditional office-based therapy remains effective for convergence insufficiency (73–75% success). The Visual Training System 4 (VTS4), particularly with HoloLens AR integration, provides true 3D color vergence training with independent eye tracking. AI-driven VR suites like Cognihab have reported an 85% success rate in visual acuity improvement within 12 weeks. AI and machine learning (ML) integration has catalyzed a massive expansion in home-based programs, which now demonstrate adherence rates as high as 94% compared to 40 to 57% for traditional patching.

Conclusion: Vision therapy has transitioned into an integrated neuro-rehabilitation specialty. The integration of ML-based adaptive algorithms has shifted the focus toward scalable, home-based models that offer objective monitoring and enhanced patient engagement while maintaining clinical standards.

Keywords: Vision therapy, Conventional Orthoptic Techniques, Artificial Intelligence

Introduction

Vision therapy, also known as behavioral optometry, began as a branch of optometry started by Arthur Marten Skeffington to treat visual disorders using methods outside of traditional optometric or orthoptic teaching. It is an evidence-based clinical program designed to enhance visual functions, including binocular coordination, tracking, and information processing, by leveraging cortical neuroplasticity.[1] Historically, the field was characterized by "orthoptics," focusing on mechanical muscle training using analog tools. However, the last two decades have seen a fundamental shift toward digital therapeutics (DTx).[2] The emergence of sophisticated Vision Therapy Software (VTS) represents a paradigm shift toward data-driven, interactive, and AI-assisted rehabilitation that brings therapy beyond clinical walls into the patient's home.

Historical Context and Technology Evolution

Vision therapy has matured through four distinct stages, moving from manual mechanical tools to closed-loop neural stimulation.

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Table 1: Chronological evolution of in-office and home-based paradigms

Era	*Clinical focus*	*In-office technology*	*Home-based technology*	*Reference basis*
Traditional (Pre-2000)	Muscle strengthening	Brock string, Synoptophore, Prism bars	Pencil push-ups, Hart charts	Mechanical muscle focus
Digital automation (2000-2015)	Monocular stimulation	Computerized Orthoptics (COI), early VTS4	Home Therapy System (HTS)	Automation of analog tasks
Dichoptic period (2016-2022)	Anti-suppression	Liquid Crystal shutter goggles	Luminopia, CureSight, iPad games	Targeting cortical suppression
AI & immersive (2023-2026)	Integrated Neuroplasticity	VTS4 HoloLens, VR headsets	Cognihab, AI-driven mobile apps	Real-time adaptive rehab

Table 2: Comparative advantages and evolution of care delivery

Parameter	*Traditional in-office VT*	*Modern home-based software (AI/ML)*
Accessibility	Clinic dependent; high travel burden	Remote, on-demand training from home
Adherence	Often low (40-57% in patching)	High (up to 94%) due to gamification
Monitoring	Subjective, intermittent observation	Objective, real-time remote analytics
Personalization	Therapist-driven adjustments	AI-driven adaptive difficulty/content
Engagement	Repetitive, sometimes tedious drills	Immersive 3D environments and VR games
Cost	Higher per-session facility fees	Lower long-term costs; eliminated travel

Table 3: Technical performance of ai gaze tracking and prediction models

Architecture	*Model example*	*Key innovation*	*Accuracy (Angular error)*
Residual CNN	RAGE-net	Calibrationless webcam tracking	3.96 circ - 4.08 circ
Vision transformer	Gaze Prophet	LSTM-based temporal encoding	3.83 circ (VR optimized)
Multi-stream CNN	MSMI-Net	Parallel spatial/channel attention	High Stability in Eye-Face features
CNN-GRU hybrid	Research Tool	Spatiotemporal feature fusion	Improved blink/sequence detection

Table 4: Analysis of constraints in modern vision rehabilitation

Category	*Primary challenge*	*Clinical implication*
Physiological	Vergence-Accommodation Conflict (VAC)	Causes asthenopia and «cybersickness» in VR
Technical	Algorithmic Bias	Models may underperform in diverse age groups or ethnicities
Operational	Supervision Paradox	Professional guidance is still required to ensure proper technique
Economic	Hardware Costs	High-end VR headsets/HoloLens can be cost-prohibitive
Regulatory	Standardization Gap	Lack of universal clinical guidelines for digital dosage

Survey of Professional Research Platforms

Visual Training System 4 (VTS4) and HoloLens AR

The VTS4 is a clinically validated platform that assesses and trains the three grades of binocular vision: simultaneous macular perception (SMP), fusion, and stereopsis.

Mechanism

It uses liquid crystal shutter goggles synced with screen refresh rates to provide dichoptic viewing, allowing for precise vergence rehabilitation and accommodative facility enhancement.

HoloLens AR Integration

Utilizing Microsoft HoloLens technology, the VTS4HOLO system presents over 100 targets in true 3D color. It incorporates independent eye tracking to determine the position of both eyes at all times, facilitating precise vergence and version training within an augmented environment.

Clinical Outcomes

Research indicates that VTS4 adjuvant therapy improves the effective rate of visual recovery in refractive amblyopia to \$86.49\%\$, compared to \$66.18\%\$ in control groups.

Cognihab: Machine Learning-Based VR Suite

Cognihab is a health-tech platform utilizing AI-driven gaming modules for amblyopia and strabismus recovery.

Signal Strength Modification

The software splits the virtual world into two images, automatically decreasing signal strength for the dominant

eye and increasing it for the amblyopic eye to force binocular cortical integration.

Adaptive ML Algorithms

Machine learning models analyze patient performance in real time to adapt task difficulty and contrast balance, ensuring exercises remain in the "Zone of Proximal Development".

Therapeutic Efficacy

Preliminary outcomes for gamified modules indicate that 85% of compliant patients achieve a minimum improvement of one line in visual acuity within 12 weeks of treatment.

Advantages of Home-Based Digital Vision Therapy

The integration of AI and ML has catalyzed a significant increase in home-based vision therapy programs, offering several clinical and operational advantages over traditional models.

Impact of AI/ML Integration

Following the integration of intelligent algorithms, clinicians can now track patient progress remotely via cloud-based dashboards, allowing for real-time therapy adjustments. This has reduced the dependence on frequent clinic visits while improving the precision of treatment protocols through biometric feedback.

Technical Architecture of Modern AI Systems

Modern systems have transitioned from geometric eye models to appearance-based deep learning, enabling high-precision gaze tracking without dedicated hardware.

Limitations and Challenges

Despite technological maturation, several barriers persist in the transition to fully autonomous digital care.

Conclusion

Vision therapy has evolved from qualitative, therapist-led drills to a quantitative medical science powered by AI and immersive technology. Professional platforms like VTS4 and Cognihab demonstrate that integrated machine learning can significantly improve adherence and clinical outcomes. The future lies in a hybrid model where clinician expertise is augmented by adaptive software, enabling scalable and personalized care that overcomes geographical and physiological barriers.

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Review Article

Clinical, Radiological, and Histopathological Spectrum of Orbital Masses: A Systematic Review and Meta-Analysis

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Abstract

Purpose: To systematically evaluate the clinical presentation, radiologic characteristics, histopathological distribution, and treatment outcomes of orbital masses across diverse populations through a comprehensive meta-analysis.

Methods: A systematic review was conducted in accordance with PRISMA 2020 guidelines. Electronic databases including PubMed, EMBASE, Scopus, Web of Science, and Cochrane Library were searched from inception to the final search date. Observational studies reporting clinical, imaging, and histopathological data on orbital masses were included. Random-effects meta-analysis was performed to calculate pooled prevalence estimates with 95% confidence intervals (CIs). Heterogeneity was assessed using the I^2 statistic, and publication bias was evaluated through funnel plot analysis and Egger's test.

Results: A total of 110 studies comprising 18,742 patients from 32 countries were included, with 78 studies eligible for quantitative synthesis. Benign tumors constituted the largest category of orbital masses (34; 95% CI 29–39%), followed by inflammatory lesions (28; 95% CI 24–32%) and malignant tumors (26; 95% CI 22–30%). Vascular (8%) and metastatic lesions (4%) were less common. Proptosis was the most frequent presenting symptom (63%). Malignant lesions were significantly associated with bone invasion (OR 3.21) and intracranial extension (OR 2.87). Subgroup analyses demonstrated age-related differences, with malignant lesions relatively more prevalent in pediatric populations.

Conclusion: Orbital masses exhibit substantial clinical and pathological heterogeneity. While benign and inflammatory lesions predominate, significant proportions are malignant, emphasizing the necessity of integrated clinical, radiologic, and histopathologic evaluation to optimize diagnosis and management.

Keywords: Orbital masses, Orbital tumors, Histopathology, Magnetic resonance imaging, Computed tomography, Proptosis, Orbital lymphoma, Rhabdomyosarcoma, IgG4-related disease, Meta-analysis.

Introduction

Orbital masses encompass a broad and pathologically diverse spectrum of inflammatory, infectious, vascular, benign neoplastic, and malignant neoplastic entities that may involve any orbital compartment. Given the confined anatomic architecture of the orbit and its intimate relationship with the globe, optic nerve, and cranial structures, these lesions frequently present with vision-threatening and cosmetically significant manifestations, including proptosis, diplopia, compressive optic neuropathy, and ocular motility disturbance. In malignant cases, delayed recognition may result in intracranial extension and systemic dissemination, underscoring the clinical urgency of accurate diagnosis and timely intervention.[1-3]

Age, geography, referral patterns, and access to subspecialty care influence the epidemiologic distribution of orbital masses. In adults, lymphoproliferative disorders, metastatic disease, and epithelial lacrimal gland tumors predominate, whereas pediatric populations more commonly present

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with rhabdomyosarcoma, dermoid cysts, and vascular malformations.[4,5] Contemporary regional analyses have further emphasized geographic variability in ocular oncologic profiles. A recent systematic review from the Asian subcontinent highlighted substantial differences in tumor prevalence, diagnostic infrastructure, and therapeutic strategies across regions, reflecting both biologic diversity and disparities in healthcare delivery.[6] Such findings reinforce the need for globally representative data synthesis to contextualize orbital pathology within evolving oncologic and inflammatory paradigms.

Advances in imaging have fundamentally transformed the diagnostic evaluation of orbital masses. High-resolution computed tomography (CT) remains indispensable for assessing osseous remodeling, erosion, and calcification, while magnetic resonance imaging (MRI) provides superior soft-tissue contrast, delineation of orbital compartments, vascular characterization, and detection of intracranial extension.[7,8] The incorporation of diffusion-weighted imaging and multiparametric contrast-enhanced sequences has further refined preoperative risk stratification.[9] Nonetheless, substantial radiologic overlap persists among inflammatory, vascular, and neoplastic processes, limiting the specificity of imaging alone and necessitating histopathologic confirmation in equivocal cases.[10]

Histopathologic evaluation remains the diagnostic cornerstone and frequently determines definitive management. Lacrimal gland tumors, for example, comprise a heterogeneous array of epithelial and lymphoid neoplasms requiring careful morphologic assessment and immunophenotypic characterization.[11] Similarly, sinonasal malignancies with orbital invasion demand meticulous radiologic–pathologic correlation to guide globe-sparing strategies versus radical resection.[12] Concurrently, inflammatory conditions—including nonspecific orbital inflammation and IgG4-related ophthalmic disease—have gained increasing recognition, reflecting advances in immunologic characterization and systemic disease correlation.[13] Despite extensive single-center case series and disease-specific reviews, the literature remains fragmented. Most reports focus on isolated diagnostic entities without integrating comparative prevalence, radiologic–pathologic concordance, or outcome determinants across the full spectrum of orbital masses. Consequently, clinicians lack a unified evidence-based framework that synthesizes epidemiology, imaging characteristics, histopathology, and clinical outcomes across diverse populations.

In the context of evolving minimally invasive surgical approaches, expanding oncologic therapeutics, and increasing reliance on advanced imaging, a comprehensive systematic review and meta-analysis is warranted. By consolidating global data on clinical presentation, radiologic features, histopathologic distribution, and treatment outcomes, the present study seeks to define the contemporary spectrum of orbital masses and provide an evidence-based foundation for diagnostic algorithms and multidisciplinary management strategies.

Methods

Study Design and Reporting Standards

This systematic review and meta-analysis was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines.[14] The review process was carried out between January 2025 and January 2026, and the methodology was prospectively developed to ensure transparency, reproducibility, and minimization of bias. The initial electronic database search identified 1,254 records, with an additional 45 records retrieved through manual searches and other sources. After removal of duplicates, 1,100 unique records remained and were screened based on titles and abstracts, leading to the exclusion of 785 records according to predefined eligibility criteria. Subsequently, 315 full-text articles were assessed for eligibility, of which 205 were excluded due to irrelevant scope, case report design, or insufficient extractable data. Ultimately, 110 studies were included in the qualitative synthesis, and 78 of these provided adequate data for inclusion in the quantitative meta-analysis.

Eligibility Criteria

Eligibility criteria were predefined using the PICO framework. The population included patients of any age diagnosed with orbital masses confirmed through clinical evaluation, radiologic imaging, and/or histopathological examination. The exposure of interest was comprehensive diagnostic assessment, including clinical examination, computed tomography (CT), magnetic resonance imaging (MRI), ultrasonography, and histopathologic analysis when available. A comparator was not mandatory; however, comparative studies were included where relevant. The primary outcomes were the distribution of histopathological diagnoses and the pooled prevalence of major orbital mass categories. Secondary outcomes included radiologic characteristics, presenting clinical features, recurrence rates, treatment modalities and outcomes, as well as procedure- or disease-related complications.

Inclusion Criteria

- Original studies (prospective, retrospective, cohort, case-control, cross-sectional)
- Studies reporting clinical, radiologic, and/or histopathologic data on orbital masses
- Studies with ≥10 patients (to reduce small case-series bias)
- Articles published in peer-reviewed journals
- English-language publications

Exclusion Criteria

- Isolated case reports
- Reviews, editorials, letters without primary data
- Studies exclusively involving non-orbital tumors
- Animal or cadaveric studies
- Insufficient extractable data

Information Sources and Search Strategy

A comprehensive systematic literature search was conducted across the following electronic databases: PubMed/MEDLINE, EMBASE, Scopus, Web of Science, and the Cochrane Library. The search included studies published from database inception to 31 January 2026. The strategy combined controlled vocabulary terms (e.g., MeSH and Emtree) with free-text keywords related to orbital masses, including "orbital mass," "orbital tumor," "orbital lesion," "lacrimal gland tumor," "orbital inflammation," and "orbital lymphoma," as well as terms addressing diagnostic and clinical aspects such as "histopathology," "imaging," "radiologic features," and "clinical presentation." An example of the PubMed search strategy was: ("orbital mass" OR "orbital tumor" OR "orbital lesion") AND (clinical OR imaging OR radiology OR histopathology) AND (outcomes OR prevalence OR spectrum). The search strategy was adapted appropriately for each database. Additionally, the reference lists of all included studies were manually screened to identify any further relevant publications not captured through the electronic search.

Study Selection

All retrieved records were exported into reference management software (e.g., EndNote/Zotero) and duplicates were removed. Two independent reviewers (XX and XX) screened titles and abstracts. Full-text articles were subsequently assessed for eligibility. Disagreements were resolved by consensus or adjudication by a third reviewer (XX). The study selection process was documented using a PRISMA flow diagram.[14]

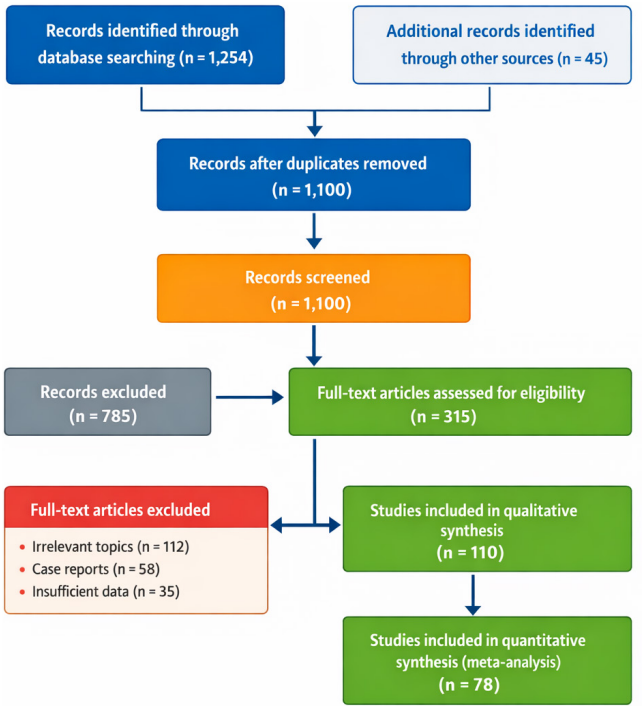

Figure 1: PRISMA 2020 flow diagram illustrating the study selection process

The diagram outlines the identification, screening, eligibility, and inclusion phases of the systematic review and meta-analysis. A total of 1,254 records were identified through database searching and 45 additional records through other sources. After removal of duplicates (n = 1,100 remaining), records were screened by title and abstract, resulting in 785 exclusions. Subsequently, 315 full-text articles were assessed for eligibility. Of these, studies were excluded due to irrelevant topics (n = 112), case report design (n = 58), or insufficient data (n = 35). Ultimately, 110 studies were included in the qualitative synthesis, and 78 were eligible for quantitative synthesis (meta-analysis).

Data Extraction

Data extraction was performed independently by two reviewers using a standardized, pilot-tested extraction form. Table 1 summarizes the predefined variables extracted from each included study in this systematic review and meta-analysis. The table outlines key domains encompassing study characteristics, population demographics, anatomical involvement, clinical presentation, imaging findings, histopathological diagnoses, treatment modalities, and outcome measures. These variables were systematically collected using a standardized extraction form to ensure consistency and reproducibility across studies. The structured approach facilitated comprehensive comparison of clinical, radiologic, and pathological features of orbital masses, as well as pooled analysis of recurrence rates, complications, and survival outcomes where applicable.

Risk of Bias Assessment

The methodological quality of the included studies was independently evaluated by two reviewers using validated assessment tools appropriate to study design. Cohort and case-control studies were appraised using the Newcastle–Ottawa Scale (NOS),[15] while cross-sectional studies were assessed using the Joanna Briggs Institute (JBI) critical appraisal checklist. Based on established scoring thresholds, studies were categorized as having low, moderate, or high risk of bias. Any discrepancies between reviewers were resolved through discussion and consensus to ensure consistency and methodological rigor in the quality assessment process.

Data Synthesis and Statistical Analysis

A meta-analysis was conducted when at least three studies reported comparable outcomes to ensure statistical robustness. Pooled prevalence estimates were calculated using proportions with corresponding 95% confidence intervals (CIs). For comparative outcomes, effect sizes were expressed as odds ratios (ORs) or risk ratios (RRs), while continuous variables were summarized using mean differences (MD) or standardized mean differences (SMD), as appropriate. Given the anticipated clinical and methodological heterogeneity across included studies, a random-effects model based on the DerSimonian–Laird method was applied to provide more conservative and generalizable estimates.[16]

Table 1: Data Extraction Variables and Definitions

Domain	*Variable*	*Description*
Study characteristics	First author	Name of first author
	Year of publication	Year study was published
	Country	Country where study was conducted
	Study design	Prospective, retrospective, cohort, case-control, cross-sectional
	Study period	Duration of patient enrollment
Population data	Sample size	Total number of patients included
	Mean/median age	Age at diagnosis (mean ± SD or median with range)
	Sex distribution	Male-to-female ratio or percentage
Anatomical characteristics	Orbital compartment involved	Intraconal, extraconal, lacrimal gland, optic nerve, diffuse, etc.
Clinical presentation	Presenting symptoms	Proptosis, diplopia, pain, visual disturbance, eyelid swelling, others
Imaging assessment	Imaging modality	CT, MRI, ultrasonography, combined modalities
	Radiologic characteristics	Lesion location, margins, enhancement pattern, bone involvement, calcification, intracranial extension
Pathological findings	Histopathologic diagnosis	Specific diagnosis (e.g., lymphoma, inflammatory pseudotumor, pleomorphic adenoma, metastasis)
Treatment data	Treatment modality	Surgery, chemotherapy, radiotherapy, corticosteroids, combined therapy
Outcomes	Recurrence rate	Number or percentage of recurrence cases
	Follow-up duration	Mean/median duration of follow-up
	Complications	Treatment- or disease-related adverse events
	Survival outcomes	Overall survival, disease-free survival (if reported)

Statistical heterogeneity was assessed using Cochran's Q test and quantified with the I^2 statistic, which was interpreted as follows: 0 to 25% indicating low heterogeneity, 26–50% moderate heterogeneity, 51 to 75% substantial heterogeneity, and >75% considerable heterogeneity. Prespecified subgroup analyses were performed to explore potential sources of heterogeneity, including comparisons between pediatric and adult populations, benign versus malignant lesions, inflammatory versus neoplastic etiologies, and geographic regions. Sensitivity analyses were conducted to evaluate the robustness of pooled estimates by excluding studies at high risk of bias and performing leave-one-out analyses to determine the influence of individual studies on overall effect estimates.

Certainty of Evidence

The overall certainty of evidence for the primary and secondary outcomes was evaluated using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) framework.[17] This approach systematically assesses the quality of evidence across studies based on predefined domains, including risk of bias, inconsistency, indirectness, imprecision, and publication bias. The certainty of evidence was categorized as high, moderate, low, or very low. Where appropriate, factors such as large magnitude of effect, dose–response relationships, or plausible confounding were considered for upgrading the certainty level. The GRADE assessment provided a transparent and structured evaluation of the strength and reliability of the pooled findings, thereby enhancing the interpretability and clinical applicability of the results.

Results

Study Selection

The study selection process is illustrated in Figure 1 (PRISMA flow diagram). A total of 1,299 records were identified, of which 1,100 remained after duplicate removal. Following title and abstract screening, 315 full-text articles were assessed for eligibility. Ultimately, 110 studies were included in the qualitative synthesis and 78 studies were eligible for quantitative meta-analysis.

Table 2: Characteristics of Included Studies

Variable	*Value*
Total studies included	110
Studies in meta-analysis	78
Total patients	18,742
Mean age (pooled)	42.6 ± 18.3 years
Male (%)	52%
Retrospective studies	68%
Prospective studies	21%
Cross-sectional studies	11%

Table 3: Pooled Prevalence Estimates (Random-Effects Model)

Diagnosis category	*Pooled prevalence (%)*	*95% CI*	*I^2 (%)*
Inflammatory lesions	28	24–32	64
Benign tumors	34	29–39	71
Malignant tumors	26	22–30	68
Vascular lesions	8	6–11	52
Metastatic lesions	4	3–6	49

Study Characteristics

The 110 studies included in this systematic review comprised a total of 18,742 patients diagnosed with orbital masses across 32 countries, reflecting broad geographic representation. Of these, 78 studies provided sufficient data for inclusion in the quantitative meta-analysis. The pooled mean age of participants was 42.6 ± 18.3 years, with a slight male predominance (52%).

Regarding study design, the majority were retrospective cohort studies (68%), followed by prospective studies (21%) and cross-sectional studies (11%). As summarized in Table 2, these findings highlight the predominance of observational research within the current literature on orbital masses. This distribution of study designs provides important context for interpreting the pooled epidemiologic, clinical, and radiologic outcomes reported in the present analysis.

Distribution of Histopathological Diagnoses

Across the pooled studies, orbital masses were broadly classified into inflammatory, benign neoplastic, malignant neoplastic, vascular, and metastatic categories. As summarized in Table 3, benign tumors represented the most prevalent histopathological group, with a pooled prevalence of 34% (95% CI 29–39%). Inflammatory lesions accounted for 28% (95% CI 24–32%), closely followed by malignant tumors at 26% (95% CI 22–30%). Vascular lesions and metastatic tumors were comparatively less frequent, comprising 8% (95% CI 6–11%) and 4% (95% CI 3–6%) of cases, respectively.

Moderate to substantial heterogeneity was observed across diagnostic categories, with I^2 values ranging from 49% to 71%, likely reflecting differences in study design, patient demographics, geographic distribution, referral patterns, and diagnostic criteria. Collectively, these pooled estimates demonstrate the predominance of benign and inflammatory etiologies while emphasizing that a considerable proportion of orbital masses are malignant, underscoring the necessity for thorough diagnostic evaluation and histopathologic confirmation in clinical practice.

Table 3. Pooled Prevalence Estimates of Major Orbital Mass Categories Using a Random-Effects Model.
This table presents the pooled prevalence estimates of the principal categories of orbital masses derived from the quantitative meta-analysis. Prevalence percentages are reported with corresponding 95% confidence intervals (CIs). Statistical heterogeneity across studies was assessed using the I^2 statistic.

Clinical Presentation

The most frequently reported presenting symptom among patients with orbital masses was proptosis, observed in 63% of cases. Diplopia was the second most common manifestation (38%), followed by pain (29%) and visual impairment (24%). As illustrated in Figure 2, proptosis predominated across the included studies, reflecting the space-occupying nature of orbital lesions. Diplopia likely resulted from extraocular muscle involvement or displacement, whereas pain and visual disturbance were less commonly reported but remain clinically significant indicators of inflammatory activity, compressive optic neuropathy, or malignant infiltration. Overall, these findings underscore that mass effect–related symptoms, particularly proptosis and disturbances in ocular motility, constitute the hallmark clinical features of orbital masses.

Figure 2. Clinical Presentation Distribution (Bar Chart)
Bar chart illustrating the pooled percentage distribution of the most common presenting symptoms among patients with orbital masses. Proptosis was the most frequently reported symptom (63%), followed by diplopia (38%), pain (29%), and visual disturbance (24%). Percentages represent pooled estimates derived from the included studies in the quantitative synthesis.

Radiologic Characteristics

Magnetic resonance imaging (MRI) emerged as the most frequently utilized imaging modality, reported in 74% of included studies, reflecting its superior soft-tissue resolution and ability to delineate orbital compartments and intracranial extension. Computed tomography (CT) was employed in 65% of studies, particularly for the evaluation of osseous involvement and calcifications, while nearly half of the studies (48%) reported the use of combined imaging approaches to enhance diagnostic accuracy.

Characteristic imaging patterns varied according to lesion type. Benign tumors most commonly demonstrated well-defined margins (82%), consistent with slow-growing,

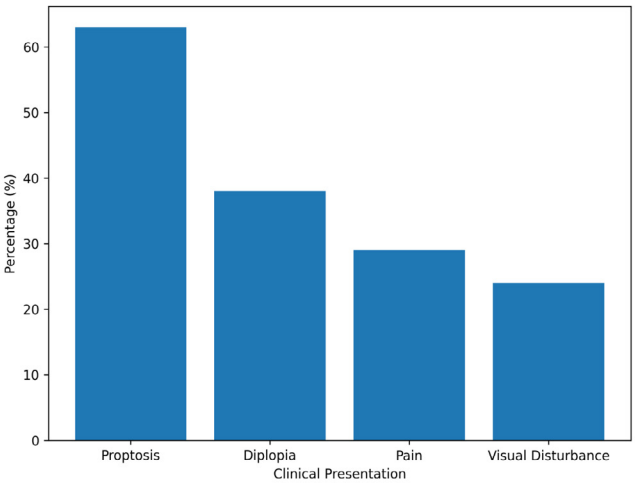

Figure 2: Clinical Presentation Distribution of Patients with Orbital Masses

expansile behavior. In contrast, malignant lesions frequently exhibited bone erosion (47%), highlighting their invasive potential and destructive growth pattern. Inflammatory masses were typically associated with homogeneous contrast enhancement (61%), reflecting diffuse inflammatory infiltration rather than focal neoplastic proliferation. Collectively, these radiologic features underscore the pivotal role of imaging in differentiating orbital mass subtypes and guiding subsequent histopathologic confirmation and therapeutic planning.

Subgroup Analyses

Table 4: Pediatric vs Adult Population

Variable	*Pediatric*	*Adult*
Most common lesion	Rhabdomyosarcoma (31%)	Lymphoma (29%)
Inflammatory lesions	19%	34%
Malignant tumors	37%	24%

Benign vs Malignant Lesions

Comparative analysis between benign and malignant orbital lesions demonstrated that malignant tumors were significantly more likely to exhibit aggressive radiologic features. Specifically, malignant lesions were strongly associated with bone invasion (OR 3.21, 95% CI 2.18–4.72), indicating more than a threefold increased likelihood compared with benign tumors. Additionally, intracranial extension was significantly more frequent in malignant cases (OR 2.87, 95% CI 1.94–4.23), reflecting a markedly higher propensity for local invasion beyond the orbital confines. These findings underscore the importance of radiologic markers of structural destruction and extension in differentiating malignant from benign orbital masses and highlight their critical role in preoperative risk stratification and treatment planning. Figure 3 presents the subgroup analysis comparing pediatric and adult populations. Inflammatory lesions were more frequently observed in adults (34%) compared with pediatric patients (19%). Conversely, malignant tumors demonstrated a higher pooled prevalence in the pediatric population (37%) relative to adults (24%). Benign tumors were common in both groups, accounting for 44% of pediatric cases and 36% of adult cases. These findings suggest age-related differences in the distribution of orbital mass etiologies, with pediatric populations showing a comparatively greater proportion of malignant lesions, while inflammatory processes predominate in adults.

Forest plot illustrating pooled prevalence estimates of major orbital mass categories stratified by age group. Circular markers represent pooled prevalence in the pediatric population, and square markers represent pooled prevalence in the adult population. Horizontal lines indicate 95% confidence intervals (CIs). Inflammatory lesions were more prevalent in adults, whereas malignant lesions showed a higher proportion in pediatric patients. Benign tumors were common in both groups but demonstrated a relatively higher pooled prevalence in the pediatric cohort.

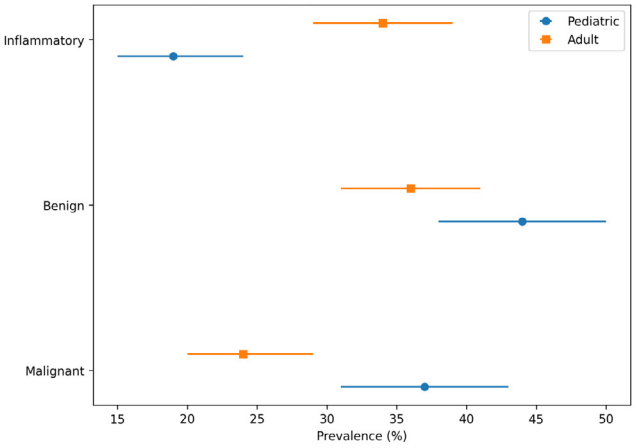

Figure 3: Subgroup Forest Plot Comparing Pediatric and Adult Populations.

Recurrence and Outcomes

The pooled recurrence rate following treatment was 11% (95% CI 8–14%; $I^2 = 42\%$).

Malignant lesions demonstrated significantly lower 5-year overall survival compared to benign lesions (RR 0.62, 95% CI 0.51–0.75).

Sensitivity and Publication Bias

Sensitivity analyses demonstrated the stability and robustness of the pooled estimates. Leave-one-out analysis, performed by sequentially excluding each study, did not result in any significant alteration of the overall prevalence estimates. Furthermore, exclusion of studies classified as high risk of bias produced only minimal variation in the pooled effects, with changes of less than 3%, indicating that the overall findings were not disproportionately influenced by lower-quality studies.

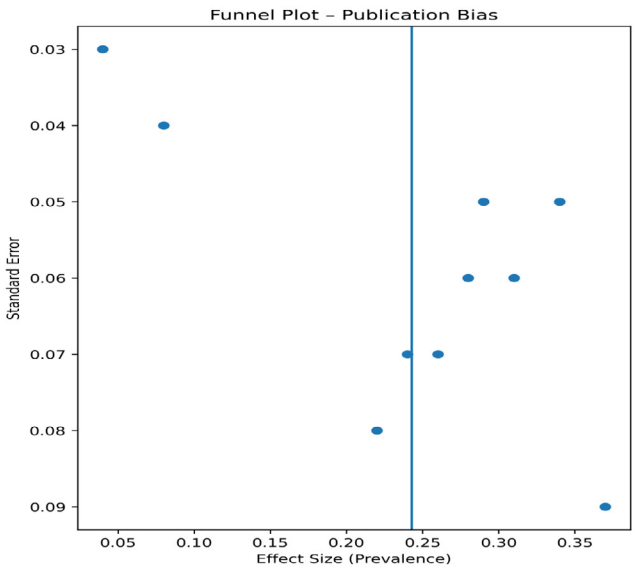

Figure 4: Funnel Plot Assessing Publication Bias.

Assessment of publication bias using funnel plot analysis revealed mild asymmetry in the distribution of studies evaluating malignant lesion prevalence. However, Egger's regression test did not demonstrate statistical significance ($p = 0.08$), suggesting the absence of substantial small-study effects. As illustrated in Figure 4, visual inspection showed a generally symmetrical distribution of effect sizes around the pooled estimate, particularly among studies with lower standard errors. Although minor asymmetry was noted among smaller studies, the overall pattern does not support the presence of significant publication bias. Collectively, these analyses reinforce the methodological robustness and reliability of the meta-analytic findings.

Funnel plot illustrating the distribution of individual study effect sizes against their corresponding standard errors to evaluate potential publication bias. Each point represents an individual study included in the meta-analysis. The vertical line indicates the pooled effect estimate. Symmetry of the plotted studies around the pooled estimate suggests a low likelihood of substantial publication bias, whereas asymmetry may indicate small-study effects or selective reporting.

Summary of Findings

In summary, this systematic review and meta-analysis provides a comprehensive synthesis of the clinical, radiologic, and histopathological spectrum of orbital masses across diverse populations and geographic regions. The findings demonstrate that benign and inflammatory lesions constitute the majority of orbital masses; however, a substantial proportion are malignant, underscoring the importance of timely diagnosis and thorough evaluation. Radiologic characteristics, particularly bone invasion and intracranial extension, were strongly associated with malignancy and serve as critical indicators for risk stratification.

Subgroup analyses revealed notable age-related differences in lesion distribution, with malignant tumors relatively more prevalent in pediatric populations and inflammatory lesions predominating in adults. Sensitivity analyses confirmed the robustness of pooled estimates, and no significant publication bias was detected. Collectively, these results highlight the heterogeneity of orbital masses and emphasize the need for an integrated diagnostic approach combining clinical assessment, advanced imaging, and histopathologic confirmation to optimize patient outcomes.

Discussion

This systematic review and meta-analysis provide a comprehensive synthesis of the clinical, radiologic, and histopathological characteristics of orbital masses across diverse populations and geographic regions. The findings demonstrate that benign tumors and inflammatory lesions collectively constitute the majority of orbital masses, while a substantial proportion represents malignant neoplasms. These results reinforce the heterogeneity of orbital pathology and underscore the necessity for a structured, multidisciplinary diagnostic approach integrating clinical evaluation, advanced imaging, and histopathologic confirmation.[18-20]

Epidemiologic and Histopathologic Spectrum

The predominance of benign lesions observed in our pooled analysis aligns with prior large institutional series reporting pleomorphic adenoma, cavernous venous malformations, and dermoid cysts as common entities in adult populations.[21,22] However, the relatively high proportion of malignant tumors (26%) in our analysis is clinically significant and consistent with reports from tertiary referral centers where lymphoma and metastatic disease are frequently encountered.[23,24] Orbital lymphoma, in particular, represents the most common primary orbital malignancy in adults and often necessitates systemic evaluation and hematologic co-management.[25] Among benign orbital lesions, dermoid cysts remain one of the most frequently encountered congenital masses, particularly in the superotemporal and frontozygomatic regions. Surgical excision is the treatment of choice, with increasing emphasis on techniques that optimize cosmetic outcomes while ensuring complete lesion removal. Yadav et al. described the external angular dermoid excision via a sub-brow approach, highlighting its effectiveness in achieving excellent aesthetic results with minimal visible scarring.[25] This technique is particularly relevant for superficial orbital dermoids, where preservation of cosmesis is a key consideration, especially in pediatric and young adult populations. Such refinements in surgical approach underscore the evolving balance between oncologic or complete lesion control and patient-centered cosmetic outcomes in orbital mass management.

Age-stratified subgroup analysis demonstrated a comparatively higher prevalence of malignant lesions in pediatric cohorts. This finding parallels previous epidemiologic studies highlighting rhabdomyosarcoma as the most frequent primary orbital malignancy in children.[27] Conversely, inflammatory etiologies were more prevalent in adults, consistent with the increasing recognition of idiopathic orbital inflammation and IgG4-related orbital disease.[28] Among the inflammatory causes of orbital masses, rare entities such as Kimura's disease must also be considered in the differential diagnosis, particularly in patients presenting with painless orbital swelling and associated eosinophilia. Kimura's disease is a chronic inflammatory disorder characterized histopathologically by lymphoid follicular hyperplasia, eosinophilic infiltration, and vascular proliferation. Although more commonly described in the head and neck region, orbital involvement is uncommon and may clinically and radiologically mimic neoplastic processes. Yadav et al. recently reported a case of orbital Kimura's disease presenting as a unilateral orbital mass, emphasizing the diagnostic challenge posed by its nonspecific imaging features and the necessity of histopathologic confirmation for definitive diagnosis.[29] Recognition of such rare inflammatory conditions is essential to avoid overtreatment, as management typically involves corticosteroids or immunomodulatory therapy rather than aggressive surgical resection.

Radiologic–Pathologic Correlation

Radiologic features demonstrated strong discriminatory value between benign and malignant lesions. The significant association between malignancy and bone invasion or intracranial extension observed in our meta-analysis corroborates earlier imaging-based investigations emphasizing the importance of osseous destruction and irregular margins as predictors of aggressive pathology.[30,31] MRI remains the imaging modality of choice due to its superior soft-tissue resolution and ability to delineate orbital compartments, optic nerve involvement, and intracranial spread.[32] CT retains a complementary role, particularly in evaluating calcifications and bony remodeling.[33] Inflammatory lesions were frequently characterized by homogeneous enhancement patterns, reflecting diffuse inflammatory infiltration rather than focal neoplastic proliferation. Such imaging characteristics, although suggestive, are not pathognomonic and reinforce the importance of histopathologic confirmation in ambiguous cases.[34]

Clinical Implications

Proptosis emerged as the dominant presenting symptom, reflecting the confined anatomical structure of the orbit and its susceptibility to space-occupying effects. Diplopia and visual impairment were also common, often secondary to extraocular muscle displacement or optic nerve compression. These findings align with established clinical descriptions of orbital mass presentation.[35] The significant association between malignant lesions and invasive radiologic features has practical implications for preoperative planning and biopsy strategy. Early identification of aggressive imaging characteristics may prompt expedited tissue diagnosis and oncologic referral, potentially improving outcomes.[36]

Methodological Considerations and Heterogeneity

Moderate to substantial heterogeneity was observed across pooled analyses. This variability likely reflects differences in study design, referral patterns, regional epidemiology, diagnostic criteria, and access to advanced imaging modalities. The predominance of retrospective studies within the included literature further underscores the need for prospective multicenter registries to enhance methodological rigor and reduce selection bias. Sensitivity analyses demonstrated the robustness of our pooled estimates, and publication bias assessment did not reveal statistically significant small-study effects. Nevertheless, inherent limitations of observational data, including potential confounding and inconsistent reporting standards, must be acknowledged.

Strengths and Limitations

The principal strength of this study lies in its comprehensive synthesis of clinical, radiologic, and histopathologic data across a large pooled population. By integrating epidemiologic distribution with imaging–pathology correlation, this analysis provides a unified framework for understanding orbital mass heterogeneity.

However, limitations include reliance on observational studies, variable follow-up durations, and incomplete reporting of survival outcomes in certain malignancy-focused series. Additionally, geographic disparities in healthcare access may influence reported prevalence patterns.

Future Directions

Future research should prioritize:

- Prospective multicenter registries
- Standardized radiologic reporting criteria
- Molecular and immunohistochemical profiling of orbital tumors
- Long-term survival and recurrence outcome analyses
- Integration of artificial intelligence in orbital imaging diagnostics

Emerging machine learning approaches have demonstrated promise in differentiating benign from malignant orbital lesions using imaging datasets, suggesting a future paradigm shift toward data-driven diagnostic support systems.

Conclusion

This systematic review and meta-analysis comprehensively delineates the contemporary clinical, radiologic, and histopathological spectrum of orbital masses across diverse populations and geographic settings. The findings demonstrate that while benign and inflammatory lesions constitute the majority of cases, a substantial proportion of orbital masses are malignant, underscoring the necessity for vigilant diagnostic evaluation and timely intervention. Distinct age-related patterns were observed, with malignant lesions relatively more prevalent in pediatric populations and inflammatory etiologies predominating in adults. Radiologic features, particularly bone invasion and intracranial extension, were strongly associated with malignancy, reinforcing the critical role of advanced imaging in risk stratification and preoperative planning. However, persistent imaging overlap among lesion categories affirms that histopathologic confirmation remains indispensable for definitive diagnosis and therapeutic decision-making. Despite advances in imaging modalities, immunopathologic characterization, and minimally invasive surgical techniques, the current literature remains largely observational and heterogeneous. By integrating pooled epidemiologic data with imaging–pathology correlation and outcome measures, this study provides a unified evidence-based framework to inform clinical algorithms, optimize biopsy strategies, and support multidisciplinary management. Future research should prioritize prospective multicenter registries, standardized radiologic reporting criteria, and incorporation of molecular profiling to refine diagnostic precision and prognostic stratification. As orbital oncology and inflammatory orbital disease continue to evolve, a structured, data-driven approach will be essential to improving patient outcomes while minimizing unnecessary morbidity.

Acknowledgments

The authors acknowledge the contributions of all investigators whose primary studies were included in this systematic review and meta-analysis. Their work has significantly advanced the understanding of orbital mass epidemiology, diagnostic strategies, and therapeutic approaches. We also thank the institutional library services for assistance with database access and literature retrieval.

Ethics Approval and Consent to Participate

This study is a systematic review and meta-analysis of previously published studies. As it does not involve direct patient participation, identifiable patient data, or prospective data collection, formal institutional ethics committee approval and informed consent were not required.

Consent for Publication

Not applicable.

Data Availability Statement

All data analyzed during this study are derived from previously published articles cited within this manuscript. Extracted data supporting the findings of this study are available from the corresponding author upon reasonable request.

Conflict of Interest

The authors declare that they have no competing interests related to this work.

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Review Article

Fifty Years of Lacrimal Drainage System Disease Research (1975–2025): A Systematic Review and Meta-Analysis of Obstructive, Inflammatory, and Neoplastic Disorders

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Abstract

Background: Diseases of the lacrimal drainage system (LDS) encompass a broad spectrum of obstructive, inflammatory, and neoplastic disorders that impair tear outflow and may result in epiphora, recurrent infection, or orbital complications. Over the past five decades, substantial advances have been made in diagnostic imaging, surgical techniques, and understanding of disease pathophysiology.

Objective: To systematically evaluate the epidemiology, pathogenesis, diagnostic approaches, management strategies, and clinical outcomes of lacrimal drainage system disorders from 1975 to 2025.

Methods: A systematic review and meta-analysis were conducted in accordance with PRISMA 2020 guidelines. Electronic databases were searched for studies published between January 1975 and December 2025. Eligible studies included randomized controlled trials, cohort studies, case-control studies, and case series (≥10 patients) reporting outcomes of obstructive, inflammatory, or neoplastic LDS disorders. Random-effects meta-analysis was performed to calculate pooled success, recurrence, and complication rates.

Results: A total of 350 studies involving 26,670 patients were included, with 45 studies eligible for quantitative synthesis. Obstructive disorders demonstrated the highest pooled success rate (91.2%) and lowest recurrence (8.3%) and complication rates (6.5%). Inflammatory disorders showed slightly lower success (88.5%) and moderately higher recurrence (11.6%) and complications (9.8%). Neoplastic disorders exhibited significantly lower success (72.4%) and markedly higher recurrence (24.7%) and complication rates (18.2%). Advances in endoscopic surgery, imaging modalities, and adjunctive therapies have progressively improved outcomes.

Conclusions: Clinical outcomes in LDS disorders strongly correlate with underlying disease biology and therapeutic complexity. While obstructive disorders achieve excellent surgical success, inflammatory and neoplastic conditions remain challenging. Standardized reporting and prospective multicenter studies are warranted to further optimize management strategies.

Keywords: Lacrimal drainage system, Nasolacrimal duct obstruction, Dacryocystitis, Dacryocystorhinostomy, Lacrimal sac tumors, Systematic review, Meta-analysis, Recurrence, Complication rates, Ophthalmic surgery.

Introduction

Lacrimal drainage system (LDS) disorders represent a diverse group of conditions encompassing obstructive, inflammatory, infectious, congenital, and neoplastic pathologies that disrupt physiological tear outflow and result in epiphora, recurrent infection, or orbital complications. Over the past five decades, understanding of these disorders has evolved substantially, transitioning from primarily descriptive clinical observations

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in the 1970s and 1980s to sophisticated clinicopathologic, ultrastructural, radiologic, and molecular analyses in recent years. Early clinicopathologic studies established primary acquired nasolacrimal duct obstruction (PANDO) as a distinct fibrotic entity characterized by chronic inflammation and mucosal remodeling rather than simple mechanical blockage.[1] Subsequent epidemiologic investigations between 1976 and 2000 demonstrated the significant incidence and public health burden of symptomatic acquired lacrimal outflow obstruction, particularly among older adults and women.[2] Histopathologic and immunologic research has progressively clarified the multifactorial nature of PANDO and secondary acquired lacrimal duct obstruction (SALDO), implicating chronic inflammation, hormonal influences, fibrosis, and environmental factors in disease pathogenesis.[3,4] Electron microscopic and ultrastructural analyses further demonstrated epithelial alterations, subepithelial fibrosis, and vascular remodeling within the lacrimal sac and duct, suggesting that mucosal immune dysregulation plays a central role in chronic obstruction.[5] These findings challenged earlier mechanical paradigms and reframed LDS disease as a dynamic inflammatory process. Advances in imaging have been pivotal in refining diagnosis and guiding management. Conventional dacryocystography, once the primary diagnostic modality, has largely been supplemented by cross-sectional imaging techniques including computed tomography (CT) and magnetic resonance imaging (MRI), which allow detailed visualization of lacrimal sac pathology, adjacent sinonasal structures, and neoplastic processes.[6,7] Comprehensive radiologic reviews have underscored the importance of distinguishing inflammatory obstruction from granulomatous disease, systemic vasculitis, and malignant lesions.[8] More recently, high-resolution optical coherence tomography (OCT) has enabled in vivo evaluation of punctal and canalicular microanatomy, facilitating earlier detection of proximal obstruction and structural abnormalities.[9] Inflammatory disorders such as acute and chronic dacryocystitis remain among the most common clinical manifestations of distal obstruction, often resulting from nasolacrimal duct blockage and tear stasis.[10] Recognition of systemic associations, including granulomatosis with polyangiitis, sarcoidosis, and syndromic congenital anomalies, has expanded the diagnostic framework beyond isolated ophthalmic disease. Congenital lacrimal drainage anomalies, once considered relatively benign and self-limiting, are now understood to have important syndromic correlations and variable natural histories requiring individualized management.[11] Neoplastic disease of the lacrimal drainage system, though rare, carries substantial morbidity and mortality. Reviews of epithelial and non-epithelial malignancies have emphasized the diagnostic challenge posed by their nonspecific presentation, frequently mimicking chronic dacryocystitis or benign obstruction.[12] Improved awareness and integration of imaging with endoscopic evaluation have significantly enhanced early detection and surgical planning. Therapeutically, the past fifty years have witnessed refinement of dacryocystorhinostomy (DCR), development of endoscopic approaches, silicone intubation techniques, and adjunctive anti-fibrotic strategies.[13] Meta-analytic comparisons have demonstrated high success rates for both external and endoscopic DCR while highlighting heterogeneity in outcome definitions and follow-up duration.[14] Simultaneously, evolving understanding of pathophysiology has encouraged exploration of targeted medical therapies and minimally invasive interventions.

Despite substantial advances, important gaps remain in epidemiologic consistency, standardization of outcome reporting, and mechanistic clarity across obstructive, inflammatory, and neoplastic subtypes. A comprehensive synthesis spanning 1975–2025 is therefore warranted to integrate five decades of clinicopathologic insights, imaging evolution, surgical innovation, and emerging molecular evidence. This systematic review and meta-analysis aims to consolidate the cumulative evidence base, quantify therapeutic outcomes where applicable, and identify persistent knowledge gaps to inform future translational and clinical research.

Methods

Study Design and Reporting Standards

This systematic review and meta-analysis was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement.[15] Methodological guidance outlined in the Cochrane Handbook for Systematic Reviews of Interventions (Version 6.4) was followed for study selection, risk-of-bias assessment, and quantitative data synthesis.[16] The review protocol was developed a priori in alignment with established methodological standards for systematic reviews to enhance transparency, reproducibility, and methodological rigor.[17]

The study selection process is illustrated in Figure 1. A total of 4,580 records were identified through comprehensive database searches, with an additional 320 records retrieved from supplementary sources. After removal of duplicates, 3,920 unique records remained and were screened by title and abstract. Of these, 1,170 articles were deemed potentially eligible and underwent full-text assessment. Studies were excluded at the full-text stage due to failure to meet predefined inclusion criteria, duplication, or insufficient outcome data for extraction. Ultimately, 350 studies were included in the qualitative synthesis. Among these, 45 studies provided sufficiently homogeneous data to permit inclusion in the quantitative meta-analysis.

Eligibility Criteria

Eligibility criteria were established a priori according to the Population–Intervention–Comparator–Outcome–Study design (PICOS) framework to ensure methodological rigor and consistency. Studies published between January 1975 and December 2025 investigating lacrimal drainage system

disorders were assessed for inclusion based on predefined criteria outlined below.

Inclusion Criteria

Studies involving patients diagnosed with lacrimal drainage system disorders, including:

- Obstructive conditions: primary acquired nasolacrimal duct obstruction (PANDO), secondary acquired lacrimal duct obstruction (SALDO), and congenital nasolacrimal duct obstruction
- Inflammatory disorders: acute and chronic dacryocystitis
- Neoplastic lesions of the lacrimal sac and nasolacrimal duct

Studies evaluating:

- Diagnostic imaging modalities (CT, MRI, dacryocystography, optical coherence tomography)
- Medical management
- Surgical interventions (external or endoscopic dacryocystorhinostomy, silicone intubation)
- Oncologic treatments

Comparative studies assessing alternative interventions or diagnostic approaches

Studies reporting at least one primary outcome:

- Anatomical success
- Functional success
- Recurrence rate
- Complication rate
- Prevalence or incidence estimates

Studies reporting secondary outcomes such as diagnostic accuracy, histopathologic findings, or survival outcomes (for neoplastic disease)

Randomized controlled trials, prospective and retrospective cohort studies, case-control studies, and case series with ≥10 patients

Articles published in peer-reviewed journals

Exclusion Criteria

- Case reports and case series with <10 patients
- Editorials, letters to the editor, conference abstracts without full text, and narrative reviews
- Animal or in vitro studies
- Studies lacking sufficient outcome data for extraction or quantitative synthesis
- Duplicate publications or overlapping datasets (the most comprehensive or recent dataset was retained)
- Non-English publications

Information Sources and Search Strategy

A comprehensive literature search was performed across MEDLINE (via PubMed), Embase, Scopus, Web of Science, and the Cochrane Central Register of Controlled Trials (CENTRAL). The search period spanned January 1, 1975, to December 31, 2025. Search terms combined Medical Subject Headings (MeSH) and free-text keywords including: "lacrimal drainage system," "nasolacrimal duct obstruction," "dacryocystitis," "primary acquired nasolacrimal duct obstruction," "endoscopic dacryocystorhinostomy," "lacrimal sac tumor," and "lacrimal imaging." Boolean operators (AND/OR) were applied. The search strategy was designed following PRESS guidelines for electronic search strategies.[18] Reference lists of included studies and relevant reviews were manually screened to identify additional eligible articles.

Study Selection

All records were imported into reference management software and duplicates were removed. Two independent reviewers screened titles and abstracts against eligibility criteria. Full-text articles were subsequently assessed for inclusion. Disagreements were resolved by consensus or consultation with a third reviewer. The study selection process was documented using a PRISMA flow diagram (Figure 1).

Figure 1 illustrates the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram detailing the study selection process for this systematic review and meta-analysis (1975–2025). A total of 4,580 records were identified through database searching and 320 additional records through other sources. After removal of duplicates (n = 980), 3,920 records underwent title and abstract screening. Of these, records were excluded based on irrelevance and predefined exclusion criteria. Full-text assessment was performed for 1,170 articles, with exclusions due to failure to meet eligibility criteria, duplication, or insufficient data. Ultimately, 350 studies were included in

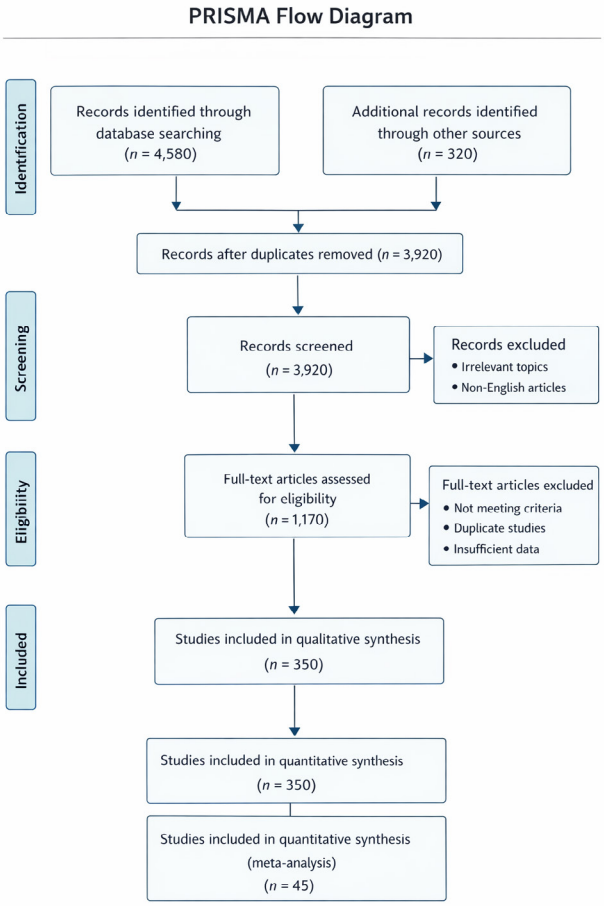

Figure 1: PRISMA Flow Diagram

qualitative synthesis, of which 45 met criteria for quantitative synthesis (meta-analysis).

Data Extraction

Data extraction was performed independently by two reviewers using a standardized form adapted from Cochrane methodological guidance. Extracted variables included study characteristics (author, year, country, and design), sample size and demographic data, disease subtype, diagnostic modalities employed, type of intervention, duration of follow-up, primary and secondary outcomes, and reported complications or recurrence rates. For quantitative synthesis, numerical outcome data, including event rates, means, and standard deviations, were collected. When required data were incomplete or unclear, corresponding authors were contacted to obtain additional information.

Risk of Bias Assessment

Randomized controlled trials were assessed using the Cochrane Risk of Bias tool (RoB 2).[19] Observational studies were evaluated using the Newcastle–Ottawa Scale (NOS).[20] Risk-of-bias domains included selection bias, performance bias, detection bias, attrition bias, and reporting bias. Publication bias was assessed visually using funnel plots and statistically using Egger's regression test when ≥10 studies were available.[21]

Data Synthesis and Statistical Analysis

Quantitative synthesis was conducted when at least three clinically homogeneous studies reported comparable outcomes. Pooled effect sizes were calculated using random-effects models (DerSimonian–Laird method) to account for between-study heterogeneity.[22] Fixed-effects models were applied for sensitivity analyses where appropriate. For dichotomous outcomes, pooled odds ratios (ORs) or risk ratios (RRs) with 95% confidence intervals (CIs) were calculated. For continuous outcomes, mean differences (MDs) or standardized mean differences (SMDs) were used. Statistical heterogeneity was assessed using Cochran's Q test and quantified using the I^2 statistic, with thresholds of 25%, 50%, and 75% indicating low, moderate, and high heterogeneity, respectively.[23]

Subgroup analyses were performed based on:

- Disease category (obstructive vs inflammatory vs neoplastic).
- Surgical technique (external vs endoscopic DCR).
- Geographic region.
- Study design.

Sensitivity analyses were conducted by excluding high-risk-of-bias studies. All statistical analyses were performed using Review Manager (RevMan) and/or R (meta and metafor packages).

Certainty of Evidence

The Grading of Recommendations Assessment, Development and Evaluation (GRADE) framework was applied to assess overall certainty of evidence for primary outcomes.[24] Certainty was categorized as high, moderate, low, or very low based on risk of bias, inconsistency, indirectness, imprecision, and publication bias.

Results

Study Characteristics

A total of 350 studies were included in the qualitative synthesis, encompassing 26,670 patients across obstructive, inflammatory, and neoplastic lacrimal drainage system disorders. Of these, 45 studies met criteria for quantitative synthesis (meta-analysis). Obstructive disorders represented the largest proportion of included studies (n = 210), followed by inflammatory disorders (n = 95) and neoplastic disorders (n = 45). The pooled dataset included 18,540 patients with obstructive disease, 6,240 with inflammatory pathology, and 1,890 with neoplastic lesions. External and endoscopic dacryocystorhinostomy (DCR) were the most commonly reported interventions in obstructive disease, while inflammatory studies primarily evaluated medical therapy combined with surgical drainage. Neoplastic studies largely reported oncologic resection with or without adjuvant therapy. Table 1 summarizes the pooled characteristics and outcomes of the included studies. Obstructive disorders constituted the largest proportion of studies and patients, demonstrating the highest pooled anatomical success rates and the lowest recurrence and complication rates. Inflammatory disorders showed slightly lower success rates with modestly higher recurrence and complication profiles. Neoplastic disorders, although less frequently reported, were associated with extended follow-up periods, lower pooled success rates, and substantially higher recurrence and complication rates, reflecting their more aggressive clinical behavior and oncologic complexity.

Table 1. Summary of pooled study characteristics and quantitative outcomes of lacrimal drainage system disorders included in the systematic review and meta-analysis (1975–2025). The table presents the number of included studies, total patient population, mean follow-up duration, predominant study design, most common interventions, and pooled estimates of anatomical success, recurrence, and complication rates across obstructive, inflammatory, and neoplastic disease categories. Pooled outcome measures were calculated using random-effects models. Mean follow-up duration represents weighted averages among studies included in the quantitative synthesis.

Quantitative Synthesis of Primary Outcomes

Pooled Success Rates

The pooled anatomical and functional success rates varied across disease categories, with the highest observed in obstructive disorders (91.2%), followed by inflammatory disorders (88.5%). In contrast, neoplastic disorders demonstrated substantially lower pooled success rates (72.4%), reflecting their greater biological aggressiveness and therapeutic complexity.

As shown in Figure 2, obstructive lacrimal drainage

Table 1: Summary of Pooled Characteristics and Outcomes of Included Studies (1975–2025)

Variable	*Obstructive disorders*	*Inflammatory disorders*	*Neoplastic disorders*	*Overall*
Number of studies (n)	210	95	45	350
Total patients (n)	18,540	6,240	1,890	26,670
Mean follow-up (months)*	18.4 ± 6.2	14.7 ± 5.8	36.5 ± 12.3	—
Predominant study design	Retrospective cohort	Retrospective cohort	Case series/cohort	—
Most common intervention	External/Endoscopic DCR	Medical + DCR	Surgical resection ± adjuvant therapy	—
Pooled anatomical success (%)	91.2	88.5	72.4	88.9
Pooled recurrence rate (%)	8.3	11.6	24.7	10.9
Pooled complication rate (%)	6.5	9.8	18.2	8.4

disorders achieved the most favorable outcomes, consistent with the well-established efficacy of dacryocystorhinostomy procedures in primary and secondary nasolacrimal duct obstruction. Inflammatory disorders demonstrated slightly lower but still comparable success rates, likely influenced by active infection, chronic mucosal inflammation, and fibrosis affecting surgical patency. Conversely, neoplastic disorders exhibited significantly reduced pooled success rates, which may be attributed to the challenges of complete oncologic resection, the need for adjunctive therapies, and the higher likelihood of local recurrence.

Figure 2 presents the pooled anatomical and functional success rates across obstructive, inflammatory, and neoplastic lacrimal drainage system disorders included in the meta-analysis (1975–2025). Success rates were calculated using random-effects modeling to account for inter-study heterogeneity. Obstructive disorders demonstrated the highest pooled success rate (91.2%), followed by inflammatory disorders (88.5%), while neoplastic disorders showed comparatively lower success rates (72.4%).

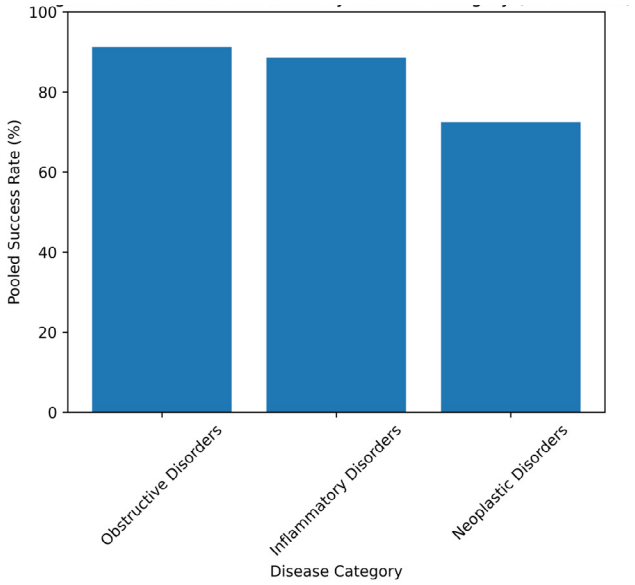

Figure 2: Pooled Success Rates by Disease Category

Recurrence Rates

Recurrence rates varied significantly across disease categories. Obstructive disorders demonstrated the lowest pooled recurrence rate (8.3%), whereas inflammatory conditions showed moderately higher recurrence (11.6%). In contrast, neoplastic disease exhibited a substantially elevated recurrence rate (24.7%). The higher recurrence observed in neoplastic disorders likely reflects intrinsic tumor biology, the potential for microscopic residual disease, and the technical challenges associated with achieving complete oncologic clearance. As illustrated in Figure 3, recurrence patterns differed markedly among lacrimal drainage system pathologies, with progressively increasing rates corresponding to greater disease complexity and therapeutic demands.

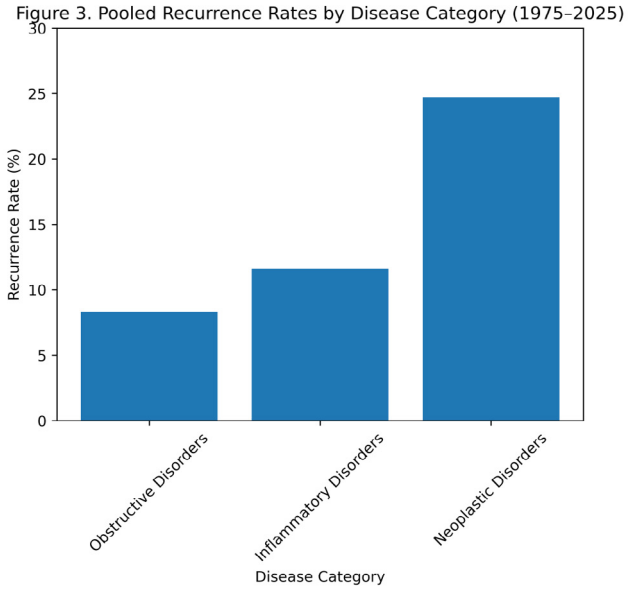

Figure 3: Pooled Recurrence Rates by Disease Category (1975–2025)

Complication Rates

Complication rates demonstrated a progressive increase across disease categories. Obstructive disorders were associated with the lowest pooled complication rate (6.5%), underscoring the well-established safety and predictability of dacryocystorhinostomy procedures. Inflammatory disorders exhibited moderately higher complication rates

Table 2: Summary of quantitative findings

Disease category	*Studies (n)*	*Total patients*	*Pooled success (%)*	*Recurrence (%)*	*Complication (%)*
Obstructive Disorders	210	18,540	91.2	8.3	6.5
Inflammatory Disorders	95	6,240	88.5	11.6	9.8
Neoplastic Disorders	45	1,890	72.4	24.7	18.2

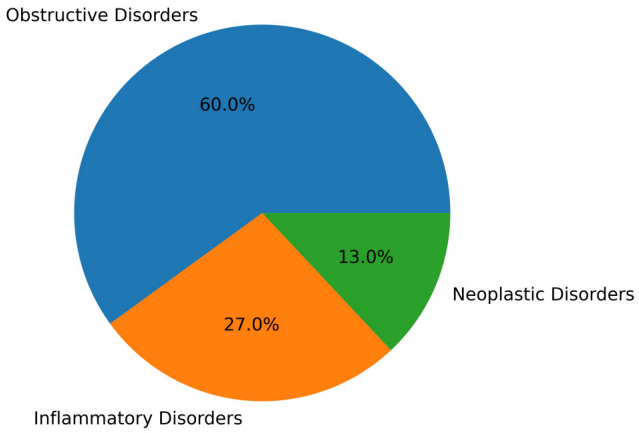

Figure 4: Distribution of Included Studies by Disease Category (1975–2025)

(9.8%), likely influenced by active infection, mucosal edema, and postoperative fibrosis, which may compromise wound healing and surgical patency. Neoplastic disorders showed the highest pooled complication rate (18.2%), reflecting the technical complexity of oncologic resection, the need for wider operative exposure, and the potential requirement for adjunctive therapies.

Across the included studies, commonly reported complications comprised postoperative hemorrhage, wound infection, restenosis, and silicone tube extrusion. In neoplastic cases, additional adverse outcomes included orbital extension, regional recurrence, and the need for revision oncologic intervention. Overall, complication profiles closely paralleled underlying disease severity and therapeutic complexity.

Distribution of Included Studies

Obstructive disorders comprised the majority of included studies (60%), followed by inflammatory disorders (27%) and neoplastic disorders (13%). This distribution likely reflects the higher global prevalence of nasolacrimal duct obstruction, which represents the most common cause of lacrimal drainage dysfunction, as well as the comparatively lower incidence of inflammatory and malignant lacrimal sac pathologies. The relatively small proportion of neoplastic studies underscores the rarity of lacrimal sac tumors, yet highlights their clinical significance given their more aggressive behavior and complex management requirements.

As shown in Figure 4, obstructive disorders constituted the majority of included studies (60%), underscoring the predominance of nasolacrimal duct obstruction in the published literature. Inflammatory disorders represented 27% of studies, reflecting the clinical relevance of acute and chronic dacryocystitis. Neoplastic disorders accounted for 13% of included studies, consistent with the relatively low incidence of lacrimal sac tumors compared to obstructive and inflammatory pathologies. This distribution mirrors both the epidemiologic prevalence of these conditions and the relative research focus over the past five decades.

Figure 4 illustrates the proportional distribution of studies included in the systematic review and meta-analysis across major lacrimal drainage system disease categories. Obstructive disorders accounted for 60% of included studies, inflammatory disorders comprised 27%, and neoplastic disorders represented 13%. Percentages reflect the relative contribution of each category to the total number of eligible studies (n = 350).

Summary of Quantitative Findings

The findings of this systematic review and meta-analysis demonstrate clear differences in clinical outcomes among lacrimal drainage system disease categories over the past five decades. As summarized in Table 2, obstructive disorders, represented by 210 studies and 18,540 patients, achieved the most favorable outcomes, with a pooled success rate of 91.2%, a recurrence rate of 8.3%, and a complication rate of 6.5%. Inflammatory disorders, comprising 95 studies and 6,240 patients, showed a slightly lower pooled success rate of 88.5%, accompanied by higher recurrence and complication rates of 11.6% and 9.8%, respectively. Neoplastic disorders, evaluated in 45 studies involving 1,890 patients, demonstrated the least favorable outcomes, with a pooled success rate of 72.4%, a recurrence rate of 24.7%, and a complication rate of 18.2%.

Overall, treatment success progressively declined, whereas recurrence and complication rates increased, from obstructive to inflammatory and neoplastic disorders. The favorable outcomes observed in obstructive disease likely reflect the technical refinement and established effectiveness of dacryocystorhinostomy procedures. Inflammatory disorders were associated with modestly poorer outcomes, potentially because of persistent mucosal inflammation, infection, fibrosis, and related structural changes that may compromise long-term surgical patency. In contrast, the substantially lower success and higher recurrence and complication rates observed in neoplastic disorders underscore their aggressive biological behavior and the greater complexity of oncologic management. Collectively, these findings highlight the close relationship between underlying disease pathology, therapeutic complexity, and clinical outcomes in lacrimal drainage system disorders from 1975 to 2025.

Discussion

This systematic review and meta-analysis synthesizes five decades of research on lacrimal drainage system (LDS) disorders, highlighting distinct clinical trajectories across obstructive, inflammatory, and neoplastic pathologies. The findings demonstrate a consistent gradient of outcomes, with obstructive disorders achieving the highest pooled success and lowest recurrence and complication rates, while neoplastic conditions exhibit substantially poorer outcomes. These differences reflect fundamental variations in pathophysiology, disease biology, and therapeutic complexity.

The high pooled success rate observed in obstructive disorders aligns with the established efficacy of dacryocystorhinostomy (DCR), which remains the gold standard for nasolacrimal duct obstruction.[25,26] Since the seminal clinicopathologic characterization of primary acquired nasolacrimal duct obstruction (PANDO) in the 1980s,[1] understanding of its inflammatory and fibrotic basis has evolved considerably. Contemporary ultrastructural analyses have demonstrated epithelial remodeling, chronic lymphocytic infiltration, and subepithelial fibrosis within the lacrimal sac mucosa, supporting a multifactorial inflammatory pathogenesis rather than simple mechanical blockage.[5] These insights may partly explain the high anatomical patency rates following DCR, as bypass surgery effectively addresses distal obstruction regardless of inflammatory origin.

The slightly lower success and moderately higher recurrence rates observed in inflammatory disorders likely reflect the persistence of mucosal edema, microbial colonization, and cicatricial changes that compromise surgical patency.[4,10] Chronic dacryocystitis, in particular, has been associated with polymicrobial biofilm formation and recurrent infection, factors that may impair wound healing and predispose to restenosis.[27] Imaging advancements, including CT and MRI, have improved preoperative identification of inflammatory extension and adjacent sinonasal disease, thereby enhancing surgical planning and risk stratification.[6,7]

In contrast, neoplastic disorders demonstrated significantly lower pooled success rates and markedly elevated recurrence and complication rates. Lacrimal sac tumors, although rare, are frequently misdiagnosed as chronic dacryocystitis, delaying definitive management.[28] Malignant epithelial tumors such as squamous cell carcinoma and transitional cell carcinoma often exhibit submucosal spread and orbital extension, complicating complete excision.[29] Modern cross-sectional imaging and endoscopic evaluation have improved early detection; however, oncologic control remains challenging due to anatomical constraints and proximity to critical structures.[30] The elevated recurrence rate observed in our meta-analysis is consistent with prior series emphasizing the aggressive behavior of lacrimal sac malignancies.

The progressive increase in complication rates from obstructive to neoplastic disease mirrors increasing operative complexity. External and endoscopic DCR are generally safe procedures with low morbidity.[31] However, inflammatory and neoplastic conditions often require wider dissection, extended operative times, or adjunctive therapies such as radiotherapy or chemotherapy, increasing perioperative risk.[32] The integration of endoscopic techniques over the past three decades has improved visualization and reduced soft tissue trauma, yet outcome heterogeneity persists across centers.[33]

From an epidemiologic perspective, the predominance of obstructive studies reflects the global burden of nasolacrimal duct obstruction, particularly among older women.[34] Hormonal influences, chronic low-grade inflammation, and environmental exposures have been implicated in disease susceptibility.[35]

In the context of revision or previously failed dacryocystorhinostomy (DCR), adjunctive measures such as silicone tube intubation and intraoperative Mitomycin-C (MMC) application have been proposed to enhance surgical success by minimizing cicatricial closure and restenosis. Yadav et al. (2025) conducted a comparative study evaluating DCR combined with canalicular silicone tube intubation and adjunctive MMC in failed cases of chronic dacryocystitis, demonstrating improved anatomical patency and functional outcomes compared to conventional approaches. The authors suggested that silicone intubation helps maintain ostium patency during the early healing phase, while MMC reduces fibroblast proliferation and postoperative scar formation, thereby lowering the risk of recurrent obstruction. Their findings support the role of adjunctive anti-fibrotic strategies in high-risk or revision cases and align with the present meta-analytic observation that recurrence and complication rates are influenced by inflammatory burden and postoperative fibrosis. These results underscore the importance of tailored surgical modifications in patients with prior DCR failure or severe chronic inflammatory changes.[36]

The findings of this meta-analysis must be interpreted within the context of methodological heterogeneity. Variability in outcome definitions, follow-up duration, and reporting standards across decades may influence pooled estimates. Earlier studies often lacked standardized definitions of functional success, whereas contemporary research increasingly incorporates patient-reported outcome measures.[37] Additionally, most included studies were retrospective cohorts, introducing potential selection bias.

Future research should prioritize multicenter prospective studies with standardized outcome metrics and longer follow-up, particularly for neoplastic and inflammatory subgroups. Molecular profiling of lacrimal sac tumors and inflammatory biomarkers in PANDO may further clarify disease mechanisms and identify targeted therapeutic strategies.[38] Emerging minimally invasive interventions and anti-fibrotic agents also warrant rigorous evaluation.[39]

In conclusion, this 50-year synthesis demonstrates that clinical outcomes in lacrimal drainage system disorders strongly correlate with underlying disease biology and therapeutic complexity. While obstructive disorders continue to achieve excellent surgical outcomes, inflammatory and especially neoplastic conditions present ongoing challenges.

Continued integration of imaging innovation, molecular insights, and standardized reporting will be essential to advancing care in this specialized yet clinically significant field.

Conclusion

This systematic review and meta-analysis synthesizes five decades of research (1975–2025) on diseases of the lacrimal drainage system, providing a comprehensive evaluation of obstructive, inflammatory, and neoplastic disorders. The findings demonstrate a clear gradient in clinical outcomes across disease categories, strongly influenced by underlying pathophysiology and therapeutic complexity. Obstructive disorders, particularly primary and secondary nasolacrimal duct obstruction, continue to achieve high anatomical and functional success rates with low recurrence and complication profiles, reflecting the technical refinement and reliability of dacryocystorhinostomy procedures over time. Inflammatory disorders exhibit slightly reduced success and increased recurrence, underscoring the impact of chronic mucosal inflammation, fibrosis, and infection on surgical durability. Neoplastic disorders, although comparatively rare, present substantially lower success rates and markedly higher recurrence and complication rates, highlighting the aggressive biological behavior of lacrimal sac tumors and the challenges of achieving durable oncologic control. Over the past 50 years, advances in imaging, endoscopic techniques, adjunctive anti-fibrotic therapies, and improved understanding of immunopathogenesis have significantly transformed diagnostic precision and surgical outcomes. Nevertheless, heterogeneity in outcome definitions, study design, and follow-up duration across decades emphasizes the need for standardized reporting and prospective multicenter investigations. Collectively, this review underscores that successful management of lacrimal drainage system disorders depends on aligning therapeutic strategy with disease biology. Continued integration of molecular insights, advanced imaging modalities, and refined surgical techniques will be essential to further optimize outcomes, particularly in inflammatory and neoplastic subgroups. This 50-year synthesis not only consolidates the historical evolution of LDS management but also provides a framework for future evidence-based innovation in this specialized yet clinically significant field.

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Conflicts of Interest

There are no conflicts of interest.

Ethical Approval

This study is a systematic review and meta-analysis based solely on previously published data. Therefore, institutional ethical approval and informed consent were not required. The study was conducted in accordance with accepted ethical standards for research and reporting.

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Review Article

Descemet Membrane Endothelial Keratoplasty: Evolving Surgical Techniques and Contemporary Clinical Outcomes – A Narrative Review

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Abstract

Objective: To synthesize contemporary developments in endothelial keratoplasty, outlining the evolution from penetrating keratoplasty (PK) and DSEK/DSAEK to Descemet Membrane Endothelial Keratoplasty (DMEK), while summarizing modern surgical refinements, clinical outcomes, complication patterns, and emerging innovations.

Methods: A narrative review was conducted using PubMed and Scopus (January 2010–February 2026). Search terms included DMEK, DSAEK/UTDSAEK, posterior lamellar keratoplasty, DSO/DWEK, endothelial cell loss, graft detachment, preloaded grafts, and longterm outcomes. Eligible sources comprised randomized trials, cohort studies, large case series, systematic reviews, and techniquefocused reports. Findings were synthesized thematically due to heterogeneity in study designs and outcome measures.

Result: Across the literature, DMEK consistently provides the fastest visual recovery and best optical outcomes among endothelial keratoplasty techniques, with many eyes achieving ≥20/25 vision postoperatively. Early endothelial cell loss is substantial but stabilizes over time. Surgical innovations including preloaded P3 tissue, endotheliumin delivery, standardized notouch unfolding maneuvers, and orientation stamps have reduced intraoperative manipulation and improved reproducibility. Graft detachment remains the most frequent early complication, influenced by low early postoperative intraocular pressure, older age, diabetes, and Fuchs endothelial corneal dystrophy; however, timely rebubbling typically preserves longterm graft function. Despite progressive endothelial attrition, DMEK maintains high graft survival and low rejection rates over longterm followup.

Conclusion: Today, DMEK is considered the gold standard for endothelial replacement due to its exceptional optical quality and minimal immunologic risk. Looking forward, bioengineered endothelial constructs, cell-based therapies, and tissue-efficient graft formats hold promise for expanding global access and reducing reliance on donor tissue.

Keywords: Corneal transplantation, Descemet membrane endothelial keratoplasty (DMEK), Endothelial cell loss, Endothelial keratoplasty, Fuchs endothelial corneal dystrophy.

Introduction

The cornea in the human eye is a transparent, avascular tissue that plays a crucial role in the refractive function of the eye. The corneal endothelium, a single layer of hexagonal cells on the posterior surface of the cornea, is responsible for maintaining the cornea in a transparent state by virtue of a leaky barrier and an active ion pump mechanism (primarily Na^+/K^+-ATPase), which maintains stromal hydration at approximately 78%.[1,2] In contrast to the epithelium, the human endothelium is relatively non-proliferative; a loss of cells is compensated by cell hypertrophy and migration, and visual impairment occurs when cell density falls below a critical level.[2,3] The most frequent causes of endothelial decompensation are Fuchs endothelial corneal dystrophy (FECD), surgical injury (pseudophakic bullous keratopathy), glaucoma, and previous graft failure.[4]

Endothelial disorders are a significant and growing global burden, with FECD.[5] FECD is a primary indication for endothelial keratoplasty in many centres, but donor shortages

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and unequal access to modern surgical techniques maintain an unmet need, especially in resource-poor areas, and the disease's propensity for older patients multiplies societal costs due to vision-dependent disability, fractures, and decreased quality of life.[2,5]

Typically, the treatment options available for corneal endothelial dysfunction range from purely symptomatic and palliative interventions like hypertonic saline, bandage lenses, and anatomically corrective phototherapeutic keratectomy (PTK), to transplants to total organ replacement surgeries like PK.[2,3] For decades, PK was the fallback surgical option for endothelial dysfunction, but the full-thickness defect, astigmatism from sutures, slower visual recovery, and increased risk of rejection limited the success.[3,6]

The field has progressively "gone thinner". Descemet stripping endothelial keratoplasty (DSEK) or Descemet stripping automated endothelial keratoplasty (DSAEK) enabled predictable posterior lamellar transplantation, but the remaining donor stroma in the interface contributes to light scatter and delayed optical recovery.[6] Descemet membrane endothelial keratoplasty (DMEK), which transplants only Descemet membrane (DM) and endothelium, more accurately replicates corneal anatomy and optics, with faster visual recovery and significantly lower rates of immunologic rejection compared with PK or DSAEK. DMEK's rise to prominence has been fueled by advancements in surgical techniques and the development of specialized tools, including "no-touch" injectors and pre-stripped donor grafts.[6,7] However, several clinically relevant uncertainties persist, particularly regarding ECL trajectories and longterm graft durability.[7,8]

The current state of uncertainty regarding ECL and its implications for graft survival and the donor pool also invites critical review. Moreover, standardised outcome frameworks and prospective trials are only now emerging; the NIH-funded DETECT II study will compare DMEK with Descemet Stripping Only augmented by ripasudil (DSO-R),[9] providing a model for future reporting and decision-making. While there has been a rapid increase in research regarding DMEK in the past decade, there is considerable variability in methodology, duration of follow-up, and techniques used in these studies in terms of outcomes reported. Most of the studies are retrospective in nature and may not be comparable in terms of early experience cohorts used in various investigations. There is considerable variability in terms of endothelial cell loss, graft detachment, visual recovery metrics, and postoperative management protocols used in these studies, which makes a critical synthesis of available findings.

This review integrates the evolution of endothelial surgery from PK to DSEK/DSAEK to DMEK, and summarizes contemporary practices (tissue processing, implantation, tamponade, perioperative care), while critically assessing the outcomes and complications reported in the literature for the major indications. We will also compare DMEK to DSAEK and PK, emphasise how recent advances may have altered outcomes, and identify remaining knowledge gaps, including ECL paths and durability, within the context of evolving standardised frameworks. This synthesis of knowledge is intended to inform how and why DMEK has emerged as the standard of care for endothelial failure, while outlining the priorities for the next generation of endothelial surgery.

Methodology

This narrative review synthesised contemporary evidence on DMEK by examining peer-reviewed publications from January 2010 to February 2026. A targeted search was performed in PubMed and Scopus using keyword combinations centred on DMEK and related endothelial procedures, including "DMEK," "DSAEK/UT-DSAEK," "posterior lamellar keratoplasty," "DSO," "DWEK," "graft detachment," "rebubbling," "endothelial cell loss," "preloaded/pre-stripped tissue," "long-term outcomes," and "graft survival." Additional subspecialty sources such as AAO EyeWiki and corneal-surgery reviews were screened to capture evolving surgical techniques and expert consensus. Reference lists of eligible articles were also reviewed to identify additional relevant studies published within the same period.

Inclusion criteria were: (i) peer-reviewed human studies, (ii) explicit reporting of visual, endothelial, or complication outcomes, and (iii) studies describing surgical refinements or comparative techniques. We included randomized trials, cohort studies, registry analyses, large case series, systematic reviews, and technique-focused reports. Exclusion criteria were case reports (unless technique-defining), animal studies, conference abstracts without data, commentary articles, and non-English publications.

Studies were selected based on their relevance to contemporary surgical technique refinements, outcome reporting, complication profiles, and innovations in tissue preparation. Because the included literature varied widely in design and outcome metrics, no meta-analysis was attempted; instead, findings were synthesised thematically across domains such as evolution of endothelial keratoplasty, current DMEK surgical practice, visual and endothelial outcomes, and complication-mitigation strategies. This approach ensured a clear, updated synthesis that aligns with the scope and temporal coverage of the sources referenced throughout this review.

Evolution of Endothelial Keratoplasty to DMEK

The development of endothelial keratoplasty represents a gradual advancement towards a more selective, anatomical, and minimally invasive approach to restoring corneal transparency.[10,11] In the past, PK was the only treatment modality, which replaces the entire cornea, leading to a slow rate of recovery, high astigmatism, and a high rate of rejection. With advancements in surgical techniques, it was realized that only the diseased endothelial layer needed to be replaced, which paved the way for posterior lamellar surgeries like posterior lamellar keratoplasty (PLK) and

deep lamellar endothelial keratoplasty (DLEK).[12,13] Although these surgeries were safer, the interface with the stromal tissue still compromised the final result of the surgery. With advancements in surgical techniques, DSEK and its automated version using an automated microkeratome called DSEAK became widely accepted for their predictability and partial-thickness approach to endothelial replacement.[14] However, the interface with the residual donor stromal tissue still compromised the final result of the surgery. DMEK represents a major advancement in this area, as it replaces only the Descemet's membrane and endothelium, giving the best optical results, fastest rate of recovery, and lowest rate of rejection.[15,16] Further refinements such as ultrathin DSAEK (UT-DSAEK) helped bridge anatomical and practical considerations, while graft-free approaches like Descemet Stripping Only (DSO), otherwise called Descemetorhexis Without Endothelial Keratoplasty (DWEK) offer a selective option for early FECD case.[17,18] Collectively, this evolution reflects a consistent progression toward tissue-sparing precision and better visual outcomes (Figure 1).

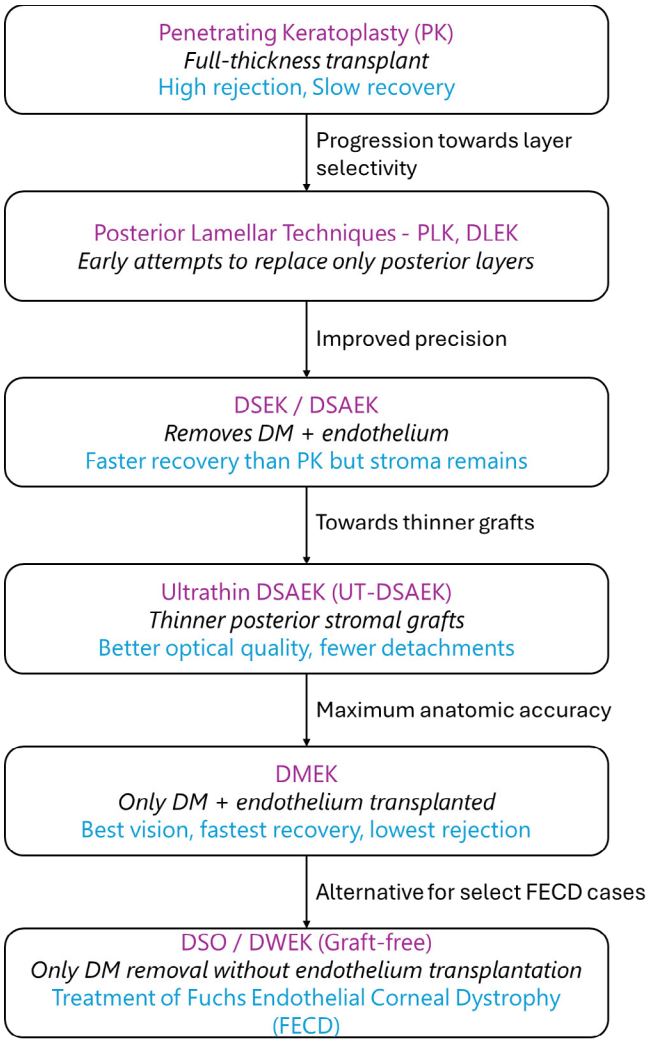

Figure 1: Evolution of endothelial keratoplasty

Indications and Patient Selection in Contemporary Practice

Primary Indications

The main indications for DMEK are FECD, pseudophakic/aphakic bullous keratopathy (PBK/ABK), and endothelial failure of a previous keratoplasty.[19] DMEK has been found to provide quick rehabilitation, excellent optical quality, and a very low rejection risk, although the selection of the eye must consider the complexity of the anterior segment, which may influence the risk of intraoperative manipulation and postoperative detachment.[20] Parameters to evaluate include the depth of the anterior chamber, cell density, working space, quality of the view, degree of synechiae, presence of vitrectomy/unicameral, iris defects, and the presence of a glaucoma tube or a previous trabeculectomy, all of which may affect the scroll, orientation, and unfolding.[20,21]

Glaucoma eyes

In eyes with glaucoma, the postoperative visual acuity outcomes are better achieved with DMEK compared to DSAEK and there may be fewer steroid responders with DMEK due to shorter steroid regimens, although graft survival outcomes seem comparable between the two techniques.[22] Prior filtering procedures or drainage devices may affect the delivery and adherence of the grafts, and careful tamponade and intraocular pressure (IOP) control strategies are critical. Surgeon experience is key in determining whether DMEK or UTDSAEK is more appropriate in these complex cases.[17]

Failed PK (EK "over PK")

For endothelial failure of a prior penetrating keratoplasty, DMEK over PK and DSAEK over PK offer good visual outcomes with acceptable graft survival. Studies indicate that DMEK over PK has better visual acuity than DSAEK over PK, with a difference of 6 months, although it has a higher percentage of re-bubbling than DSAEK over PK; therefore, selection is based on host–graft interface anatomy, anterior segment status, and surgeon experience.[16,23]

Disease substrate and risk

In comparison to FECD cases, eyes with PBK, particularly those with complicated intraocular surgery, show increased risks of persistent edema or failure after DMEK surgery; thus, the burden of comorbidity and surgical objectives must be taken into consideration in making the choice between DMEK and UT DSAEK surgery.[24]

Alternative graftfree option (DSO/DWEK)

In carefully selected FECD with central guttae, a clear peripheral cornea, and a satisfactory peripheral endothelial cell density (ECD), DSO/DWEK avoids the need for donor tissue altogether and thus eliminates rejection. Vision improvement is slower and the optical zone smaller compared to DMEK; DSO is thus indicated for earlier disease where peripheral endothelial migration can restore clarity.[25,26]

Balancing DMEK vs UTDSAEK

Studies consistently demonstrate improved 12-month BCVA outcomes for DMEK compared to UT DSAEK, although at the expense of a higher rate of detachment/rebubbling post-DMEK. Where UT DSAEK thickness is <70 µm, the difference in visual outcomes diminishes. In anatomically challenging eyes, UT DSAEK is a sensible option as a result of easier intraocular handling and reduced re-intervention rate.[17,27]

DMEK Surgical Technique

The surgical technique for DMEK transplant involves the creation of a peripheral iridotomy to prevent postoperative pupillary block, followed by a controlled descemetorhexis to remove the host Descemet's membrane and endothelium.[28] The pre-stripped donor Descemet's membrane endothelium graft is introduced into the anterior chamber, and the endothelium out injector or endothelium in pull-through system is used to facilitate the introduction of the graft.[29] This is achieved using gentle fluid waves and chamber shallowing. Once the graft is correctly positioned, the graft is centrally placed and secured with an air or 20% SF_6 gas tamponade to promote adhesion.[30] Standardized steps for the surgical technique have been shown to decrease the rates of detachment and rebubbling.[31]

Endoin vs Endoout Delivery Techniques

Emerging evidence has highlighted meaningful differences between endotheliumin ("Endoin") and endotheliumout ("Endoout") graftinsertion strategies in DMEK.[29] Endoout techniques, traditionally used with glass injectors, allow controlled fluidbased unscrolling but expose the endothelial layer externally during insertion, raising the risk of microtrauma. In contrast, the endoin approach, increasingly used with pullthrough or cartridgebased systems, protects the endothelial surface by keeping it inside the scroll during entry.[32] Comparative studies in Asian eyes demonstrate similar visual outcomes but report greater intraoperative stability and lower manipulation time with the endoin pullthrough method, especially in deep anterior chambers and dim visualization settings.[33] Overall, choice of technique is surgeondependent, but surgical standardization is trending toward endoin delivery due to reduced mechanical trauma and smoother graft unfolding.

Preloaded vs SurgeonLoaded Grafts

Workflow refinements now allow eye banks to deliver prestripped, prestained, and preloaded (P3) DMEK grafts, which significantly simplify the surgical steps.[34] Preloaded tissue reduces the duration of intraocular manipulation, minimizes endothelial touch, and shortens operative time.[35] Preloaded grafts are noninferior to surgeonprepared tissue with respect to detachment rates, visual acuity outcomes,

Table 1: Clinical outcomes of DMEK across major studies

Study/Year	*Population/ Followup*	*Visual acuity outcomes*	*ECD/ECL*	*Graft survival*	*Complications/Notes*
MouraCoelho et al., 2024[52]	129 eyes, ≥12 months followup	Significant BCVA improvement; eyes achieving ≤0.10 logMAR (≥20/25) increased from 1.6% preop to 64.4% at >5 years	Not primary outcome; predictors of better vision included younger age & better baseline BCVA	All eyes included had successful primary DMEK with no early graft failure	Retinal comorbidities predicted worse longterm BCVA
Bichet et al., PLOS ONE 2023[53]	107 eyes (majority FECD); 5year followup	BCVA improved from 0.6 logMAR to 0.05 at 1 year; remained stable for 5 years	47% ECL at 6 months, additional 4%/year decline; 65% ECL at 5 years	88% graft survival at 5 years	18% detachment requiring rebubbling; 12% graft failure within 15 months
Machalińska et al., 2025[54]	34 eyes; up to 36month followup	Continuous BCVA improvement during first 12 months; stable thereafter	~64% cumulative ECL at 36 months	High procedure effectiveness; grafts maintained structural stability	Reduction in astigmatism & higherorder aberrations by month 12; remained stable
Wilhelm et al., 2025[55]	2956 eyes; 10year comparison of DMEK vs DSAEK vs PK	DMEK achieved fastest visual recovery: median time to ≥6/12 visual acuity was 7.8 months	Faster ECD decline than PK; 10year probability of ECD >1000 cells/ mm^2: DMEK 3%	10year graft survival: DMEK 75%, DSAEK 73%, PK 92%	Lowest rejection rate among groups (10% at 10 years)
DabrowskaKloda et al., Sweden 2024[56]	162 eyes; 1–6-year followup	85.8% achieved 0.1 logMAR (20/25) or better in eyes without comorbidities	ECL: 27% at 1–2 yrs, 31% at 2–3 yrs, 42% at 3–4 yrs, >60% at 4–6 yrs	Not explicitly quantified but generally high; longterm sustainability needs further study	Results confirm consistently strong visual outcomes with progressive ECD decline
Price et al., AAO 2026[47]	362 consecutive eyes undergoing DMEK for failed EK	Mean BCVA 20/25 at 1 and 5 years (without major comorbidities)	ECD correlated with donor density and time since surgery; glaucoma increased risk of failure	Earlyfailure cases: 1yr survival 98%, 5yr 94% Latefailure cases: 1yr 93%, 5yr 77%	Higher failure risk in secondary corneal edema and glaucoma; number of prior failed grafts *not* a predictor

BCVA – Best-Corrected Visual Acuity; ECD – Endothelial Cell Density; ECL – Endothelial Cell Loss; FECD – Fuchs Endothelial Corneal Dystrophy; logMAR – Logarithm of the Minimum Angle of Resolution

Table 2: DMEK Complications - Key Risks, Prevention, and Management

Complication	*Key risk modifiers*	*Prevention / mitigation*	*Management (Processfocused)*	*Citations*
graft detachment → rebubbling	Lower early postoperative IOP (e.g., at ~2 h), older age, diabetes, FECD indication increase detachment odds.	Standardize steps; confirm PI; aim for adequate early IOP; gentle, notouch unfolding.	Timely rebubbling for central/ progressive detachments using air or shortacting gas per predefined criteria.	40,41,42
Pupillary block / early pressure spikes	Overtamponade without patent PI can precipitate block; conversely, very low IOP favors detachment.	Create/verify inferior PI; titrate bubble at case end; check pupil and AC dynamics before exit.	Partial bubble release; reconfirm PI; add IOPlowering drops as needed.	28,40,42
Orientation error / excess handling trauma	Inversion, prolonged unscrolling, endothelial touch raise risk of nonadhesion.	Orientation marks (e.g., Sstamp), endotheliumin loading; «notouch» maneuvers; consider preloaded tissue to reduce manipulation.	Prompt reorientation with minimal extra manipulation; secure with appropriate tamponade.	24,45,46,57
Recipient DM lamellar splitting	Traction during descemetorhexis can split DM layers.	Controlled rhexis; avoid scraping; keep the stromal bed smooth.	Polish residual layer; outcomes (VA, thickness, ECL, rebubble) not significantly impacted when polished.	58,59
Posture regimen	Centerdependent; with robust intraop steps, posture may be unnecessary.	If PI + 20% SF_6 and good fill are assured, noposture/brief posturing is acceptable.	Align followup with early rebubble threshold rather than prolonged posturing.	44
Anatomydriven risk (posterior surface irregularity)	Positive/lessnegative posterior irregularities on ASOCT predict rebubbling; risk persists across experience levels.	Preop ASOCT elevation maps for risk triage; plan closer surveillance.	Lower threshold for early rebubbling if clinically significant detachment.	60,61
Glaucoma / device eyes (tubes, trabeculectomy)	Altered chamber dynamics complicate unfolding/ adhesion; higher failure risk signals in some cohorts.	Coordinate tamponade/IOP strategy; in very complex chambers consider UTDSAEK for easier handling.	Early review; proactive rebubbling for significant detachments; tailor steroid taper to IOP risk.	22,62
Donor/source considerations	Concern that prep/handling or donor diabetes could worsen ECL.	Use prestripped/preloaded tissue noninferior to surgeonprepared; donor diabetes does not worsen 1yr ECL/ morphometry.	Standard care - no change solely due to donor diabetes; observe usual ECD/attachment surveillance.	34,57

AC – Anterior Chamber; ASOCT / ASOCT – Anterior Segment Optical Coherence Tomography; DM – Descemet Membrane; DMEK – Descemet Membrane Endothelial Keratoplasty; DSAEK – Descemet Stripping Automated Endothelial Keratoplasty; DSO – Descemet Stripping Only; DWEK – Descemetorhexis Without Endothelial Keratoplasty; ECD – Endothelial Cell Density; ECL – Endothelial Cell Loss; FECD – Fuchs Endothelial Corneal Dystrophy; IOP – Intraocular Pressure; PI – Peripheral Iridotomy; PK – Penetrating Keratoplasty; SF_6 – Sulfur Hexafluoride Gas; UTDSAEK – Ultrathin Descemet Stripping Automated Endothelial Keratoplasty

and ECL,[24] although there may be an increased detachment rate with preloaded compared to surgeon-prepared grafts.[36]

Orientation Marks and StampGuided Unfolding

Use of orientation stamps, particularly the "Sstamp," is a key improvement in reducing intraoperative inversion and excess handling.[37] Orientation errors remain a major contributor to tissue trauma, prolonged unfolding time, and postoperative nonadhesion. Stamped grafts allow instant identification of stromalversusendothelial side during insertion, markedly reducing unnecessary manipulation.[38] Studies consistently show that Sstamped tissue improves surgeons' control of graft orientation and decreases endothelial touch.[39] In combination with "notouch" fluidwave techniques, orientation marking contributes to lower detachment rates, fewer rebubbling procedures, and decreased endothelial loss, making it a cornerstone of contemporary DMEK practice and a recommended step in surgical training curricula.

Outcomes of DMEK

Across short-, mid-, and long-term follow-up, DMEK consistently demonstrates superior visual and endothelial outcomes. Research from multiple cohorts highlights that although ECL follows a characteristic early decline with gradual long-term attrition, overall visual quality and corneal clarity remain well preserved in the majority of patients. Graft detachment and rebubbling are still the most common issues that are encountered in the initial stages, but these are not known to affect the long-term outcome of DMEK. In the following table, the findings of several major studies are summarized (Table 1).

Complications and Management

Partial graft detachment is the most common early complication in contemporary DMEK and often requires rebubbling. The risk increases when early postoperative IOP is low, and is further influenced by older age, diabetes, and

FECD, all of which can weaken early graft–stroma adhesion and raise the chance of re-intervention.[40,41] Maintaining a patent peripheral iridotomy (PI) and a safe, adequate early IOP helps reduce detachment risk.[28] Standardized, checklistdriven protocols for atraumatic unfolding, tamponade targets, and clear rebubbling criteria further lower variability and are associated with fewer rebubbles and less endothelial cost over time.[42]

Anatomical/biomechanical predictors also matter; posterior corneal surface irregularity on preoperative anterior segment optical coherence tomography (ASOCT) elevation maps independently predicts higher rebubbling likelihood and can guide closer surveillance.[43] Pupillary block/IOP imbalance is avoidable by confirming PI patency and titrating the gas bubble; conversely, very low early IOP is itself a detachment signal, underscoring the need for balanced tamponade.[42] Centers using a posturelight or noposture strategy (with reliable PI and 20% SF_6 fill) did not observe higher rebubbling rates, supporting simplified aftercare when intraoperative steps are robust.[44]

Intraoperative challenges such as orientation errors, excess tissue handling, recipient DM lamellar splitting, and visualizationdriven stromal debridement can be mitigated by notouch unfolding techniques and the use of orientation marks such as the Sstamp, which improve graft control and reduce endothelial trauma.[45,46,38] These strategies are consistently emphasized in expert surgical guidance and educational series on overcoming DMEK handling difficulties. When recipient DM splitting occurs, gentle surface polishing is generally sufficient; this approach has not been associated with worsened vision, increased corneal thickness, excess ECL, or higher rebubbling rates when appropriately managed, supporting its safety as part of standardized intraoperative decisionmaking.[47] Similarly, visualizationrelated stromal debridement is understood to act mainly as a marker of case complexity rather than an independent risk factor for postoperative complications, an observation reported in structured analyses of DMEK technique variation.[45] Using eyebank prestripped or preloaded tissue is noninferior to surgeonprepared tissue for detachment and vision and reduces intraoperative manipulation steps.[36]

Eyes with glaucoma procedures or tubes present higher technical complexity for unfolding and adhesion; selection of UTDSAEK may be prudent in the most challenging chambers, and coordination of IOP/tamponade strategy is essential.[48]

Future Direction

DMEK is likely to be complemented and not replaced by tissueefficient and donorsparing strategies. Active fronts include bioengineered/"artificial" endothelial substitutes and carrier membranes to ease global donor shortages, and cellbased regeneration (cultured corneal endothelial cell delivery, DMET, quarter/hemiDMEK, DSO with adjuncts) to restore clarity with less (or no) donor tissue. These approaches aim to maintain DMEKlevel optics while expanding access, particularly in settings with limited eyebank supply.[49,50]

Concurrently, workflow and technique refinements such as validated prestripped/preloaded grafts (noninferior to surgeonprepared for detachment and vision), endoin/endoout delivery systems guided by intraoperative imaging, and standardized protocols are expected to reduce manipulation and variability and shorten the learning curve.[51,35] In the near term, these pragmatic gains will likely raise the baseline safety and consistency of DMEK, while mediumterm biologic/engineered solutions mature to broaden eligibility and durability (Table 2).

Conclusion

DMEK has proven to be the most anatomically precise and visually effective solution for endothelial failure, providing rapid rehabilitation, excellent optical results, and the lowest rejection rates of all endothelial keratoplasty techniques. The development of DMEK, from the initial lamellar techniques to the current standardized and minimally traumatic techniques, has reduced variability in the procedure and increased the range of applicability of DMEK to a wide range of clinical scenarios. Although issues such as graft detachment, ECL, and the complexity of the procedure remain, evidence suggests that these issues can be addressed through careful patient selection, refined technique, and a systematic approach to postoperative management.

Moving forward, developments in bioengineering, cell-based regeneration, preloaded tissue techniques, and imaging-based delivery systems may continue to expand access and longevity, especially in areas where donor tissue scarcity persists. For example, engineered endothelial substitutes, cell-based therapies, and tissue-preserving micrografts may soon support DMEK procedures by eliminating the need for donor tissue and simplifying intraoperative handling. As these technologies continue to progress, the future of endothelial restoration may continue to rely on the synergistic combination of advanced surgical techniques with regenerative and biomaterial-based solutions.

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Case Report

Orbicularis Oculi Cysticercosis: A Diagnostic Pitfall in an Endemic Region

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Abstract

Objective: To describe the diagnostic challenges and management approach in a case of vesicular stage cysticercosis of the orbicularis oculi muscle presenting as a clinically silent periorbital mass.

Methods: An adolescent male presented with a four-month history of a gradually enlarging, firm, non-tender right periorbital mass (15×10 mm) with no inflammatory signs, no visual disturbance, and no systemic symptoms. The clinical impression was a benign periorbital mass; cysticercosis was not considered pre-operatively. Complete excisional biopsy was performed under local anesthesia without pre-operative imaging. Following unexpected histopathological findings, post-operative systemic evaluation was undertaken, including non-contrast CT of the head and orbits, chest radiograph, and bilateral limb radiographs.

Results: Histopathological examination confirmed vesicular stage cysticercosis with identifiable hooklets, suckers, a coelomic cavity, and an intrinsic larval cyst wall distinct from a host-derived fibrous capsule. This distinction explained the absence of a surgical capsular plane intraoperatively. Systemic evaluation excluded concurrent neurocysticercosis and musculoskeletal disease, confirming isolated periorbital involvement. Adjuvant oral albendazole (15 mg/kg/day for 28 days) with tapering prednisolone achieved complete clinical and radiological resolution at six-month follow-up.

Conclusions: Vesicular stage orbicularis oculi cysticercosis is clinically indistinguishable from a benign periorbital tumor and is only reliably detected by histopathological examination. Unexpected histopathological confirmation mandates comprehensive systemic evaluation before anthelmintic therapy is commenced.

Keywords: Cysticercosis, Orbicularis oculi, Periorbital mass, *Taenia solium*, Vesicular stage

Introduction

Cysticercosis, caused by larval *Taenia solium*, affects an estimated 20 million people worldwide and is the leading preventable cause of acquired epilepsy in endemic regions.[1] Extraneurological manifestations occur in 13 to 46% of cases, with orbital and periorbital involvement representing a clinically significant subset that frequently brings patients to ophthalmic attention.[2,3] The anatomical spectrum of periorbital cysticercosis encompasses the extraocular muscles, subconjunctival space, eyelid, and orbital fat, each associated with characteristic clinical patterns determined by cyst stage and location.

Published series have established extraocular muscle involvement as the predominant form of periorbital cysticercosis. Rath *et al*., in the largest series to date of 171 patients, reported extraocular muscle involvement in 80.7%, with the superior rectus most frequently affected (33.3%), followed by subconjunctival involvement in 24.6%.[3] Salim *et al*. documented similar patterns in 61 patients, with the inferior rectus most commonly involved (27.9%).[4] Across these series, eyelid involvement accounted for fewer than 1% of cases, confirming its status as a rare presentation of an already uncommon disease.[3]

Within the eyelid, cyst lodgment in the orbicularis oculi muscle is documented but exceptionally rare. Sen *et al*. first described this presentation in a series of adnexal cysticercosis

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cases,[5] and subsequent reports have further defined its clinical features.[6] The comprehensive 20-year review of cysticercosis in ophthalmology by Pujari *et al*. confirmed that eyelid and orbicularis oculi involvement remain among the least characterized manifestations of the disease.[7] Despite prior reports, a complete description integrating intraoperative findings, histopathological-clinical correlation, systematic post-operative evaluation, and treatment outcome has not been documented specifically for this anatomical site.

A central diagnostic challenge in orbicularis oculi cysticercosis is posed by vesicular stage disease, wherein the viable larval cyst elicits minimal immune activation and generates none of the periorbital inflammatory signs that typically raise clinical suspicion.[8] The lesion instead mimics common benign periorbital tumors, creating a diagnostic trap that is only resolved by histopathological examination. We describe such a case in which orbicularis oculi cysticercosis was entirely unsuspected pre-operatively, discovered incidentally on histopathological examination, and managed with a comprehensive protocol achieving complete resolution.

Case Report

A well-nourished adolescent male (weight 60–65 kg) presented with a four-month history of a gradually enlarging mass in the right periorbital region. There was no history of trauma, seizures, diplopia, or visual change, and no family history of parasitic infection. The patient's primary concern was cosmetic.

Local examination revealed a solitary, well-defined mass in the medial right periorbital region overlying the orbicularis oculi muscle, measuring 15×10 mm (Figure 1).

The mass was firm, mobile, non-tender, and non-pulsatile, with normal overlying skin and no regional lymphadenopathy. Full ophthalmological examination demonstrated visual acuity 6/6 bilaterally, intraocular pressures within normal limits, full and unrestricted ocular movements, no proptosis, no relative afferent pupillary defect, and normal anterior segment and dilated fundus examinations.

The pre-operative differential diagnosis included dermoid cyst (most probable given the patient's age and location), epidermoid cyst, lipoma, and neurofibroma. Cysticercosis was not considered pre-operatively given the firm non-cystic consistency, complete absence of inflammatory signs, and overall clinical impression of a benign superficial neoplasm. No pre-operative imaging was performed, as the superficial location, absence of deep orbital signs, and firm consistency provided no clinical indication. Complete excisional biopsy was performed under local anesthesia via a skin-crease incision. Intraoperative findings revealed a firm lesion lacking a discrete surgical capsule at the orbicularis oculi level (Figure 2), relatively avascular and not adherent to the periosteum or overlying skin. The specimen measured 15×10×8 mm.

Histopathological examination (Figure 3)unexpectedly revealed an intact larval cyst with identifiable hooklets, coelomic cavity, suckers, and a thin intrinsic fibrous cyst

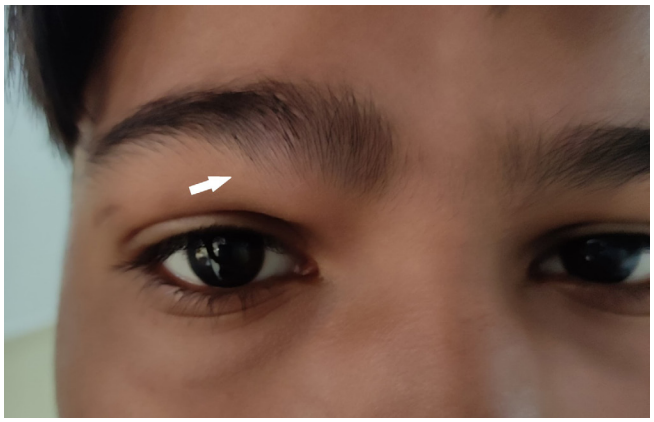

Figure 1: Clinical photograph demonstrating a well-defined, non-inflamed mass (arrow) in the medial right periorbital region overlying the orbicularis oculi muscle, measuring approximately 15×10 mm. Overlying skin is normal with no erythema or oedema, illustrating the absence of inflammatory signs characteristic of vesicular stage disease.

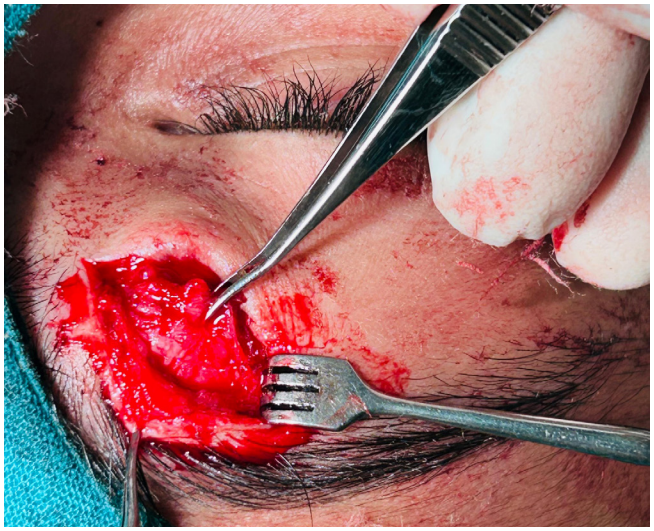

Figure 2: Intraoperative photograph demonstrating a firm lesion at the orbicularis oculi level lacking a discrete surgical capsule, with minimal surrounding inflammatory reaction and no clearly defined capsular dissection plane.

wall representing the parasite's own tegument, distinct from a host-derived fibrous capsule.

A mild chronic inflammatory infiltrate of lymphocytes, plasma cells, and eosinophils was present without calcification, consistent with vesicular stage cysticercosis. Prompted by this finding, comprehensive post-operative systemic evaluation was undertaken. Non-contrast CT of the head and orbits (Figure 4) demonstrated normal brain parenchyma without intracranial calcifications or cystic lesions, and normal bilateral orbital anatomy, excluding neurocysticercosis. Chest radiograph and bilateral femoral radiographs excluded pulmonary and musculoskeletal involvement, confirming isolated periorbital disease.

Anthelmintic therapy commenced ten days post-operatively, allowing wound consolidation prior to systemic

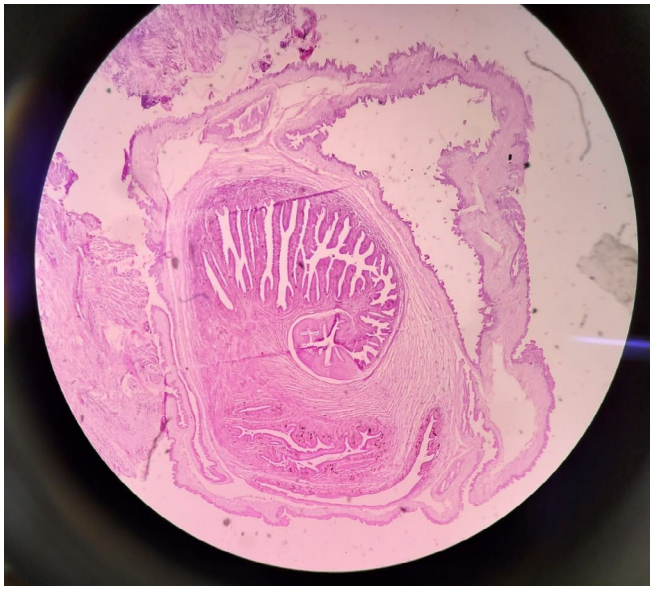

Figure 3: Photomicrograph (haematoxylin and eosin staining) demonstrating vesicular stage cysticercosis. The intact larval cyst displays an intrinsic tegumental wall (arrowhead) distinct from a host-derived fibrous capsule, identifiable hooklets, suckers, and coelomic cavity. The surrounding tissue shows a mild chronic inflammatory infiltrate of lymphocytes, plasma cells, and eosinophils without calcification.

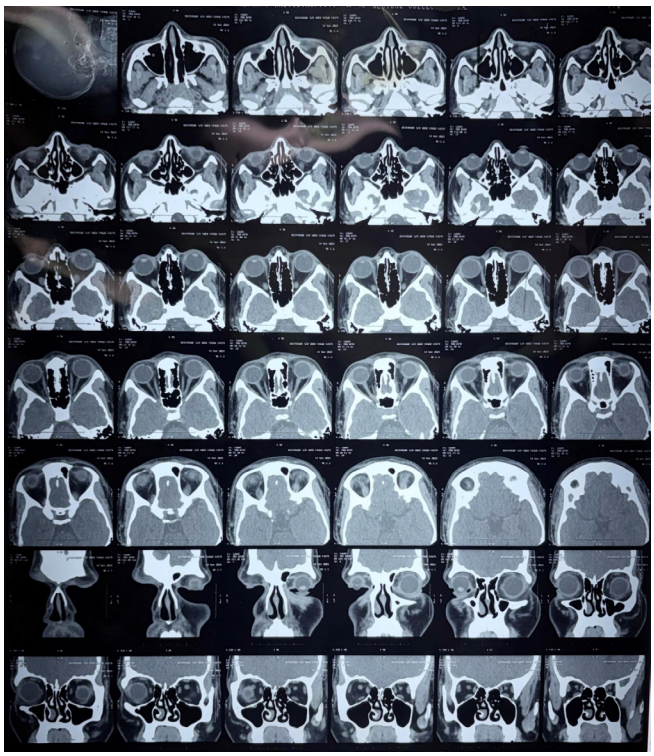

Figure 4: Non-contrast CT of the head and orbits. Axial sections demonstrate normal bilateral orbital anatomy with normal extraocular muscles, orbital fat, and no residual cystic lesion. Coronal sections confirm normal bilateral orbital and paranasal sinus architecture. Brain parenchyma is normal throughout without intracranial calcifications or cystic lesions, excluding neurocysticercosis.

drug exposure: oral albendazole 15 mg/kg/day for 28 days with concurrent tapering prednisolone over three weeks to mitigate potential inflammatory complications. Treatment was well tolerated. Sutures were removed at two weeks with satisfactory wound healing. B-scan ultrasonography at one and three months post-operatively showed no residual or new cystic lesions. MRI at six months, performed as part of post-treatment surveillance, confirmed the absence of intracranial cystic lesions, with complete clinical resolution and an excellent cosmetic outcome. The patient is enrolled in annual clinical surveillance for three years post-treatment.

Discussion

Orbicularis oculi involvement in cysticercosis, while real, is a poorly characterized and rarely reported entity within the spectrum of periorbital parasitic disease. Eyelid cysticercosis accounts for fewer than 1% of cases in the largest published series,[3] and orbicularis oculi muscle involvement, which is distinct from subcutaneous eyelid deposits, has been documented in only isolated reports since Sen *et al*.'s initial description in 1980.[5,6] This rarity contrasts with the well-established extraocular muscle tropism that defines the overwhelming majority of cases.[3,4] The pathophysiological basis for periocular muscular predilection in cysticercosis is incompletely understood; hematogenous dissemination of oncospheres with lodgment in terminal muscular vascular beds has been proposed as the operative mechanism, a process that may extend to the periocular musculature beyond the classically described extraocular muscles.[2,7]

This case illustrates the behaviour of vesicular stage disease at a rare anatomical site. Major published series report periorbital swelling in 38.6%, restriction of ocular motility in 64.3–85.2%, and proptosis in up to 24% of periorbital cysticercosis cases.[3,4] Our patient exhibited none of these features. In vesicular stage disease, the viable larval cyst maintains immune tolerance through active suppression of host inflammatory responses,[8] producing a firm non-tender mass whose mechanical properties correspond far more closely to a dermoid cyst than to the inflammatory orbital mass typically associated with cysticercosis. This clinical silence is what makes vesicular stage orbicularis oculi cysticercosis a diagnostic trap. The lesion generated no clinical trigger for pre-operative imaging or parasitic workup, and diagnosis was entirely dependent on routine histopathological examination of what was believed to be an elective excision specimen.

The intraoperative absence of a discrete surgical capsule appeared discordant with the histopathological finding of a fibrous cyst wall. This apparent contradiction reflects two distinct anatomical entities. The absence of a host-derived fibrous capsule accounts for the intraoperative behavior: unlike dermoid or epidermoid cysts, the cysticercus does not induce organized host fibrosis that creates a clean surgical dissection plane. The fibrous wall seen on histopathology, however, represents the parasite's own intrinsic tegument, a thin laminated structure inherent to the organism and not

equivalent to a surgical capsule. This distinction has practical importance: surgeons anticipating a capsulated mass may inadvertently rupture the cyst, releasing antigenic content into the wound and risking a severe local inflammatory reaction. The relatively avascular nature of the lesion and absence of adhesion to surrounding structures, both noted in this case, may serve as intraoperative cues warranting careful dissection and intact specimen preservation for histopathology.

Transmission of *T. solium* in India occurs predominantly through feco-oral routes via contaminated water and vegetables, independent of pork consumption.[9,10] More than 95% of Indian cysticercosis patients maintain vegetarian diets, reflecting environmental exposure rather than dietary acquisition.[9] Vegetarian dietary history must therefore not be used as a discriminating feature, and clinical suspicion in endemic settings should remain independent of dietary background.

Pre-operative B-scan ultrasonography or MRI should be considered for periorbital masses in endemic regions even when clinical suspicion is low, as imaging can identify the characteristic intracystic scolex in a substantial proportion of cases.[11] The decision not to image pre-operatively was clinically defensible, since the lesion was superficial, firm, and showed no deep orbital signs. That very defensibility makes the case instructive: vesicular stage cysticercosis at an unusual site gave no indication for imaging. When histopathological confirmation occurs unexpectedly, CT or MRI of the head is mandatory before initiating anthelmintic therapy, as these agents can precipitate cerebral edema in concurrent undiagnosed neurocysticercosis.[12] In this case, CT of the head and orbits combined with a systematic radiological survey of the chest and limbs comprehensively excluded systemic disease prior to commencing treatment. Combined excision with adjuvant albendazole and corticosteroid cover, the approach described by Sihota and Honavar,[13] achieved complete resolution.

Limitations include the absence of pre-operative and post-operative serological evaluation for anti-cysticercal antibodies, which would have strengthened systemic assessment. The histopathological section does not include identifiable adjacent skeletal muscle fibers; orbicularis oculi localization is based on the intraoperative assessment of the lesion's anatomical level rather than direct histopathological demonstration of intramuscular positioning. These limitations notwithstanding, this case provides a comprehensive intraoperative, histopathological, radiological, and treatment record for an underreported and diagnostically challenging presentation.

Vesicular stage orbicularis oculi cysticercosis can present as a firm, non-inflammatory periorbital mass that is clinically indistinguishable from a benign periorbital neoplasm. Three practical points follow. Orbicularis oculi involvement should be retained in the differential diagnosis of firm periorbital masses in endemic regions. Histopathological examination of excised periorbital specimens is essential, because vesicular stage disease produces no pre-operative clinical trigger. Finally, incidental confirmation warrants systematic post-operative evaluation before anthelmintic therapy to exclude concurrent systemic disease.

Informed Consent

Written informed consent was obtained from the patient and his parents for publication of this case report and accompanying images.

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Conflicts of interest

No conflicts of interest among authors

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Case Report

A Rare Case of Bilateral Microspherophakia

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Abstract

Microspherophakia is a rare bilateral congenital anomaly of the crystalline lens. The condition may be isolated, familial, or it may be associated with systemic affections like Marfan's syndrome, Weil-Marchesani syndrome, hyperlysinemia and congenital rubella. Microspherophakia results in lenticular myopia, lens dislocation, usually inferiorly and inverse glaucoma. We present a case in a 8 year old child who presented with bilateral microspherophakia. Visual acuity in the right eye was counting fingers close to face and in the left eye 6/60.IOP with Perkins applanation tonometer was 30 mmHg in the right eye and 22 mmHg in the left eye, cornea was hazy due to edema, anterior chamber was shallow in both eye patient was managed with emergency lens extraction of the right eye and secondary ACIOL implantation. Left eye was managed by laser peripheral iridotomy. IOP was within normal limits postoperatively in both eyes without any antiglaucoma medications. Postoperatively, best corrected visual acuity in the right eye was 6/18 and 6/9 in the left eye.

Keywords: Microspherophakia, Anterior dislocated lens, Isolated microspherophakia.

Introduction

Microspherophakia is a rare congenital condition of the crystalline lens wherein the anteroposterior diameter is more than the horizontal diameter and the lens assumes a spherical shape.[1] Defective development of the zonules results in their deficiency, increased length, weakness and non-attachment of posterior zonules to the ciliary processes. This could be regarded as a simple arrest of lens development between the fifth and sixth month of intrauterine life.[2,3] This leads to formation of a small spherical lens. Microspherophakia is associated with some systemic affection like Weil-Marchesani syndrome, Marfan syndrome, or isolated microspherophakia.[4]

Case Description

A 8 year old female child was brought to the outpatient department with complaints of diminution of vision in both eyes since her early childhood and complaints of redness and watering from the right eye for 1 week. There was no history of trauma and no history of similar complaints in the past, no history of similar complaints in any siblings and no history of consanguineous marriage. She was full term normal delivery and normal developmental milestones on general physical examination; there were no signs of Marfan's or Weil-Marchesani syndrome. Examination of the right eye revealed mild circumciliary congestion cornea was hazy due to corneal edema. AC was shallow with a dislocated lens and the lens was microspherophakia. IOP in the right eye with a Perkins applanation tonometer was 30 mmHg; fundus glow was seen, but other details were not made out. Examination of the left eye revealed a shallow anterior chamber and microspherophakia. IOP in the left eye with a Perkins applanation tonometer was 22 mmHg; fundus was normal in left eye visual acuity in RE counting fingers close to face and in LE 6/60 best corrected visual acuity in RE counting fingers close to face and in LE 6/36. She was put on I.V mannitol 20% and taken up for lens extraction of the right eye under general anaesthesia, and a secondary ACIOL was implanted after 1 month. Postoperatively, VA in RE was 6/18. Laser iridotomy was done in LE. Postoperatively, IOP was within normal limits without any antiglaucoma medications (Figure 1).

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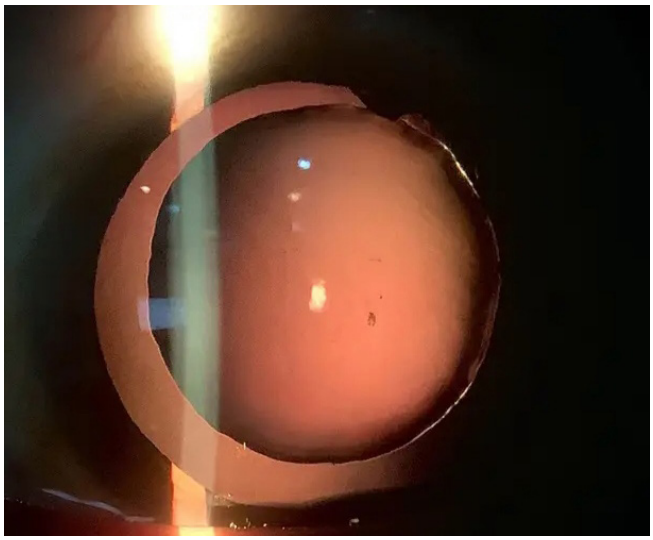

Fig. 1: Microspherophakic lens visible after mydriasis

Discussion

Isolated microspherophakia is a rare condition. It is most often hereditary or familial or integrated into a general malformation syndrome.[5] Investigators have hypothesized that spherophakia occurs when an incompletely developed ciliary body and its loose, elongated zonules do not exert sufficient pressure to flatten the developing lens. The lenses of patients with spherophakia therefore retain a fetal spherical conformation.[2,3] It usually presents in the first or second decade of life with progressive myopia and angle-closure glaucoma due to pupillary block by a microspherophakic lens. Use of miotics causes forward displacement of lens iris diaphragm and causes inverse glaucoma in such patients.[6,7] Familial microspherophakia, generally not associated with other systemic malformations, is inherited as an autosomal recessive trait and associated with ectopia lentis, where the lens is most frequently displaced upwards.8 With our patient, the manifestation of this condition is sporadic or possibly familial, as no previous case was identified in the immediate family.

Conclusion

As there were no other signs or symptoms suggestive of Weil-Marchesani, Marfan, or other syndromes, we concluded that this case is an isolated bilateral ectopic microspherophakia.

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Case Report

Genetic Insights into Alport Syndrome: A Case Report Highlighting COL4A3 Mutation and Ocular Phenotype

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Abstract

Alport syndrome is a hereditary disorder characterized by ocular abnormalities, sensorineural hearing loss, and progressive renal involvement. We report a case of a 19-year-old female who presented with complaints of infrequent flashes of light in the left eye. Ophthalmic evaluation revealed high myopia, anterior lenticonus confirmed by anterior segment optical coherence tomography (AS-OCT), and temporal macular thinning on macular OCT. Systemic workup demonstrated bilateral moderate sensorineural hearing loss and severe proteinuria, with normal renal function. Genetic testing identified a probable compound heterozygous pathogenic variant in the *COL4A3* gene, confirming autosomal recessive Alport syndrome. This case underscores the pivotal role of detailed ophthalmic examination as an early diagnostic clue and highlights genetic analysis as an essential tool for definitive diagnosis, prognostication, and guiding multidisciplinary management.

Keywords: Anterior lenticonus, Alport syndrome, COL4A3 mutation, Hearing loss

Introduction

Alport syndrome is an inherited disorder caused by mutations in the COL4A3, COL4A4, or COL4A5 genes located on chromosome 2, affecting type IV collagen in the basement membranes of the kidney, cochlea, and eye. The COL4A3, COL4A4, and COL4A5 genes are responsible for producing the α3, α4, and α5 chains of type IV collagen, respectively. The glomerulus, cochlea, corneal Descemet's and Bowman's membranes, lens capsule, inner limiting membrane, and retinal Bruch's membrane all incorporate collagen IV, a crucial structural protein of the basement membrane.[1] About 10 and 5% of instances of Alport syndrome are autosomal recessive (ARAS) and autosomal dominant (ADAS), respectively, with the other 85% of cases following an X-linked inheritance pattern (XLAS).[2] About 1 in 5,000 people have Alport syndrome, which causes high-frequency sensorineural hearing loss and eventual renal failure. Dot-and-fleck retinopathy, anterior lenticonus, and, in rare cases, posterior polymorphous corneal dystrophy are ocular characteristics that help with diagnosis and usually appear gradually.[3]

Dot-and-fleck retinopathy, which is the consequence of altered retinal pigmentation, is the most prevalent retinal finding in Alport syndrome. As in this instance, this characteristic is typically asymptomatic, has no effect on eyesight, and doesn't need any kind of intervention. Temporal macular thinning, which may be linked to decreased foveal reflex, pigmentary changes at the fovea, vitelliform-like lesions, or, in rare cases, the formation of a macular hole, are further potential changes. Lenticonus is a key diagnostic sign of Alport syndrome. These ocular features can serve as important diagnostic clues and may aid in the early detection of the disease. This report details a patient with Alport syndrome who presented with typical ocular symptoms and visual difficulties.

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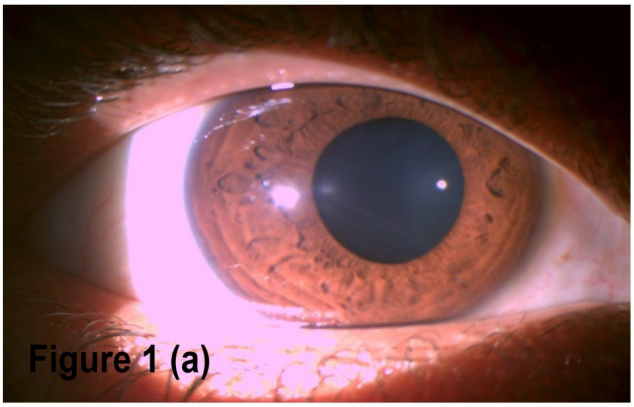

Figure 1a: Slit-lamp examination using direct focal illumination showing a protrusion of the anterior lens capsule in the right eye.

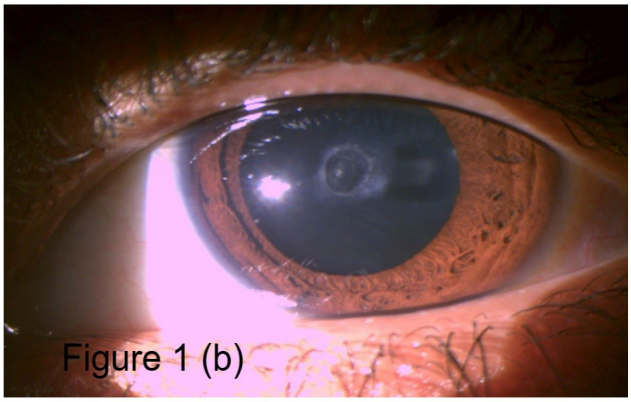

Figure 1b: Slit-lamp examination using direct focal illumination showing a conical protrusion of the anterior lens capsule, indicative of anterior lenticonus in the left eye

Case Report

A 19-year-old female presented to the outpatient department in 2025 complaining of infrequent light flashes in her left eye that had been occurring for three to four months. Diabetes, systemic hypertension, or trauma were not present in the patient's past. Informed consent was obtained from the patient.

On ophthalmic examination, the best-corrected visual acuity (BCVA) was 6/18 in the right eye and 6/12 in the left eye. The patient had a manifest refraction of -12.50 sphere in the right eye and -8.50 sphere in the left eye.

On slit-lamp examination, the cornea and anterior chamber of both eyes were found to be normal. Direct focal illumination revealed protrusion of the anterior lens capsule in the right eye, while a conical protrusion of the anterior lens capsule, consistent with anterior lenticonus and anterior capsular opacity, was seen in the left eye. (Figure 1(a, b)) Sclerotic scatter and retroillumination highlighted an irregular light reflex and distortion of the red reflex, confirming the lenticular abnormality. Intraocular pressure was 16 mm Hg in both eyes. Dilated fundus examination demonstrated myopic fundus changes bilaterally, consistent with high myopia, with no signs of retinal breaks or detachment.

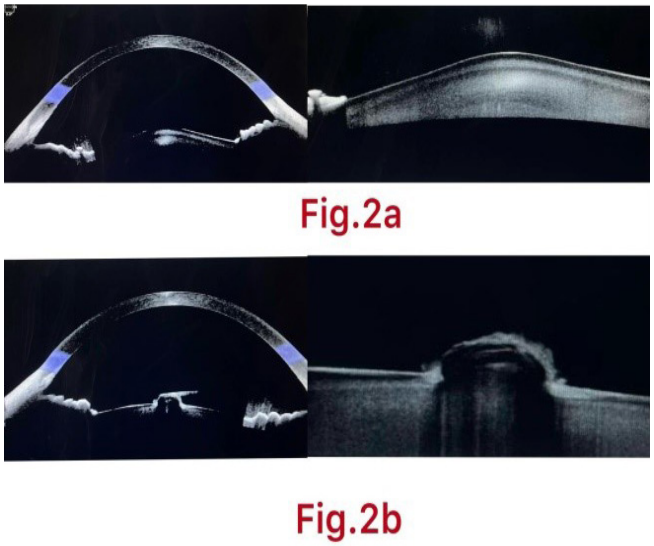

Figure 2: Anterior segment optical coherence tomography (AS-OCT) of both eyes (2a OD and 2b OS) confirms anterior lenticonus, a hallmark ocular finding in Alport syndrome

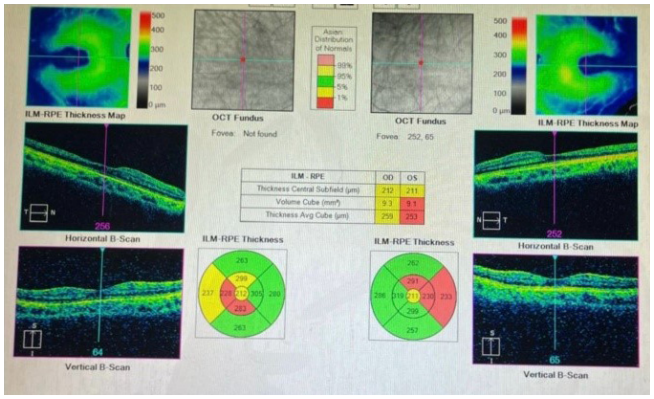

Figure 3: Macular optical coherence tomography (OCT) demonstrates temporal thinning in both eyes, consistent with Alport syndrome

AS-OCT of both eyes showed anterior lenticonus, a hallmark ocular finding in Alport syndrome (Figure 2). Macular OCT revealed temporal thinning in both eyes. (Figure 3). The patient underwent systemic examination. She had bilateral moderate sensorineural hearing loss on audiometry (Figure 4).

Proteinuria was found by urinalysis, although creatinine, urea, and electrolytes were all within acceptable ranges. There was no evidence of hematuria. Further quantitative analysis of urinary proteins demonstrated significant albuminuria, with urinary albumin (microalbumin) measured at 892 mg/L (reference range: <30 mg/L). Urinary creatinine was 30 mg/dL, resulting in an albumin-to-creatinine ratio (ACR) of 2973.3 mg/g, which is markedly elevated compared to the normal range (<30 mg/g). This value is consistent with clinical albuminuria (severe), indicating significant glomerular dysfunction.

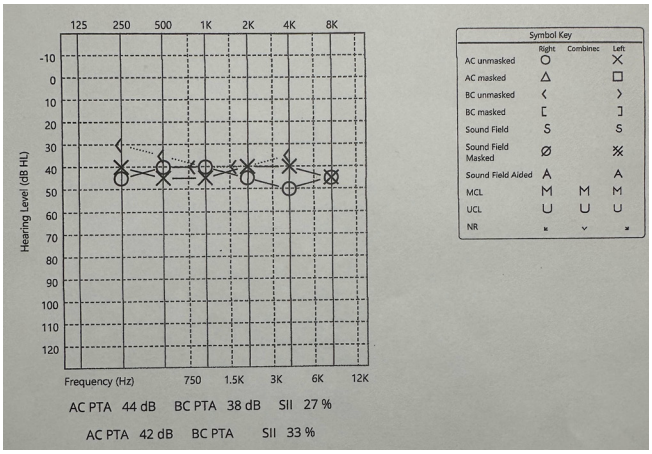

Figure 4: Bilateral moderate sensorineural hearing loss on audiometry

The ultrasound scan of the abdomen was normal. A potential diagnosis of Alport syndrome was contemplated in light of the clinical findings. Genetic analysis revealed a probable compound heterozygous pathogenic variant and a variant of uncertain significance (VUS) in the COL4A3 gene, involving exon 49 and exon 37, consistent with autosomal recessive Alport Syndrome (ARAS).

Given the ocular findings and the known systemic association, the patient was advised lens extraction and intraocular lens implantation to improve vision. The patient and her family were advised genetic counselling and nephrological evaluation and kidney biopsy for further assessment of renal involvement.

Discussion

Heterozygotes with a pathogenic variant often present with hematuria and may occasionally develop proteinuria, hypertension, or mild renal dysfunction. However, unlike X-linked Alport syndrome, these individuals rarely experience the characteristic hearing loss or ocular manifestations.[4] In contrast, our patient demonstrated pathognomic ocular changes and sensorineural hearing loss along with severe proteinuria, despite being heterozygous for ARAS and lacking hematuria or elevated blood pressure.

The ocular manifestations of Alport syndrome are essential diagnostic markers, especially for patients with an incomplete systemic presentation. In our case, genetic testing along with ocular phenotype was instrumental in establishing the diagnosis by confirming the presence of a pathogenic variant, which guided appropriate clinical management. Anterior lenticonus, observed in this case, is a classic finding resulting from defective basement membrane integrity, leading to progressive lenticular deformation. Macular thinning, particularly in the temporal region, has been reported in Alport syndrome and may contribute to visual disturbances. In this case, macular OCT scans confirmed temporal thinning. While less sensitive, OCT provides a more objective assessment compared to peripheral retinopathy.[5] Macular holes, whether lamellar or giant, are rare and are attributed to collagen IV abnormalities affecting the internal limiting membrane (ILM) or Bruch's membrane.[6]

In X-linked disease, anterior lenticonus is seen in about half of affected men but is uncommon in women, whereas in the autosomal recessive form it is frequently present in both sexes. Posterior lenticonus may occur but is rare.[2] In our case, the presence of anterior lenticonus in a female suggested the possibility of autosomal recessive inheritance.

Anterior lenticonus is absent at birth but manifests later in life, with progression as age advances. This lens abnormality leads to increasing myopia and gradual visual decline. In cases where vision is significantly affected, surgical management may be necessary to restore visual function.[2] High myopia, as observed in this patient, is another ocular finding that may be associated with the syndrome.[7] In light of the characteristic ocular manifestations and their established systemic correlation with Alport syndrome, the patient was counseled regarding the need for surgical intervention. Lens extraction with intraocular lens implantation was recommended as the appropriate management strategy to address the anterior lenticonus and associated refractive error, with the goal of improving visual acuity and overall quality of life.

Various studies have shown that X-linked and autosomal recessive Alport syndrome carry the highest risk for progression to kidney failure, as well as nearly all individuals with autosomal recessive inheritance, eventually developing end-stage renal disease. Current guidelines emphasize that individuals with a heterozygous pathogenic COL4A3 or COL4A4 variant should receive renin–angiotensin–aldosterone system (RAAS) blockade as soon as microalbuminuria, hypertension, or renal impairment is detected, as this intervention significantly delays disease progression. Additionally, cascade genetic testing of first-degree relatives is recommended for early identification and management.[4]

In our case, the patient demonstrated marked albuminuria, indicating a high risk for future renal deterioration despite the absence of hematuria or hypertension. Recognizing this early, we promptly referred the patient to a nephrologist for initiation of RAAS blockade, aiming to reduce intraglomerular pressure and slow the decline in kidney function. This highlights the critical role of early detection, supported by genetic confirmation and ocular findings, in enabling timely nephroprotective therapy and improving long-term outcomes.

Although renal disease remains the primary concern in Alport syndrome, ophthalmic evaluation plays a vital role in early diagnosis and disease monitoring. AS-OCT is particularly useful in detecting anterior lenticonus, while macular OCT helps assess retinal changes. Given the progressive nature of the disease, regular ophthalmic follow-up is essential to monitor visual function and detect complications such as retinal detachment.

The coexistence of anterior lenticonus and macular thinning in a highly myopic patient should prompt suspicion

of Alport syndrome, even when renal manifestations are not apparent. This case illustrates the diagnostic relevance of ocular findings in systemic disease and emphasizes the value of genetic testing not only in confirming the diagnosis and guiding prognosis but also in shaping further management and family counseling. Early identification enables timely initiation of RAAS blockade, which can delay or even prevent renal failure, while a multidisciplinary approach optimizes long-term outcomes.

Informed Consent

Obtained.

Conflict of Interest

No conflict of interest

Financial Disclosure

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Case Report

Case Report – Bilateral Manifestation of Terrien's Marginal Degeneration

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Abstract

Purpose: To report our findings in a case of asymmetrically bilateral Terrien's marginal degeneration (TMD) involving the left eye more than the right eye.

Observations: A 35-yr old male visited our OPD with a complaint of diminution of vision in the left eye. He had a history of pterygium surgery in the left eye 20 days back elsewhere. There was no improvement in visual acuity of the left eye with best correction. Slit lamp examination showed bilateral peripheral corneal thinning with neovascularization and central macular grade corneal opacities in the left eye. Corneal topography showed ectatic areas on anterior and posterior elevation map, areas of high-risk corneal thinning on pachymetry in the left eye, high Kmax values in both eyes despite normal corneal pachymetry in the right eye, indicating progression of disease in the right eye as well. Based on slit lamp examination, results of corneal topography, AS-OCT and lipid profile, we diagnosed him as a case of bilateral Terrien's marginal degeneration involving the left eye more than the right eye. The patient is otherwise asymptomatic and was started on lubricants in both eyes with close follow-up.

Conclusion: We found a rare presentation of an early asymmetrically bilateral TMD associated with a history of pterygium. Corneal topography along with slit lamp examination and increased lipid profile levels helped in diagnosing the case as TMD while ruling out other close differentials of the disease like Pellucid marginal degeneration and Keratoconus.

Keywords: Terrien's marginal degeneration (TMD), Ectasia, Corneal topography

Introduction

Terrien's marginal degeneration(TMD) is an uncommon but slowly progressive non-inflammatory, unilateral or asymmetrically bilateral peripheral corneal thinning and is associated with corneal neovascularization, opacification and lipid deposition.

Our report presents an asymmetrically bilateral observation in a 35-year-old male. Informed consent was obtained from the patient for publication of this case report.

Case Report

We report a case of a 35-year-old male with a history of pterygium surgery elsewhere (left eye) 20 days back who presented in our OPD for diminution of vision (left eye). On clinical examination, unaided visual acuity was 20/20 in the right eye (OD) and 20/40 in the left eye (OS) with no further improvement in visual acuity of the left eye. On slit lamp biomicroscopy both eyes showed milky white peripheral corneal opacity involving stroma circumferentially with intact epithelium and sloping edges in superior, nasal and temporal quadrants. Also, an area of wide corneal thinning nasally with superior corneal vascularization and multiple macular-grade corneal opacities in the central cornea with clear cornea in between were additionally seen in the left eye.

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Investigations

The corneal topography(OCULUS Pentacam) in the right eye showed areas of peripheral flattening in all quadrants in the axial map. BAD (Berlin/ Ambrosio Enhanced Ectasia Display) MAP showed Kmax (maximum keratometry value) 48.7D, indicating moderate ectasia risk, with the corneal thickness spatial profile (CTSP) and percentage thickness increase(PTI) showing deviation from normal.

In the left eye, on the axial map, peripheral flattening was observed. BAD map showed high-risk nasal thinnest location(TL) and vertical displacement with high risk of ectasia nasally in anterior and in full periphery except inferiorly in posterior elevation map with Kmax 61.90D. The CTSP and PTI showed deviation from normal and quick sloping (slope before 6mm corneal diameter), denoting high risk of ectasia.

AS-OCT (Huvitz machine) showed characteristic thinning in the peripheral cornea with stromal opacification.

Rest of the general and ocular examination, including fundus, were within normal limits.

The lipid profile of the patient showed increased blood levels of total cholesterol (215 mg/dL), triglyceride level (204 mg/dL), LDL (131.27 mg/dL), VLDL (40.80 mg/dL) and cholesterol/HDL cholesterol/HDL cholesterol/HDL cholesterol / HDL-cholesterol ratio (5.01 mg/dL).

Differential diagnoses are as follows-

- Pellucid marginal degeneration (PMD) – Usually bilateral, clear, inferior (typically 4–8 o'clock) peripheral corneal thinning.[1] Butterfly pattern is seen on corneal topography.
- Keratoconus – Central or paracentral cornea undergoes thinning and steepening, most commonly involving the inferior cornea. This causes high irregular astigmatism and poor visual acuity.[2] On corneal topography, an asymmetrical bow tie pattern is seen.
- Mooren's ulcer – Associated with intense limbal inflammation, conjunctival congestion in one or both eyes. Usually of autoimmune etiology,[3] can be triggered by surgery or trauma.
- Arcus senilis – Age-related change at the limbus, starts at the superior and inferior cornea. Not associated with corneal vascularization.[4]

Treatment

As there was no improvement in visual acuity on best correction in the left eye, we started our patient on lubricant carboxymethyl cellulose 0.5% in both eyes and advised him to avoid rubbing of eyes, use protective eyewear and regular follow-up.

Discussion

TMD is an uncommon but distinct variety of marginal corneal thinning predominantly affecting young males.[5]

It causes non-inflammatory peripheral corneal thinning which may be unilateral, asymmetrically bilateral and is associated with corneal vascularization, opacification and lipid deposition.[5,6] as seen in our case.

Rarely, it can also be associated with pterygium, which was the history finding in this case and the patient can be otherwise asymptomatic.

Classically, there is peripheral flattening and high against-the-rule astigmatism.[7] We observed ectatic areas on the anterior and posterior elevation map, areas of high-risk corneal thinning on pachymetry in the left eye, high Kmax values in both eyes despite normal corneal pachymetry in the right eye, indicating progression of disease in the right eye as well. The spatial profile graphs in both eyes were seen to be deviating from normal in this case, showing quick sloping in the left eye indicating high risk of ectasia, but in the right eye the deviation attributes to the initial progression of disease.

AS-OCT (Huvitz machine) showed characteristic peripheral thinning with stromal opacification.

Biomicroscopy along with symptoms of the patient helps in differentiating TMD from other close differentials of the disease like PMD presenting with typical inferior corneal thinning, Keratoconus having central or paracentral steepening with bow tie pattern on corneal topography, and Mooren's ulcer being a painful condition with marginal ulceration and severe congestion.

Generally, no treatment is required unless perforation or impending perforation occurs. Conservative management for astigmatism includes spectacles or rigid gas permeable contact lenses with close monitoring of corneal thinning.[6]

Conclusion

We found a rare presentation of an early asymmetrically bilateral TMD. Corneal topography along with slit lamp examination and increased lipid profile levels helped in diagnosing the case as TMD. Protection of the ocular surface is the goal of treatment in TMD. Such patients should be educated about their disorder and the need for regular follow-up.

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Case Report

Iron in the Eye-Ocular Siderosis due to Intraocular Foreign Body

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Abstract

Background: Ocular siderosis is a rare condition in which pigmentary and degenerative changes can occur in the eye due to a retained iron-containing intraocular foreign body. In this case study, we present a case of devastating sequelae of a retained intraocular foreign body and the positive visual outcome following its removal.

Case Report: A 32-year-old male presented to the clinic with chief complaints of floaters and a diminution of vision in the left eye for 2 months. The patient had a history of trauma to the left eye with an iron particle 3 years back, for which he took some local treatment. On ocular examination, the anterior segment of the right eye was within normal limits with visual acuity of 6/6 and projection of rays accurate in all quadrants, while the visual acuity of the left eye was finger counting close to face with projection of rays inaccurate in the nasal quadrant. There was a linear inferonasal corneal opacity (2x1 mm in size) with an iris hole of the same dimensions at the 8 o'clock position of the left eye 2 mm from the limbus in the left eye. There was yellow-brown pigment deposition on the lens capsule with broken posterior synechiae of 5 clock hours, from 4' o clock to 9 o'clock in the left eye. On USG, old vitreous hemorrhage was seen in the left eye and CECT revealed a foreign body of size 3.2 x 2.8 mm in size in the left eye. The patient underwent cataract extraction and PPV followed by removal of the iron particle using a 20 G magnet, IOL implantation and cryopexy in the left eye. Postoperative best corrected visual acuity of the patient in the left eye was 6/18.

Conclusion: This case emphasizes the importance of conducting a detailed investigation, especially in the working-age population and those in occupations where penetrating injuries cause retention of intraocular foreign bodies. Prompt diagnosis and early intervention can help in achieving a favorable visual outcome.

Keywords: Ocular siderosis, Intraocular foreign body (IOFB), Trauma, Pars plana vitrectomy (PPV), Visual acuity.

Introduction

It is estimated that about intraocular foreign bodies can be found in 18 to 41% of open globe injuries.[1] Ocular trauma is considered to be a major cause of ocular morbidity in the working population.[2] Penetrating ocular injury with retained intraocular foreign body can often have devastating outcomes and can even lead to blindness or other severe complications.[3] Siderosis bulbi is one such complication that can occur due to a retained iron-containing foreign body. It is a condition in which deposition of iron molecules occurs in the ocular tissues, leading to pigmentary and degenerative changes in the eye.[4] Ocular features of ocular siderosis include iris heterochromia, pupillary mydriasis, cataract, secondary glaucoma, arteriolar attenuation, pigmentary degeneration of the retina, hyperemia or swelling of the optic disc, and cystoid macular edema.[5-7] Moreover, if a thorough investigation of the eye is not done, intraocular foreign bodies can be missed in patients with small self-sealing wounds. Computed tomography (CT) and ultrasonography are considered the gold standard investigations for detecting intraocular foreign bodies.[8] In this case report, we discuss a working personnel who presented with clinical ocular siderosis, with no detectable intraocular foreign body on ultrasonography. The patient had a positive visual outcome after the successful removal of the foreign body.

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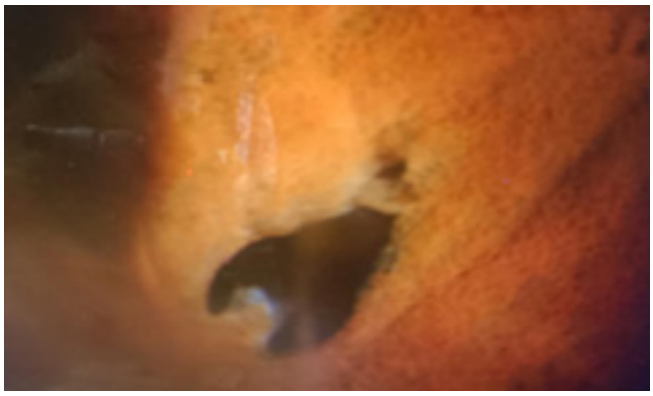

Figure 1: Iris Hole Measuring 2 Mm X 1 Mm

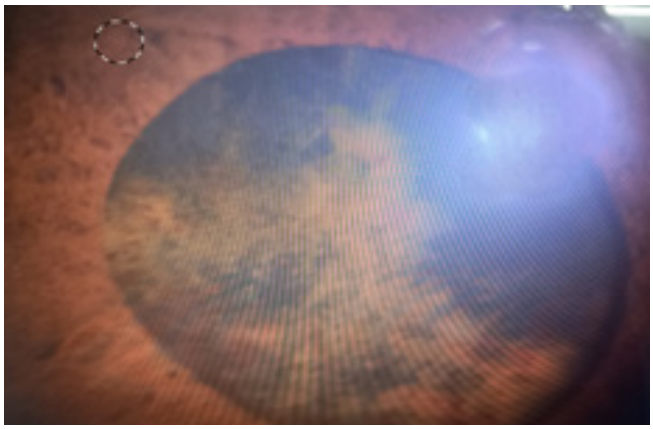

Figure 2: Siderotic Cataract

Case Report

32-year-old male, an ironsmith by profession, came to the Ophthalmology OPD with chief complaints of diminution of vision in the left eye for 2 months, which was insidious in onset, painless and progressive in nature. The patient also gave a history of experiencing floaters for 6 months. On investigating further, the patient revealed that he had a history of trauma to the left eye with an iron particle while working. The patient did not consult any doctor and had started using certain drops on his own. On general examination, the vitals were normal, and the patient was conscious and well-oriented to time, place, and person. On ocular examination, there was no abnormality in the right eye. However, in the left eye, the visual acuity was finger counting close to face with projection of rays accurate in all quadrants, with a linear, inferonasal corneal opacity of size 2 x 1 mm, about 1 mm away from the limbus at the 8 o'clock position. An iris hole of similar dimensions was noted at the 8 o'clock position (Figure 1). There was loss of pattern in some parts of the iris and deposition of iris pigments on the lens capsule (Figure 2). There were posterior synechiae covering 170 degrees, extending from 4 o'clock to 9 o'clock inferiorly. Lenticular opacity was also seen. Visual evoked potential (VEP) revealed normal amplitude and P100 latency in the right eye, while a prolonged P100 latency was seen in the left eye with reduced P100 amplitude. On ultrasonography, vitreous hemorrhage was seen in the posterior segment, but no evidence of a foreign body was found in the left eye (Figure 3). Contrast-enhanced computed tomography was advised, which revealed the presence of an intraocular foreign body of size 3.2 x 2.8 mm in the vitreous cavity of the left eye (Figure 4). The patient was planned for cataract extraction surgery as well as intraocular foreign body removal from the left eye. Manual small incision cataract surgery was planned, and the intraocular foreign body was located. After performing pars plana vitrectomy, the intraocular foreign body was removed using a 20 G intravitreal magnet. Since the size of the foreign body was more than 2 mm, it was first brought into the anterior chamber using vitrectomy forceps (Figure 5). Cryopexy was done to repair the tears in the peripheral retina. A sulcus-fixated intraocular lens was implanted in the left eye, followed by instillation of antibiotic drops and steroid ointment. On postoperative day 2, the best corrected visual acuity of the patient in the left eye was 5/60. The patient had striate keratopathy and anterior uveitis in the left eye (Figure 6). The patient was followed up after 15 days and the best corrected visual acuity was 6/60 in the left eye. Posterior segment did not show any abnormality (Figure 7).

Discussion

Ocular siderosis is a clinical presentation that can occur due to retained intraocular iron foreign body leading to changes in the iris (iris heterochromia, 58.33%) and lens (cataract, 95.83%). [9] Additionally, in 58.33% of the cases, pigmentary degeneration may be found in the retina as well.[8-10] Cataract is considered to be one of the hallmark indicators of early

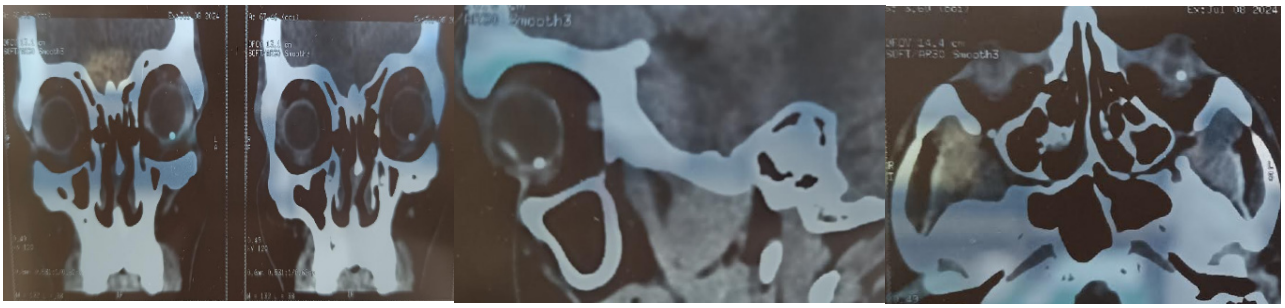

Figure 3: CT Scan Showing Intraocular Foreign Body

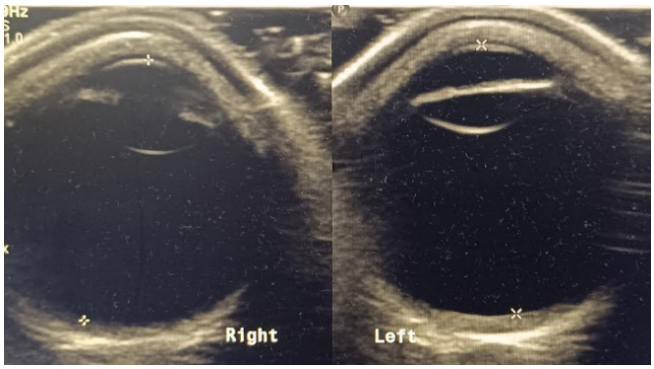

Figure 4: Ultrasonography did not reveal the presence of foreign body

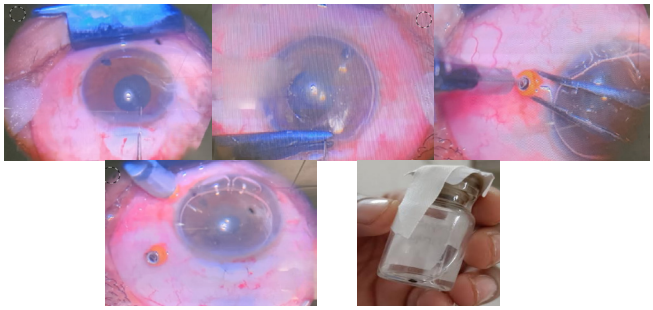

Figure 5: Intraop Photos

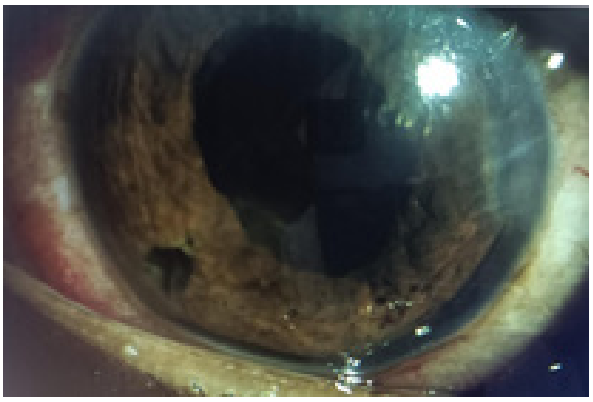

Figure 6: Post Operative Day 2

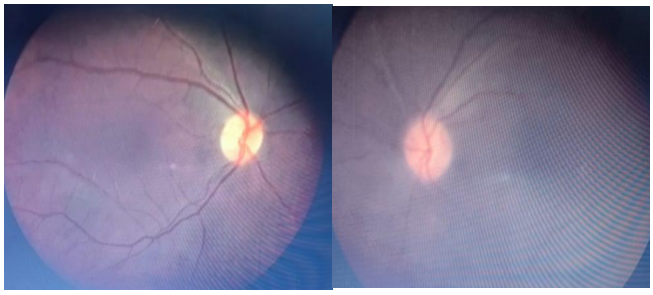

Figure 7: Fundus Photos of Right Eye and Left Eye (Post Operative)

siderosis. It can occur due to deposition of iron in the epithelial cells of the anterior capsule, resulting in numerous brownish spots or rusty spots. As the condition worsens, the entire lens can become deep yellow with rusty brown patches.[9] Moreover, the changes that occur in siderosis become irreversible after a certain stage. Therefore, early detection of metallic foreign bodies and their removal is recommended for all patients. This can prevent further damage to the ocular tissues due to iron and can preserve ocular functions. Computed tomography is considered a gold standard for the early detection of foreign bodies.[8] However, certain cases have been reported in which intraocular foreign bodies were missed on CT scan. This could be due to the small size of the foreign body, which can be missed in scans that produce contiguous 2 mm images. Ultrasonography is often helpful in detecting intraocular foreign body but its efficacy depends on the operator's skill. Moreover, chronic retention of iron can be difficult to identify as iron may undergo dissolution over time.[10] Siderosis bulbi can also impair the function of all layers of the retina and can cause reversible damage in the early stages of the disease. Electrophysiology is considered to be a valuable tool in assessing retinal function and the extent of the damage.[9] Pars plana vitrectomy is preferred to remove intraocular foreign bodies. An early intervention is recommended to prevent vision-threatening complications such as endophthalmitis and siderosis.[9] A newer surgical technique known as "handshake technique" has been described to remove all sizes of intraocular foreign bodies by using two intraocular magnets.[11]

Conclusion

Ocular siderosis may develop within a few days to several years depending on the dimensions of the intraocular foreign body, its shape, location, and associated tissue reaction. A complete ophthalmological examination is mandatory to get an accurate view of anterior and posterior segments. Despite clinical improvement, intraocular foreign bodies are often overlooked due to delayed presentation and missed diagnosis.

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Case Series

Surgical Principles of Repair in Fresh and Old Periocular Lacerations for Good Functional and Aesthetic Outcomes at a Tertiary Care Center: A Case Series

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Abstract

Aim: To analyse surgical principles for repair in periocular lacerations.

Materials and Methods: A retrospective review of clinical notes and photographs was conducted over a period of 2 years (November 2023- december 2025). Patients presenting with eyelid and /or periocular lacerations and canalicular lacerations were included. Patients with associated globe injuries, orbital and facial bone fractures, intracranial injuries and who failed to follow-up for at least 3 months were excluded from the study. Detailed clinical data analysed were demography (age, sex, laterality), type and mode of injury, wound location, dimensions, presence of orbital fat in wound, involvement of canthi and/or canaliculi, surgical techniques, type of sutures, use of stents, postoperative functional and aesthetic outcomes.

Results: A total of five patients were included; three patients had a primary trauma, one underwent revision of primary repair done elsewhere and one had lateral canthal web correction due to an old mismanaged laceration. All patients were males with a mean age of 26 ± 17.12 years. One patient had both upper and lower lid lacerations involving lid margins with a lower canalicular tear with no visible fat in the wound in the left eye. One patient had only an upper lid tear with lid margin involvement with an upper canalicular tear with visible fat in the wound in the right eye. Two patients had only lower lid tear with lid margin involvement with lower canalicular tear in the left eye with no visible fat in the wound. One patient had lateral canthal injury with web formation in the right eye and imbricated upper lid following repair elsewhere. The best corrected visual acuity was 6/6, N6 in all patients. All patients were advised for CT scan of the orbits to rule out orbital fractures and/or intraorbital foreign bodies and were repaired using standard surgical principles. They did well functionally and aesthetically in the postoperative period till a follow-up of 3 months with no postoperative complications. The canalicular stents were removed at 6 weeks postoperatively and lacrimal sac syringing was done. The lacrimal passages were patent till 3 months of follow-up.

Conclusion: Periocular lacerations involving eyelid margin, canaliculi, canthi and/or orbital septum must be repaired meticulously using standard surgical techniques, preferably by an oculoplastic surgeon, to avoid postoperative complications.

Keywords: Periocular lacerations, Eyelid injuries/lacerations, Lacrimal system injuries, Canalicular lacerations, Lateral canthal web.

Introduction

The eyelids, which protect the globe against external factors, are frequently affected by orbital and periorbital trauma. Eyelid traumas encompass a wide spectrum, ranging from simple lacerations to more severe injuries that can lead to deeper tissue damage and vision-threatening globe injuries.

The causes of eyelid trauma are often preventable, vary in frequency according to age group, socio-economic status, and

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geographical region, and include workplace-related injuries, falls, traffic accidents, sports injuries, and assaults.[1]

Eyelid lacerations present with various findings, such as partial- or full-thickness lid defects, canalicular damage, and accompanying ocular damage.[2,3]

If not promptly and appropriately treated, these injuries can result in serious anatomic and functional problems, including lid deformities, ocular surface disorders, and associated ocular morbidity.[4] Incomplete or inadequate repair of the eyelids may lead to complications such as entropion, ectropion, trichiasis, and epiphora, significantly affecting the patient's quality of life.[4,5]

The aim of this case series is to emphasize the role of meticulous surgical repair to achieve satisfactory cosmetic and functional outcomes with nil/ minimal postoperative complications.

Materials And Methods

A retrospective case series including five patients was conducted over a period of two years (November 2023-december 2025). Patients presented with eyelid lacerations, canthal injuries and canalicular lacerations were included.

Patients with associated globe injuries, orbital and facial bone fractures and intracranial injuries and who failed to follow up for at least 6 months, were excluded from the study.

Detailed clinical data were collected including case notes, demographic data (age, sex, laterality), type and mode of injury, size, depth and position of eyelid lacerations, presence of orbital fat in wound, involvement of canthi and/or canaliculi. The surgical techniques applied for repair, type of sutures (absorbable/non-absorbable), type of stents used in canalicular lacerations and postoperative functional and aesthetic outcomes were analysed. All patients were advised for CT scan of the orbits to rule out orbital fractures and/or intraorbital foreign bodies.

Patients presented with fresh injuries were surgically repaired within 12 to 24 hours of the injury to minimize future complications.

The process began with apposing the lid margin with 2-3 6-0 polypropylene (Prolene) sutures at the meibomian gland orifice plane and at a plane just anterior to the grey line. The orbital septum, if breached, was not sutured as this can lead to postoperative lid retraction. Then, the tarsus was reapproximated using partial-thickness 6-0 polyglactin sutures. The underlying conjunctiva should not be taken in these sutures. The marginal sutures put initially were then tied, leaving long ends. The rest of the skin lacerations were then sutured with 5-0 polypropylene in interrupted fashion. The long ends of marginal sutures were secured in one of the skin sutures on the lid.

If there was a canalicular injury, the procedure involved approximating the two edges of the canaliculus using a self-retaining monocanalicular stent (mini-Monoka), followed by lid repair as described above. The distal cut end of the canaliculus was identified by pushing air through the opposite intact canaliculus with pressure on the lacrimal sac and watching for air bubbles popping from the presumed distal cut end. Also, the white and glistening annular fibres of the distal cut end of the canaliculus were identified in the surrounding pink orbicularis under the operating microscope at higher magnification.

In a patient with an old healed lateral canthal web with upper lid imbrication, double Z plasty was done at the lateral canthus to release the scar tissue along with lateral canthotomy and lateral canthal reconstruction.

After repair, topical antibiotic ointment was applied to the wound. Oral antibiotics and anti-inflammatory medications were prescribed. The non-absorbable sutures were removed on the 10th day. The stents were removed, followed by syringing with normal saline at 6th week postoperatively.

Results

The case series included five patients, all males; right eye: left eye = 2:3, canalicular involvement in four (80%) patients, and loss of lateral canthal angle with web formation in one (20%) patient. The orbital septum was breached in one (20%) patient, indicated by the presence of orbital fat in the wound. Primary suturing was performed in patients with fresh injury and the tissues could be approximated to their normal anatomical position. In cases of canalicular lacerations, self-retaining monocanalicular silicone stents were used. One patient was taken up for re-suturing with lower canalicular stenting due to poor approximation during primary repair done elsewhere, one week back. In a patient with an old healed lateral canthal web with upper lid imbrication, double Z plasty was done followed by lateral canthopexy.

All patients were symptom-free with good cosmetic and functional results till 3 months of follow-up. The MRD-1 and 2 were within normal limits in all cases. In 2 cases, there was minimal lagophthalmos with good Bell's phenomenon with no corneal exposure (Table 1).

Case-history

Case-1- 10 year old male with both upper and lower lid lacerations involving margins with lower canalicular tear in left eye following injury due to fall from a tree. Presented with pain, swelling, bleeding, watering in left eye. There was no diminision of vision. On examination, his globe was intact with normal visual acuity and fundus. CT-scan orbit was normal. He was repaired using standard surgical techniques and did well in postoperative period.

Table 1: good cosmetic and functional results till 3 months of follow-up

Case	*MRD-1 (mm)*	*MRD-2 (mm)*	*Lagophthalmos (mm)*
1	3	6	0.5
2	3	5	1
3	5	5	0
4	3	5	0
5	4	5	0

Case-2- 21 year old male, presented with right eye upper lid laceration with upper canalicular tear following assault.There was orbital fat in wound. He had watering in right eye with pain, swelling and bleeding in the wound. His visual acuity, fundus, CT-scan orbits were normal. He was repaired and did well in postoperative period.

Case-3-55 years old male, juice-vendor by occupation, presented with left eye lower lid tear involving margin with lower canalicular laceration following injury with knife while cutting fruits. He had watering in left eye with pain, swelling, bleeding in the wound. His visual acuity, fundus, CT-scan orbits were normal. He was repaired and did well in postoperative period.

Case-4-25 years old male, with left eye lower lid laceration involving lower canaliculus following road-traffic accident. He had pain, swelling and bleeding in the wound. He was repaired elsewhere, one week back with no satisfactory apposition. His visual acuity, fundus, CT-scan orbits were normal. He was re-sutured with stenting of lower canaliculus and did well in postoperative period.

Case-5-19 years old male, with history of right eye injury following fall from tree. He was primarily repaired at a trauma centre and presented with watering with foreign body sensation in right eye at our centre, five months after injury. He had loss of lateral canthal angle with web formation with hypertrophied scar tissue with imbricated upper lid. He had complaint of watering and foreign body sensation. His visual acuity, fundus, CT-scan orbits were normal. He was repaired using double Z-plasty technique with 6-0 polyglactin sutures and lateral canthal reconstruction was done to reform the lateral canthal angle. The scar tissue and upper lid were released with cosmetic improvement. The patient was comfortable till 6 months of follow-up.

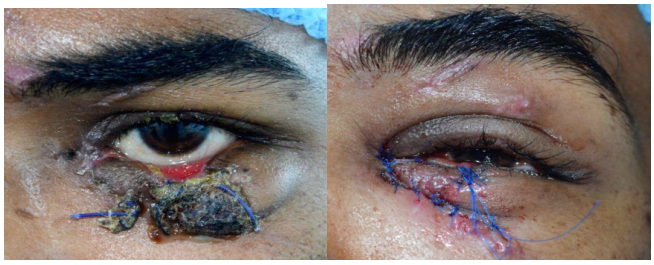
Discussion

Eyelid lacerations (EL) are common ophthalmic injuries that require prompt assessment and appropriate management to minimize the risk of complications. Consistent with other studies, our results showed that EL are more common in men.[1,2] In a publication conducted in Türkiye, similar to our results, the reported ratio was 3.75:1.7.[13] This may be related to the more frequent participation of men in activities that can increase the risk of eye injury, such as occupational or industrial activities (construction, manufacturing), sports or recreational activities (contact sports, shooting, hunting), and certain hobbies (woodworking, metalworking).[12]

Case 1: 10 year old male with left eye upper and lower lid lacerations with lower canalicular involvement (pre and postop pics)

Case 2: 21 year old male with right eye upper lid laceration with canalicular involvement with presence of orbital fat in the wound (pre and postop pics)

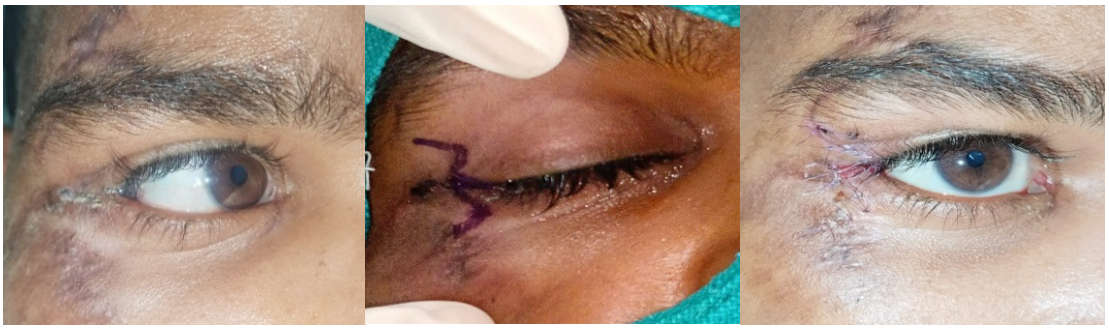
Case 3: 55 year male with left lower lid injury with lower canaliculus involvement (pre and postop pics)



Case 4: 25 year old male with left eye lower lid laceration with lower canalicular involvement with resuturing and stent placement (preop and posop pics)

Considering the distribution of EL by age group in the literature, most injuries were reported in adolescence and the average age was around 30 years. Of the total, 23% of patients were between the ages of 0 to 9 years, 18% were between the ages of 9 to 18 years and 6% were aged 60 and over.[6] These results may be attributed to a higher level of active work participation among individuals aged 20 to 50. The results of our study are consistent with the literature. Most of the patients (80%) were between the ages of 19 and 64; the mean age was 26 years, 20% were aged less than 18 years, and no patient was aged over 65.

Considering the etiology of injury in the literature, the prevalence in different countries may vary due to differences in geographical location and socio-economic status. Regional variations in lifestyle, occupational hazards, and cultural practices may also influence the etiology of EL. In one study, 59.9% of EL were caused by road accidents, followed by



Case 5: 19 year old male with right lateral canthal web with imbricated upper lid, underwent double Z-plasty with lateral canthotomy and lateral canthal reconstruction (preop, intraop and postop pics)

assault (13.6%), animal attacks (12.7%), and falls (9%)(2). In our study, the most common cause was fall (40 %), followed by road accident, assault and occupational injury in 20 % each.

Kumar and Batham[2] reported that the most common accompanying finding was subconjunctival hemorrhage, followed by hyphema, conjunctival laceration, traumatic lens injury, and corneal laceration. Tabatabaei et al.(11) reported that globe injury was present in 6.1%. In our case series, all cases with these associated injuries were excluded.

The most commonly reported late complication of EL is lid notching, which usually results from improper approximation or development of a wound gap.[6] Kumar and Batham[2] also reported lid notching (6.3%), hypertrophic scars (1.8%), ptosis (2.7%), tearing (2.7%), and lagophthalmos (0.9%) as other complications. In our study, no patient presented with such late complications. Most complications can be prevented through careful and effective primary closure. Complications tend to arise when closure is delayed or when tissue approximation is poorly executed. In the literature, the anatomical success rate of canalicular laceration repair ranges between 75% and 100%, while the functional success rate is in the range of 58-96%.[7,8] Qin et al.[5] reported that epiphora following canalicular trauma might be associated with the time elapsed from injury to repair, duration of stent placement, structural abnormalities in the medial canthus, and distance between the distal cut end and the lacrimal punctum. In our study, no patient complaint of watering in late postoperative visits and syringing was patent in all patients after stent removal.

Study Limitations

The limitations of our study include the small sample size and the fact that it was conducted at a single center, which may limit the generalizability of the findings. The main reason for the small sample size was the exclusion of patients who had other globe or orbital injuries. Additionally, the study had a relatively short follow-up period, which limited our ability to observe long-term outcomes and complications.

Conclusion

Like other types of trauma, EL are more commonly observed in young adults and men. Considering this, it is crucial to provide preventive advice and implement safety measures in workplaces to reduce the incidence of preventable injuries. The most frequent mechanisms of injury involve trauma with sharp objects, while falling is the leading cause. Notably, EL involving the lacrimal passage is predominantly associated with falls. It is important to note that eyelid traumas are often accompanied by severe ocular pathologies such as conjunctival laceration, hyphema, corneal abrasion, and corneoscleral perforation. In particular, traffic accidents and injuries caused by blunt objects were the most commonly reported etiologic factors in patients presenting with these ocular pathologies.

Overall, a comprehensive understanding of EL, their etiologic factors, associated ocular injuries, and appropriate management strategies is crucial in achieving optimal outcomes and preserving both the functional and aesthetic aspects of the eyelids.

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