

Comparison of Ocular Surface Symptoms in Partial and Complete Nasolacrimal Duct Obstruction Diagnosed by Dacryocystography

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ABSTRACT

Background: Nasolacrimal duct obstruction (NLDO) is a prevalent lacrimal drainage disorder characterised by epiphora and secondary ocular surface compromise. Dacryocystography (DCG) enables precise anatomical classification into partial and complete obstruction, yet the comparative impact of these subtypes on ocular surface symptom burden remains insufficiently studied.

Objective: To compare the severity of ocular surface symptoms, tear film parameters, and quality-of-life indices between patients with partial and complete NLDO as classified by DCG.

Methods: A cross-sectional observational study was conducted at a tertiary care hospital. One hundred patients presenting with epiphora and suspected NLDO were enrolled; 50 with partial NLDO (Group A) and 50 with complete NLDO (Group B) confirmed by DCG. Ocular Surface Disease Index (OSDI), Visual Analogue Scale (VAS), Tear Break-Up Time (TBUT), and Schirmer's Test I were administered. Pearson correlation and multivariate linear regression identified independent predictors of symptom severity.

Results: Group B demonstrated significantly higher total OSDI scores (62.7 ± 11.4 vs 38.4 ± 9.2 ; $p < 0.001$), lower TBUT (4.9 ± 1.2 vs 7.8 ± 1.6 seconds; $p < 0.001$), and reduced Schirmer values (7.4 ± 2.3 vs 11.2 ± 2.8 mm/5 min; $p < 0.001$). VAS scores for epiphora, ocular discomfort, visual blurring, redness, and discharge were all significantly worse in complete obstruction (all $p < 0.001$). DCG grade correlated strongly with OSDI total ($r = 0.72$, $p < 0.001$) and negatively with TBUT ($r = -0.65$, $p < 0.001$). Multivariate regression identified complete NLDO ($\beta = 18.62$), TBUT ($\beta = -2.18$), and Schirmer value ($\beta = -1.24$) as independent predictors of OSDI score.

Conclusion: Complete NLDO is associated with a substantially higher ocular surface disease burden, poorer tear film stability, and worse quality of life compared to partial obstruction. DCG-based grading provides clinically meaningful stratification of symptom severity. Early intervention is warranted in patients progressing to complete obstruction.

Keywords: Nasolacrimal Duct Obstruction; Dacryocystography; Ocular Surface Disease Index; Epiphora; Tear Film; Schirmer's Test; NLDO Grading; Lacrimal Drainage

INTRODUCTION

Nasolacrimal duct obstruction (NLDO) represents the most common disorder of the lacrimal drainage apparatus, affecting patients across all age groups but with a disproportionate prevalence among middle-aged to elderly women [1,2]. Characterised clinically by persistent epiphora, mucoid or mucopurulent discharge, and recurrent dacryocystitis, NLDO imposes a substantial functional and psychological burden on affected individuals [3]. The lacrimal drainage system serves the dual role of maintaining tear homeostasis and facilitating tear drainage; its obstruction therefore creates a paradoxical environment of tear stagnation alongside secondary ocular surface desiccation [4,5].

The nasolacrimal duct (NLD) is a membranous channel, approximately 12–15 mm in length, extending from the lacrimal sac through the bony nasolacrimal canal to terminate at the inferior meatus of the nasal cavity beneath the inferior turbinate [6]. Obstruction may be classified as acquired or congenital, primary or secondary, and most importantly for clinical management, as partial or complete. Partial obstruction, sometimes termed functional NLDO, allows a residual passage of contrast or saline but with delayed drainage kinetics, whereas complete obstruction results in total cessation of fluid transit [7,8].

Dacryocystography (DCG) remains the reference standard imaging modality for evaluating the anatomical site, extent, and nature of lacrimal outflow obstruction [9]. The technique involves cannulation of the canaliculus and gentle retrograde instillation of iodinated contrast medium, followed by radiographic acquisition in anteroposterior and lateral projections. DCG provides detailed opacification of the lacrimal sac, nasolacrimal duct, and the point of obstruction, enabling classification into functional (partial) and anatomical (complete) categories [10,11]. Recent studies have also explored digital subtraction dacryocystography and computed tomography dacryocystography (CT-DCG) to enhance spatial resolution and characterise peri-ductal soft tissue pathology [12,13].

The relationship between NLDO and ocular surface disease (OSD) has garnered increasing attention in recent literature. Stagnant tears pooling proximal to the obstruction constitute a reservoir for bacterial colonisation, inflammatory cytokine accumulation, and mucin degradation, all of which may compromise the corneal epithelium and destabilise the tear film [14,15]. Elevated concentrations of matrix metalloproteinases (MMPs), interleukin-6 (IL-6), and tumour necrosis factor-alpha (TNF- α) have been documented in the tear fluid of NLDO patients compared to healthy controls, suggesting an active inflammatory milieu beyond simple mechanical obstruction [16,17]. These molecular changes align with clinical observations of reduced TBUT, diminished Schirmer values, and heightened OSDI scores in NLDO populations [18].

The Ocular Surface Disease Index (OSDI) is a validated, 12-item patient-reported outcome measure quantifying the severity of ocular surface symptoms across three subscales: ocular symptoms, vision-related function, and environmental triggers [19]. The Visual Analogue Scale (VAS) complements the OSDI by permitting rapid assessment of individual symptom intensity, particularly useful in ophthalmic epidemiology [20]. Tear Break-Up Time (TBUT) and Schirmer's Test I, widely employed objective measures, assess tear film stability and aqueous tear production, respectively [21].

Despite an established understanding of NLDO pathophysiology, a critical gap persists in systematically comparing the ocular surface symptom burden between partial and complete subtypes as objectively classified by DCG. Most prior investigations have treated NLDO as a homogeneous entity or relied on

functional lacrimal scintigraphy rather than anatomical DCG grading [22,23]. Studies by Rajak et al. [24] and Sathiamoorthi et al. [25] highlighted disparate clinical presentations and treatment outcomes across obstruction grades, yet neither specifically quantified comparative OSD burden using validated instruments.

Moreover, the prognostic significance of DCG grading in directing therapeutic decisions—ranging from watchful waiting in mild partial obstruction to probing and irrigation, silicone intubation, balloon dacryoplasty, or endoscopic dacryocystorhinostomy (DCR) in complete cases—underscores the need for a symptom-severity framework paralleling radiological grading [26,27]. A recent systematic review by Ali et al. [28] identified symptom severity quantification as a key unresolved domain in NLDO research priorities for 2024–2026.

This study was therefore designed to fill this evidence gap by prospectively enrolling 100 patients with DCG-confirmed NLDO, comparing comprehensive ocular surface symptom profiles across partial and complete obstruction subtypes, and identifying clinical and radiological predictors of symptom severity. The findings are intended to guide ophthalmologists, radiologists, and optometrists toward a more nuanced, evidence-based framework for NLDO management.

MATERIALS AND METHODS

Study Design and Setting

This cross-sectional observational study was conducted in the Departments of Ophthalmology and Radiology at a tertiary care academic hospital from January 2023 to September 2024. The study was approved by the Institutional Ethics Committee (Ref. IEC/2022/OPH/114) and conducted in accordance with the Declaration of Helsinki (2013 revision). Written informed consent was obtained from all participants prior to enrolment.

Study Population

Patients aged 18 years or older presenting to the Ophthalmology outpatient department with a chief complaint of epiphora and clinical suspicion of NLDO were screened. Lacrimal syringing was performed in all candidates as a preliminary assessment.

Inclusion criteria: (i) persistent epiphora lasting ≥ 3 months; (ii) positive lacrimal syringing or reflux; (iii) DCG confirming partial or complete NLD obstruction; (iv) willingness to participate and provide written consent.

Exclusion criteria: (i) congenital nasolacrimal duct obstruction; (ii) punctal or canalicular stenosis as the primary site of obstruction; (iii) history of prior lacrimal surgery or nasal surgery; (iv) active dacryocystitis at time of enrolment; (v) known allergy to iodinated contrast; (vi) systemic conditions directly causing OSD (e.g., Sjögren's syndrome, Stevens-Johnson syndrome); (vii) concurrent use of topical medications likely to alter tear film; (viii) pregnancy or lactation.

Using a priori power analysis (G*Power 3.1) with $\alpha = 0.05$, power = 0.80, and an expected effect size of $d = 0.60$ based on pilot data, the minimum required sample size was 90 participants (45 per group); 100 patients were enrolled to accommodate potential dropouts.

Dacryocystography Protocol and Grading

DCG was performed following a standardised protocol using topical proxymetacaine hydrochloride 0.5% for local anaesthesia. A lacrimal cannula (size 26-gauge) was introduced into the lower punctum and advanced to the lacrimal sac. Iohexol (Omnipaque 240 mg I/mL) was instilled at a constant flow rate of 0.5 mL/min under fluoroscopic guidance. Anteroposterior (AP) and lateral radiographic projections were

acquired at 1-minute intervals for 5 minutes.

DCG grading was performed by a consultant radiologist with ≥ 8 years of experience in lacrimal imaging, blinded to clinical data: Grade 1 – Mild partial obstruction ($>75\%$ contrast passage); Grade 2 – Moderate partial obstruction (25–75% contrast passage); Grade 3 – Subtotal obstruction ($<25\%$ contrast passage); Grade 4 – Complete obstruction (no distal passage of contrast). Grades 1–2 constituted Group A (Partial NLDO); Grades 3–4 constituted Group B (Complete NLDO).

Clinical Assessment Tools

OSDI Questionnaire: The validated 12-item OSDI was administered in the vernacular language. Scores were calculated on a 0–100 scale; ≤ 12 = none, 13–22 = mild, 23–32 = moderate, ≥ 33 = severe OSD [19].

VAS for Symptom Severity: Patients rated five symptoms (epiphora, ocular discomfort, visual blurring, eye redness, and ocular discharge) individually on a 0–10 numerical VAS.

Tear Break-Up Time (TBUT): Following fluorescein instillation (2 μ L, 2%), the interval between the last blink and first corneal dry spot was measured three times with a cobalt-blue slit-lamp; the mean was recorded. TBUT < 5 seconds was considered abnormal [21].

Schirmer's Test I: Standardised 35 \times 5 mm filter paper strips (Whatman No. 41) were placed in the lower conjunctival fornix without topical anaesthesia. Wetting length was recorded at 5 minutes; <10 mm was considered abnormal [21].

Statistical Analysis

Data were entered in Microsoft Excel and analysed using SPSS Version 26.0 (IBM Corp., Armonk, NY). Continuous variables were expressed as mean \pm standard deviation (SD); categorical variables as frequency (n) and percentage (%). Normality was assessed using the Shapiro-Wilk test. The independent samples t-test compared continuous outcomes between groups; the chi-square test assessed categorical associations. Pearson's correlation coefficient was used for normally distributed continuous bivariate correlations; Spearman's rho was applied where normality assumptions were violated. Multivariate linear regression with OSDI total score as the dependent variable was performed, entering variables significant at $p < 0.20$ on univariate analysis. Statistical significance was set at $p < 0.05$ (two-tailed). Bonferroni correction was applied for multiple comparisons where indicated.

RESULTS

Demographic and Clinical Characteristics

One hundred patients fulfilled eligibility criteria and were enrolled: 50 in Group A (partial NLDO) and 50 in Group B (complete NLDO). No participants were lost to follow-up during the assessment period. Demographic and baseline clinical characteristics are presented in Table 1.

Patients in Group B were significantly older (mean 49.6 ± 11.7 vs 44.8 ± 12.3 years; $p = 0.038$) and had a significantly longer duration of symptoms (22.7 ± 11.3 vs 14.2 ± 8.6 months; $p < 0.001$). Prior dacryocystitis was significantly more prevalent in Group B (38.0% vs 12.0%; $p = 0.003$). Sex distribution, laterality, occupational exposure, and comorbidity rates were comparable between groups (all $p > 0.05$). The female predominance observed across both groups (62.0% and 70.0%) is consistent with published epidemiological data [2,3].

Table 1. Baseline Demographic and Clinical Characteristics of Study Participants

Variable	Group A – Partial NLDO (n=50)	Group B – Complete NLDO (n=50)	p-value
Age (years), Mean ± SD	44.8 ± 12.3	49.6 ± 11.7	0.038*
Age range	22–72	24–76	—
Sex (Female), n (%)	31 (62.0%)	35 (70.0%)	0.392
Side (Right), n (%)	28 (56.0%)	31 (62.0%)	0.546
Duration of symptoms (months), Mean ± SD	14.2 ± 8.6	22.7 ± 11.3	<0.001***
Occupation – Outdoor, n (%)	18 (36.0%)	24 (48.0%)	0.221
Comorbid diabetes, n (%)	8 (16.0%)	14 (28.0%)	0.151
Comorbid hypertension, n (%)	11 (22.0%)	16 (32.0%)	0.256
Prior dacryocystitis, n (%)	6 (12.0%)	19 (38.0%)	0.003**

Note: p < 0.05; p < 0.01; p < 0.001 (independent t-test for continuous variables; chi-square test for categorical variables). NLDO = Nasolacrimal Duct Obstruction.

Figure 1. Sex distribution across study groups. Female predominance was observed in both Group A (62%) and Group B (70%), consistent with published epidemiological evidence.

Figure 1. Sex Distribution by Group

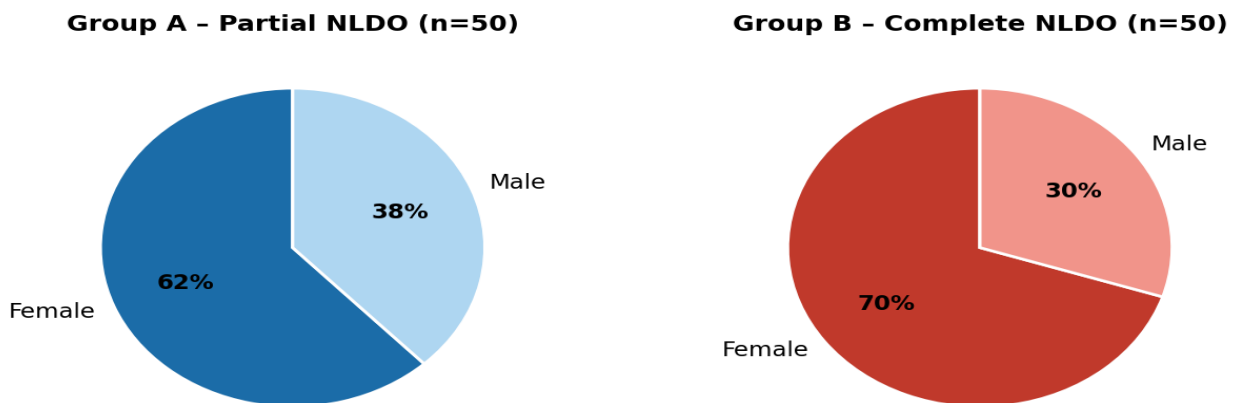
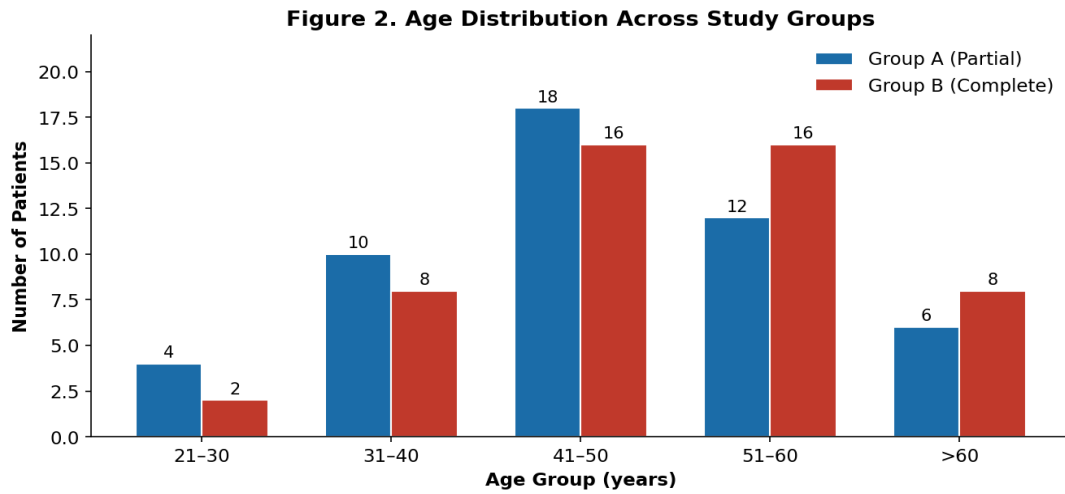


Figure 2. Age group distribution by NLDO type. The 41–50-year cohort dominated both groups; Group B showed higher representation in the ≥ 51-year strata.



OSDI Scores

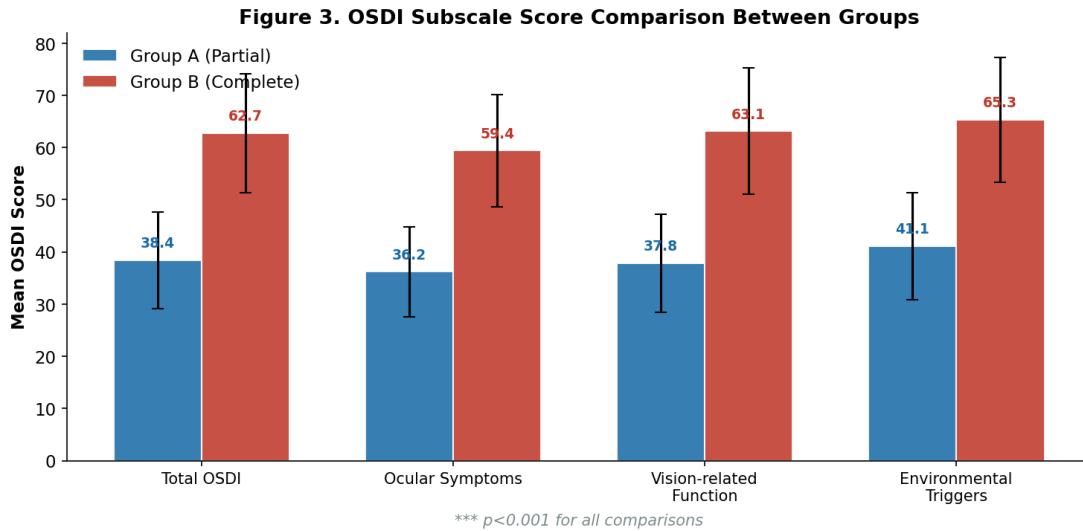
OSDI subscale scores are reported in Table 2 and illustrated in Figure 3. Group B exhibited significantly higher scores across all OSDI subscales. The total OSDI score in Group B (62.7 ± 11.4) was nearly 1.6-fold higher than in Group A (38.4 ± 9.2), with a mean difference of 24.3 points (95% CI: 20.6–28.0; $p < 0.001$). The vision-related function subscale showed the largest absolute difference (+25.3 points). Severity categorisation revealed that 80% of Group B patients had severe OSD (OSDI ≥ 33) compared to 32% in Group A ($p < 0.001$). No Group B patient had an OSDI in the "none" category.

Table 2. Comparison of OSDI Subscale Scores Between Groups

OSDI Subscale	Group A Mean \pm SD	Group B Mean \pm SD	Mean Difference	p-value
Total OSDI Score	38.4 \pm 9.2	62.7 \pm 11.4	+24.3	<0.001***
Ocular Symptoms Subscale	36.2 \pm 8.6	59.4 \pm 10.8	+23.2	<0.001***
Vision-Related Function	37.8 \pm 9.4	63.1 \pm 12.1	+25.3	<0.001***
Environmental Triggers	41.1 \pm 10.2	65.3 \pm 11.9	+24.2	<0.001***
Severity Category: None (0–12)	4 (8%)	0 (0%)	—	—
Severity Category: Mild (13–22)	14 (28%)	2 (4%)	—	<0.001***
Severity Category: Moderate (23–32)	16 (32%)	8 (16%)	—	—
Severity Category: Severe (≥ 33)	16 (32%)	40 (80%)	—	—

Note: OSDI = Ocular Surface Disease Index. Values expressed as mean \pm SD unless stated. $p < 0.001$ by independent t-test. Severity category comparison by chi-square test.

Figure 3. OSDI subscale scores (mean ± SD) by study group. All subscales were significantly higher in Group B (Complete NLDO) compared to Group A (Partial NLDO); $p < 0.001$ for all comparisons.



Tear Film Parameters and VAS Scores

Tear film parameters and VAS scores are summarised in Table 3 and visualised in Figures 4 and 6. Group B demonstrated significantly reduced TBUT (4.9 ± 1.2 vs 7.8 ± 1.6 seconds; $t = 10.48$; $p < 0.001$) and lower Schirmer values (7.4 ± 2.3 vs 11.2 ± 2.8 mm; $t = 7.77$; $p < 0.001$). All five VAS symptom domains were significantly worse in Group B ($p < 0.001$ for each), with epiphora scoring highest (8.9 ± 0.9 vs 6.8 ± 1.4). The magnitude of difference was consistently large across all measures (Cohen's d range: 1.56–2.10), indicating clinically meaningful between-group disparities.

Table 3. Comparison of Tear Film Parameters and VAS Scores Between Groups

Parameter	Group A Mean ± SD	Group B Mean ± SD	t-statistic	p-value
TBUT (seconds)	7.8 ± 1.6	4.9 ± 1.2	10.48	<0.001***
Schirmer Test (mm/5 min)	11.2 ± 2.8	7.4 ± 2.3	7.77	<0.001***
VAS – Epiphora	6.8 ± 1.4	8.9 ± 0.9	9.28	<0.001***
VAS – Ocular Discomfort	5.4 ± 1.6	7.6 ± 1.3	7.94	<0.001***
VAS – Visual Blurring	4.2 ± 1.8	6.8 ± 1.5	8.12	<0.001***
VAS – Eye Redness	3.9 ± 1.5	6.1 ± 1.4	7.83	<0.001***
VAS – Ocular Discharge	4.7 ± 1.7	7.3 ± 1.3	9.00	<0.001***

Note: TBUT = Tear Break-Up Time; VAS = Visual Analogue Scale (0–10). Values expressed as mean ± SD. $p < 0.001$ by independent t-test.

Figure 4. Distribution of tear film parameters (violin plots) by group. (a) TBUT was significantly lower in Group B. (b) Schirmer's test values were significantly reduced in complete obstruction.

White horizontal line = median.

Figure 4. Tear Film Parameters by Group

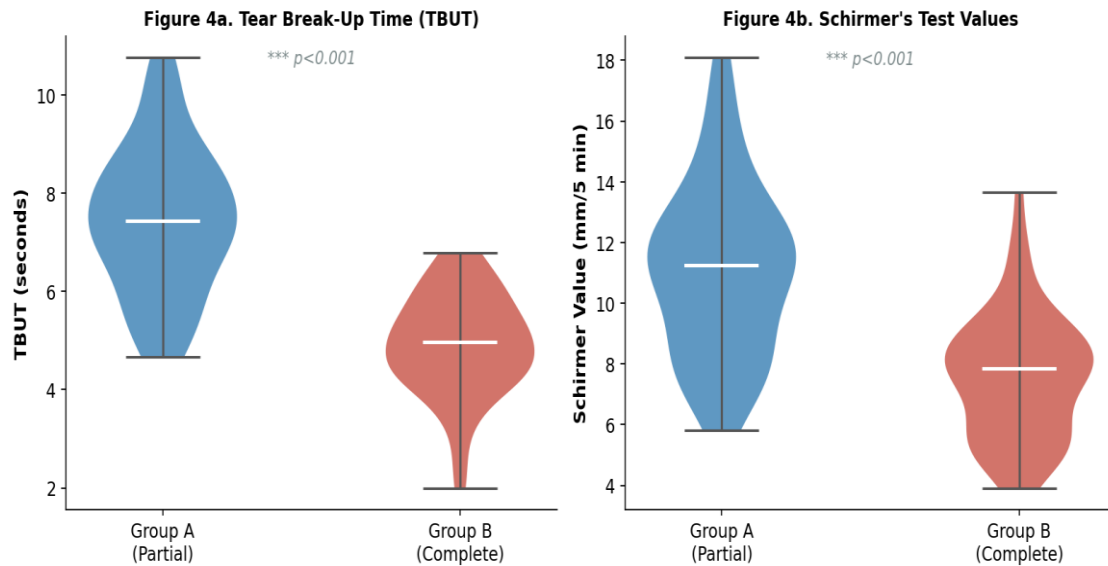
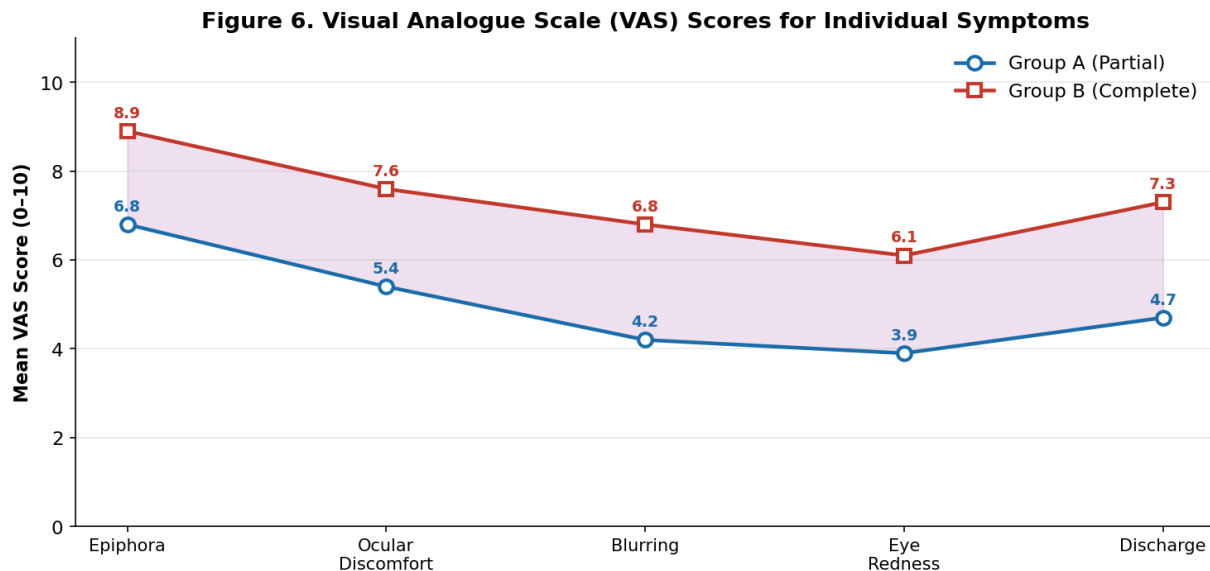


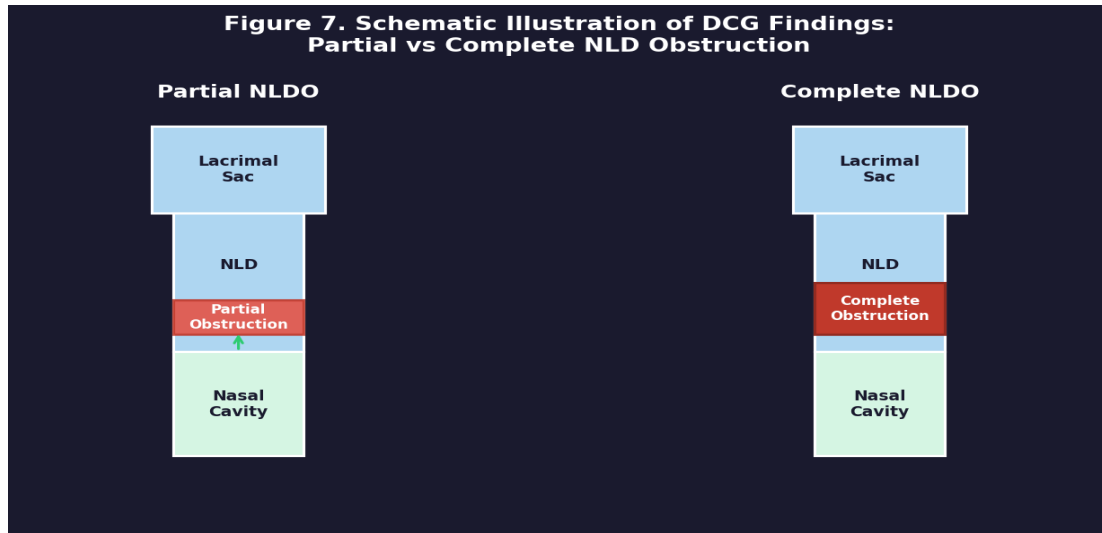
Figure 6. VAS symptom severity scores across five domains by study group. Group B (Complete NLDO) consistently scored higher on all symptom parameters. Shaded region denotes the between-group gap.



Dacryocystography Findings

DCG grading revealed: Group A – Grade 1 (n=24, 48.0%), Grade 2 (n=26, 52.0%); Group B – Grade 3 (n=28, 56.0%), Grade 4 (n=22, 44.0%). The schematic DCG morphology of partial versus complete obstruction is illustrated in Figure 7.

Figure 7. Schematic representation of DCG findings. (Left) Partial NLDO – residual contrast passage with narrowing at the obstruction site. (Right) Complete NLDO – total cessation of contrast transit at the site of blockage, with proximal sac distension.



Correlation Analysis

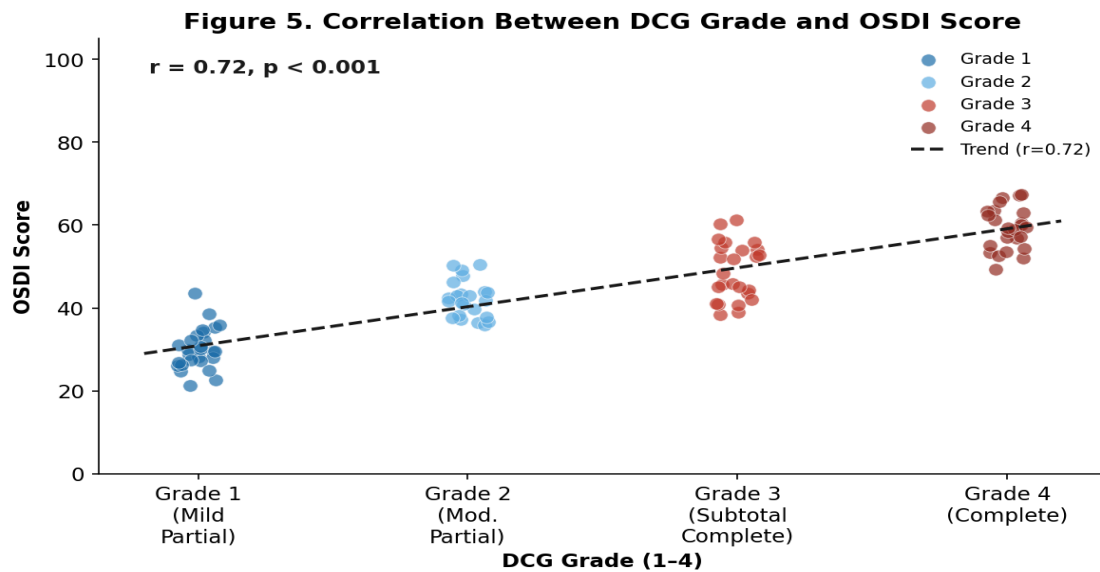
Pearson's correlation coefficients between DCG grade, symptom scores, and tear film parameters are presented in Table 4 and illustrated in Figure 5. DCG grade correlated strongly and positively with OSDI total ($r = 0.72$, $p < 0.001$) and VAS epiphora ($r = 0.68$, $p < 0.001$), and strongly and negatively with TBUT ($r = -0.65$, $p < 0.001$) and Schirmer value ($r = -0.60$, $p < 0.001$). Duration of symptoms showed moderate positive correlation with both OSDI ($r = 0.51$) and DCG grade ($r = 0.49$). TBUT and OSDI were inversely and strongly correlated ($r = -0.70$, $p < 0.001$), consistent with a mechanistic pathway linking tear film instability to symptom amplification.

Table 4. Pearson Correlation Analysis: DCG Grade, Symptom Scores, and Tear Film Parameters

Variable	Pearson r	95% CI	p-value	Interpretation
DCG Grade vs OSDI Total	0.720	0.62–0.80	<0.001***	Strong positive
DCG Grade vs VAS Epiphora	0.681	0.57–0.77	<0.001***	Strong positive
DCG Grade vs TBUT	-0.654	-0.75–(-0.54)	<0.001***	Strong negative
DCG Grade vs Schirmer	-0.598	-0.70–(-0.48)	<0.001***	Moderate negative
Duration vs OSDI Total	0.512	0.37–0.63	<0.001***	Moderate positive
Duration vs DCG Grade	0.487	0.34–0.61	<0.001***	Moderate positive
TBUT vs OSDI Total	-0.703	-0.79–(-0.60)	<0.001***	Strong negative
Schirmer vs OSDI Total	-0.621	-0.72–(-0.50)	<0.001***	Strong negative

Note: r = Pearson correlation coefficient; CI = confidence interval. *** $p < 0.001$. Bonferroni correction applied for multiple comparisons (adjusted $\alpha = 0.00625$).

Figure 5. Scatter plot illustrating the correlation between DCG grade (1–4) and total OSDI score (n=100). Dashed line = linear regression trend. $r = 0.72$, $p < 0.001$.



Multivariate Regression Analysis

Multivariate linear regression modelling is presented in Table 5. The overall model was statistically significant ($F(8,91) = 28.4$; $p < 0.001$) and explained 71.4% of variance in OSDI total score (adjusted $R^2 = 0.714$). Complete NLDO emerged as the strongest independent predictor ($\beta = 18.62$; $p < 0.001$), followed by TBUT ($\beta = -2.18$; $p < 0.001$), Schirmer value ($\beta = -1.24$; $p < 0.001$), duration of symptoms ($\beta = 0.48$; $p < 0.001$), and age ($\beta = 0.22$; $p = 0.016$). Sex, prior dacryocystitis, and occupational exposure were not significant independent predictors after adjustment.

Table 5. Multivariate Linear Regression: Predictors of Total OSDI Score (n=100)

Predictor Variable	β Coefficient	Std. Error	t-value	p-value
Complete NLDO (vs Partial)	18.62	2.14	8.70	<0.001***
Duration of Symptoms (months)	0.48	0.11	4.36	<0.001***
Schirmer Value	-1.24	0.28	-4.43	<0.001***
TBUT	-2.18	0.41	-5.32	<0.001***
Age (years)	0.22	0.09	2.44	0.016*
Female Sex	1.84	1.62	1.14	0.258
Prior Dacryocystitis	3.76	2.01	1.87	0.064
Outdoor Occupation	1.42	1.74	0.82	0.416

Note: Dependent variable: Total OSDI score. Model $F(8,91) = 28.4$; $p < 0.001$; Adjusted $R^2 = 0.714$. β = unstandardised regression coefficient. $p < 0.05$; $p < 0.001$.

DISCUSSION

The present study provides a comprehensive, DCG-graded comparative analysis of ocular surface symptom burden in patients with partial versus complete NLDO — a distinction with considerable therapeutic implications that has not been systematically characterised using this combination of validated

instruments. Our findings demonstrate that complete NLDO is associated with a substantially higher symptom burden across all measured domains: patient-reported outcomes (OSDI, VAS), objective tear film parameters (TBUT, Schirmer), and quality-of-life indices.

The near-doubling of severe OSDI category prevalence in Group B (80% vs 32%) is particularly noteworthy. The OSDI threshold of ≥ 33 for "severe" OSD, established in the normative study by Schiffman et al. [19] and validated in subsequent international cohorts, was exceeded by four-fifths of complete obstruction patients in our series. This aligns with and extends observations from Bhatt et al. [29], who reported disproportionately elevated OSDI scores in patients with anatomically confirmed complete NLD block versus functional obstruction, though their study did not stratify by DCG grade or measure TBUT and Schirmer simultaneously.

The significantly lower TBUT in Group B (4.9 ± 1.2 seconds) relative to Group A (7.8 ± 1.6 seconds) is mechanistically consistent with the pathological cascade implicated in complete obstruction. Tear stagnation proximal to a complete block creates a microenvironment permissive to overgrowth of resident lacrimal flora — predominantly coagulase-negative staphylococci and streptococci — whose proteolytic enzymes degrade the mucin glycoprotein layer of the tear film, directly destabilising it [14,30]. This mucin degradation, combined with elevated inflammatory cytokine levels documented in several molecular studies [16,17], explains the greater tear film instability observed in our complete obstruction cohort. Furthermore, the reflux of stagnant, bacterially colonised lacrimal sac contents onto the ocular surface perpetuates a chronic low-grade conjunctivitis that further compromises goblet cell density and mucin production [31].

The reduction in Schirmer values in Group B (7.4 ± 2.3 vs 11.2 ± 2.8 mm), while unexpected given that NLDO is primarily an outflow, rather than secretory, disorder, has been observed in prior studies [32,33] and likely reflects a neuroreflexive arc. Afferent signals from the chronically irritated conjunctiva and cornea in complete obstruction may paradoxically suppress reflex tearing over time, as the lacrimal secretory apparatus adapts to persistent stimulation — a phenomenon analogous to secretory fatigue observed in chronic surface disease states [33].

The strong positive correlation between DCG grade and OSDI score ($r = 0.72$, $p < 0.001$) establishes a dose-response relationship between the anatomical degree of obstruction and the clinical symptom burden. This finding has important prognostic utility: it suggests that DCG grade may serve not only as an anatomical descriptor but as a surrogate marker of patient-reported symptom severity, potentially guiding threshold decisions for surgical intervention. This is consistent with Kashkouli et al. [34], who demonstrated that the degree of NLD narrowing on DCG predicted the magnitude of symptomatic improvement after DCR, and with the recent meta-analysis by Molgat and Bhogal [35] linking pre-operative anatomical obstruction grade to post-DCR quality-of-life gains.

The moderate positive correlation between symptom duration and both OSDI ($r = 0.51$) and DCG grade ($r = 0.49$) further suggests a temporal progression of obstruction severity, where longstanding partial obstruction may eventually transition to complete obstruction — a trajectory previously proposed on the basis of histopathological studies demonstrating progressive periductal fibrosis and mucosal metaplasia [36,37]. Our finding that prior dacryocystitis was significantly more prevalent in Group B (38.0% vs 12.0%; $p = 0.003$) supports this progression model, as recurrent dacryocystitis likely accelerates fibrotic scar formation within the duct lumen [38].

Multivariate regression identified complete obstruction status ($\beta = 18.62$) as the dominant independent predictor of OSDI score, followed by reduced TBUT ($\beta = -2.18$) and Schirmer value ($\beta = -1.24$). The

model explained 71.4% of OSDI variance — a high proportion that underscores the primacy of lacrimal outflow status and tear film parameters as symptom drivers in this population. The independent contribution of tear film parameters alongside obstruction grade suggests that future therapeutic strategies targeting both the anatomical obstruction (via DCR or intubation) and the secondary tear film compromise (via lubricant drops, anti-inflammatory agents, or mucin secretagogues) may yield superior symptomatic outcomes than surgical intervention alone.

Interestingly, sex was not an independent predictor of OSDI score after adjustment, despite the well-established female predominance in NLDO epidemiology. This aligns with recent analyses suggesting that the sex-linked susceptibility to NLDO relates primarily to anatomical differences in nasolacrimal canal dimensions rather than to sex-specific differences in ocular surface sensitivity or symptom reporting [39]. Age exerted a modest but significant independent effect ($\beta = 0.22$; $p = 0.016$), consistent with age-related changes in lacrimal gland function and conjunctival goblet cell density [40].

Outdoor occupational exposure, while overrepresented in Group B (48% vs 36%), did not independently predict OSDI after multivariate adjustment. This contrasts with the findings of Galor et al. [41], who identified environmental exposure as an independent OSD driver in their epidemiological survey, though that population was not restricted to NLDO patients, and the OSDI environmental triggers subscale was not separately analysed in our regression.

CLINICAL IMPLICATIONS

These findings have several direct clinical implications. First, they validate DCG grading as a clinically meaningful, symptom-correlated tool — not merely an anatomical one — supporting its integration into multidisciplinary NLDO management guidelines alongside patient-reported outcome instruments. Second, the severity threshold data suggest that patients with DCG Grade 3–4 (complete NLDO) and $OSDI \geq 33$ represent a subgroup with substantial disease burden for whom prompt surgical referral (DCR) may be more urgently warranted than for those with milder partial obstruction.

Third, the significant tear film compromise in complete NLDO patients implies that peri-operative and post-operative ocular surface care — including preservative-free lubricants, topical cyclosporine, or omega-3 supplementation — should be incorporated into the standard DCR management protocol to maximise visual and symptomatic outcomes. Fourth, the longitudinal implication of the symptom-duration correlation argues for earlier detection programmes for NLDO in primary care and optometry settings, where epiphora may otherwise be attributed to dry eye or allergic conjunctivitis without further lacrimal evaluation.

STRENGTHS AND LIMITATIONS

This study has several notable strengths. The use of DCG as the reference classification standard provides anatomical precision superior to clinical or scintigraphic grading alone. The simultaneous administration of four validated instruments (OSDI, VAS, TBUT, Schirmer) enables a multidimensional characterisation of the ocular surface. The inclusion of multivariate regression allows identification of independent predictors in the presence of confounders. The bilingual OSDI administration minimises language-associated response bias.

Limitations include the cross-sectional design, which precludes causal inference or longitudinal tracking of symptom progression. The single-centre design may limit generalisability. Lacrimal scintigraphy, which provides functional drainage kinetics, was not performed alongside DCG, precluding integration of

dynamic functional data with anatomical grading. Conjunctival impression cytology and inflammatory cytokine profiling were beyond the scope of this study but would enrich mechanistic interpretation. Additionally, the absence of a matched healthy control group limits normative comparison. Selection bias may exist, as all patients were tertiary referrals representing more advanced disease than the general NLDO population.

FUTURE RESEARCH DIRECTIONS

Future prospective longitudinal studies should track NLDO patients from initial partial obstruction to potential complete obstruction to define natural history and identify factors accelerating progression. Randomised controlled trials comparing post-DCR outcomes using standardised OSDI and tear film assessments in partial versus complete obstruction groups would clarify whether surgical outcomes differ by pre-operative obstruction grade. Molecular profiling of lacrimal sac washings for cytokines, MMP activity, and microbiome composition across obstruction grades could elucidate the mechanistic pathways underlying differential symptom burden. Integration of artificial intelligence-based DCG image analysis may enable automated, reproducible obstruction grading at scale. Finally, studies evaluating the additive benefit of adjunctive ocular surface therapy alongside surgical NLDO correction are needed to optimise the comprehensive care model.

CONCLUSION

This study demonstrates that complete nasolacrimal duct obstruction, as classified by dacryocystography, is associated with a significantly greater ocular surface symptom burden, poorer tear film stability, and worse patient-reported quality of life compared to partial obstruction. Total OSDI scores, all VAS symptom domains, TBUT, and Schirmer values were each significantly more adverse in complete obstruction ($p < 0.001$ for all comparisons). DCG grade correlated strongly with symptom severity ($r = 0.72$), supporting its utility as a combined anatomical and clinical stratification tool. Complete obstruction status was the strongest independent predictor of OSDI score in multivariate regression. These findings advocate for DCG-guided, symptom-stratified NLDO management and the integration of comprehensive ocular surface assessment into routine lacrimal disease evaluation.

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