Clinical science

In vivo lacrimal gland imaging artefact assessment based on swept-source optical coherence tomography for dry eye disease

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ABSTRACT

Background This study aimed to characterise imaging artefacts in the lacrimal gland using swept-source optical coherence tomography (SS-OCT) in patients with dry eye disease (DED) and healthy participants and identify risk factors for these artefacts.

Methods In total, 151 eyes, including 104 from patients with DED and 47 from non-DED participants, were analysed. Demographic data collection, comprehensive ocular examinations and SS-OCT imaging of the palpebral lobe of the lacrimal gland were performed. Artefacts were classified into distinct categories with different severities. Univariate and multivariate logistic regression analyses were performed to evaluate the association of age, gender, best-corrected visual acuity, intraocular pressure (IOP) and the presence of DED with the presence of artefacts.

Results Eight artefact types and severity grading were defined by analysing 1208 lacrimal SS-OCT images. The three most prevalent artefacts were defocus (75.83%), cliff (67.47%) and Z-off (58.44%). The presence of artefacts was significantly associated with the presence of DED (OR=9.13; 95% CI, 2.39 to 34.88; p=0.001) and higher IOP (OR=1.34; 95% CI, 1.14 to 1.58; p<0.001). Furthermore, multivariate logistic analyses showed that lower tear film breakup time (OR=0.71; 95% CI, 0.55 to 0.92; p=0.009) and higher meibum quality score (OR=2.86; 95% CI, 1.49 to 5.48; p=0.002) were significantly associated with higher odds for the presence of artefacts.

Conclusions DED eyes had more SS-OCT image artefacts than normal eyes. Stringent standardised image quality control should be implemented before further image analysis when using SS-OCT to assess lacrimal gland image.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Traditional imaging methods lack the resolution and affordability required for detailed lacrimal gland analysis. Although optical coherence tomography (OCT) offers enhanced imaging capabilities, significant challenges with artefacts persist.

WHAT THIS STUDY ADDS

⇒ This study has developed a quality control methodology for lacrimal gland imaging using swept-source OCT. It has identified that dry eye disease and elevated intraocular pressure are risk factors for the occurrence of imaging artefacts.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This study provides vital insights for optimising the acquisition of lacrimal gland images in vivo, which is essential for enhancing future clinical applications.

INTRODUCTION

Optical coherence tomography (OCT) is a novel method for high-resolution, real-time imaging of the lacrimal system.[1] Evaluating the lacrimal gland in vivo has traditionally relied on MRI, CT and ultrasound.[2–4] However, these techniques have low resolution, high cost and lack quantifiable indicators, which limit their clinical application in lacrimal gland imaging. In a previous study, in vivo images of the lacrimal gland parenchyma from cross-sections of the palpebral lobe were obtained for the first time using spectral-domain optical coherence tomography (SD-OCT).[1] A subsequent study showed that OCT allows clearly observing the excretory openings on the palpebral lobe to visualise tear secretion,[5] and OCT can also be used to image punctum and vertical canaliculus.[6–8] Swept-source OCT (SS-OCT) is characterised by higher speed and resolution than SD-OCT and has superior penetration, enabling more robust and clearer imaging.[9] However, in vivo imaging evaluation of lacrimal glands based on SS-OCT has not been performed.

Assessing artefacts is critical for any novel ophthalmic imaging modality because they can lead to diagnostic and quantitative analysis errors.[10] Previous research on OCT and OCT angiography image artefacts has effectively promoted image quality and interpretation.[11–13] Similarly, conducting strict quality control is essential to reduce artefact interference on standardised quantitative measurements before applying SS-OCT for lacrimal gland imaging in research and clinical practice. The lacrimal gland is the primary organ that secretes tears and is closely related to the occurrence of dry eye disease (DED).[14] However, no studies have

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examined the distribution of lacrimal image artefacts and risk factors of the presence of artefacts.

Therefore, this study aimed to identify the types, frequency and distribution of artefact in lacrimal SS-OCT images from patients with DED and healthy participants and determine the risk factors for artefact occurrence.

MATERIALS AND METHODS

Study design and participants

This cross-sectional study was conducted at the Zhongshan Ophthalmic Center, Sun Yat-sen University, China, and enrolled individuals from October 2020 to December 2022. The study followed the Declaration of Helsinki Signed informed consent was obtained from all participants.

All individuals visited the hospital dry eye clinic are eligible to participate. Interested patients are scheduled for a comprehensive ocular evaluation, including lacrimal gland OCT imaging. Participants were excluded with: intraocular pressure (IOP)>21 mm Hg; refractive error (spherical equivalent) >+3.0 dioptres (D) or <−6.0 D; ocular diseases that may involve the lacrimal gland, like dacryoadenitis, lacrimal gland masses; other active ocular surface diseases, like infectious keratitis, allergic conjunctivitis or other pathological conditions besides DED; systemic diseases that may involve the lacrimal gland, like immunoglobulin G4-related diseases, Sjögren's syndrome and sarcoidosis; history of ocular surgery/trauma; history of ocular tumour; history of contact lens wearing in the past 6 months; allergy to fluorescein sodium; and unable to cooperate.

Data collection

General information

Demographic details and medical backgrounds of the patients were collected, which included age, gender, height, weight, prior medication use and medical history.

Ocular examination

All patients underwent complete ocular examinations, including visual acuity, IOP, slit-lamp biomicroscopy, fundus photography, corneal fluorescein sodium staining, TFBUT (tear film breakup time), Schirmer's test and meibomian gland assessment. IOP was measured using a Topcon CT-80A non-contact tonometer (Topcon, Tokyo, Japan).

Tear secretion was determined using Schirmer's tests. Sterile paper strips were applied to the inferior-temporal aspect of the conjunctival sac of both eyes. The wetted length in millimetres was measured after 5 min. Schirmer's test I without anaesthesia measured the total tear secretion, the sum of reflex and basal tear flow. Schirmer's test II measured the reflex secretion only and involved nasal stimulation after inserting the strip.

Meibomian gland function was assessed using the following four indices: meibomian gland loss score, lid margin abnormality score, meibum quality score and meibum expressibility. Meibography was performed using a Keratograph 5M (Oculus GmbH, Wetzlar, Germany), and the meibomian gland loss score was defined as 0–3 (0, no meibomian gland dropout; 1, <1/3 dropout; 2, 1/3–2/3 dropout; and 3, >2/3 dropout). Lid margin abnormality was scored from 0 to 4 based on the number of the following four abnormalities: lid margin irregularity, lid margin telangiectasia, lid margin hyperaemia and thickening of the eyelid margin. Meibum quality was graded on a scale of 0–3 (0, clear; 1, cloudy; 2, granular; and 3, toothpaste). Meibum expressibility was evaluated via the secretory capacity of the five meibomian glands in the middle of the upper lid after compression from 0 to 3 (0, all glands secreted; 1, 3–4 glands secreted; 2, 1–2 glands secreted; and 3, no gland secreted).[15] Meibomian gland function was assessed as the sum of the four scores; the higher the total score, the worse the meibomian gland function.

SS-OCT scan of the palpebral lobe of the lacrimal gland

Using a commercially available SS-OCT (BM400K BMizar, TowardPi Medical Technology, Beijing, China), all study participants also underwent the palpebral lacrimal gland imaging performed by an experienced technician (JC). In detail, the operator instructed the patient to gaze inferiorly to the nose while pushing the patient's eyelids superiorly temporally to expose the palpebral lacrimal gland. The SS-OCT was positioned at the centre of the lacrimal gland lid, and eight cross-sectional images were acquired with the following parameters: anterior chamber high-resolution mode, scanning speed of 400 000 scans/s, length of 16 mm, depth of 6 mm and resolution of 3.8 µm.

Diagnosis of DED

The diagnosis for DED follows the consensus report by the Asia Dry Eye Society: Ocular Surface Disease Index (OSDI)>13 and TFBUT<5.[16] The severity of DED was categorised by OSDI as mild (13–22), moderate (23–33) or advanced (34–100).[17] The study design is illustrated in figure 1.

Assessment of artefacts and quality of lacrimal gland images

Definition and grading of lacrimal gland images

Eight artefact categories were defined after an initial review of >1300 lacrimal OCT images: reflection, projection, defocus, cliff, blink, Z-off, shadow and motion (online supplemental table 1). Figure 2 presents a representative illustration of each artefact. The artefacts were also categorised into three levels based on the degree to which the image is affected: 0, no artefacts; 1, mild impact; and 2, severe impact (online supplemental table 2). Online supplemental figure 1 presents representative artefacts of different severity levels. Two independent, blinded analysts evaluated each image, with discrepancies resolved by a third-party adjudicator.

Quality control of lacrimal gland images

Quantity and severity-based indicators were used in this study. These indicators were determined based on previous studies.[18 19] For the amount-based indicators, researchers only need to count the number of artefacts without assessing their severity. The image quality was poor when the number of artefacts exceeded 25. For the severity-based indicators, researchers need to first grade the severity of each artefact and then count those classified as severe. The image quality was poor when the number of severe artefacts exceeded 10. Eight lacrimal gland images for each examined eye were analysed as a unit.

Statistical analysis

Demographic and clinical characteristics were summarised using the mean±SD or the median with IQR, depending on the normality of the continuous variables or numbers with proportions for categorical variables. Binary logistic regression analysis was performed to assess the factors affecting OCT image quality with an amount-based image quality indicator and a severity-based image quality indicator as outcome indicators. Three models were applied to investigate the risk factors of image quality. Model 1 is a crude model; model 2 is adjusted for age and gender; model 3 is further adjusted for IOP and best corrected visual acuity (BCVA). P value<0.05 was considered

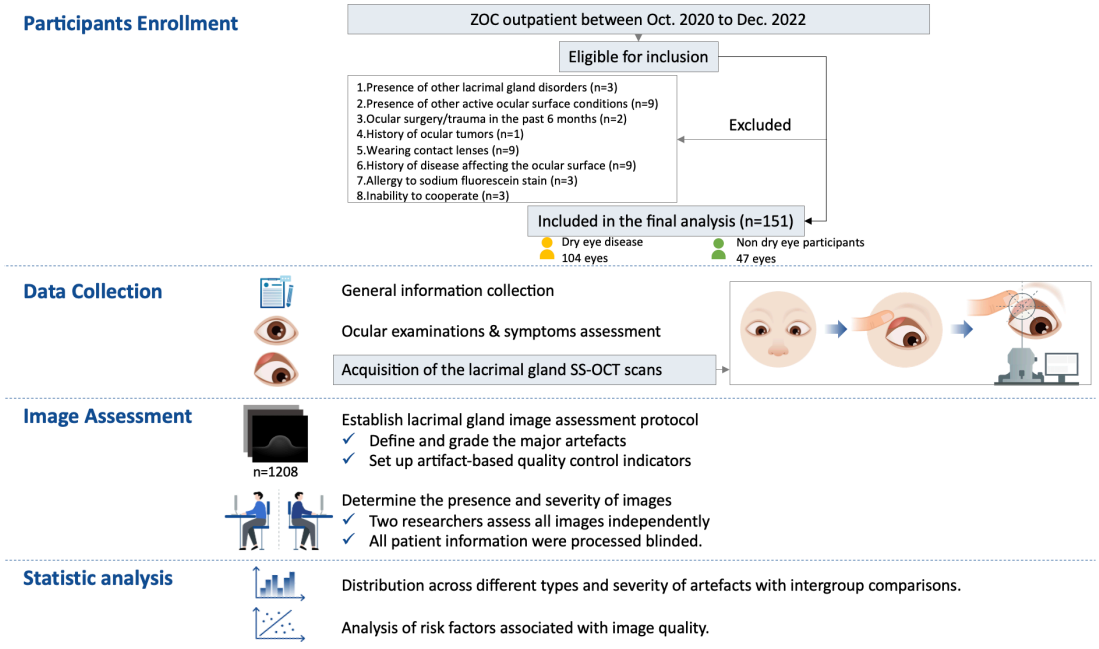

Figure 1 Workflow of this study.

SS-OCT, swept-source optical coherence tomography; ZOC, Zhongshan Ophthalmic Center.

indicative of a statistically significant difference. To ascertain the influence of dry eye symptoms on image quality, we compare the image quality across patients exhibiting different severity of symptoms. Images from the right eyes of 20 participants were obtained twice at an interval of 8 hours. Bland-Altman analysis was used to evaluate the repeatability of artefact assessment. All data analyses were performed using Stata (Stata V.17.0, StataCorp, College Station, Texas, USA).

RESULTS

Demographic and clinical characteristics of participants

Out of 190 eyes examined, 39 were excluded due to factors such as other lacrimal gland disorders (n=3), other active ocular surface conditions (n=9), recent ocular surgery or trauma (n=2), history of ocular tumours (n=1), contact lens wear (n=9), diseases affecting the ocular surface (n=9), sodium fluorescein allergy (n=3) and inability to cooperate (n=3) (figure 1). The final analysis included 151 eyes—104 from patients with DED and 47 from non-DED participants. Table 1 summarises the demographics, ocular symptoms and examination results. The average OSDI score among participants was 35.38±16.35. The average score of meibomian gland function was 7.70±2.99. Tear secretion measurements, obtained via Schirmer's tests I and II, yielded an average of 4 mm/5 min (range 2–10 mm/5 min), whereas the mean TFBUT was 2.82±1.68 s.

Artefact distribution of lacrimal gland SS-OCT images

The severity-based image quality assessment revealed that 26% of the eyes exhibited suboptimal image quality owing to artefacts, aligning with the 27% from the amount-based image quality assessment. Patients with DED exhibited a significantly higher propensity for poor image quality than non-DED participants (33% vs 13%, p=0.010) (online supplemental table 4). Measurements of the repeatability of the artefacts assessment revealed ICC (intraclass correlation coefficient) >0.80 for both indicators (amount-based indicator: ICCs=0.82 (95% CI, 0.771 to 0.872); severity-based indicator: ICCs=0.81 (95% CI, 0.748 to 0.864)). The Bland-Altman plots showed good intraobserver agreement (online supplemental figure 4).

Associated factors with artefacts and quality of SS-OCT scans

The severity-based indicator was significantly associated with DED status (OR=9.13, 95% CI, 2.39 to 34.88, p=0.001) and elevated IOP (OR=1.34, 95% CI, 1.14 to 1.58, p<0.001) after adjusting for age, gender, IOP and BCVA. And the amount-based indicator was significantly associated with DED and elevated IOP in a multivariate analysis (DED: OR=3.88, 95% CI, 1.29 to 11.70, p=0.016; IOP: OR=1.27, 95% CI, 1.10 to 1.48, p=0.002) (table 2).

Furthermore, the relationship between DED-related metrics and image quality was investigated, which incorporated tear secretion, tear film stability and meibomian gland functionality (online supplemental table 5 and online supplemental table 6). The multifactor model adjusted for age, gender, IOP and BCVA revealed that a 1 s increase in TFBUT reduced the occurrence of artefacts by 34% (OR=0.66, 95% CI, 0.50 to 0.86, p=0.002; table 3). Similarly, the amount-based quality assessment also found significant associations between decreased TFBUT (OR=0.71, 95% CI, 0.55 to 0.92, p=0.009) and worsened meibum quality (OR=2.86, 95% CI, 1.49 to 5.48, p=0.002) with the occurrence of image artefacts.

DISCUSSION

Artefacts are a common limitation of all imaging devices, especially with relatively new techniques such as lacrimal gland cross-section imaging. This study showed that artefact prevalence and severity increase with the severity of DED, which provides an objective overview of the factors to consider in the clinical use of lacrimal gland SS-OCT imaging.

This study is the first to identify the eight artefact types and distributions in lacrimal gland imaging on SS-OCT in patients with DED and healthy participants. Artefacts were common in lacrimal gland OCT images, primarily defocus (75.83%). Artefacts distorted ultrastructural and physical shapes in 26–27% of

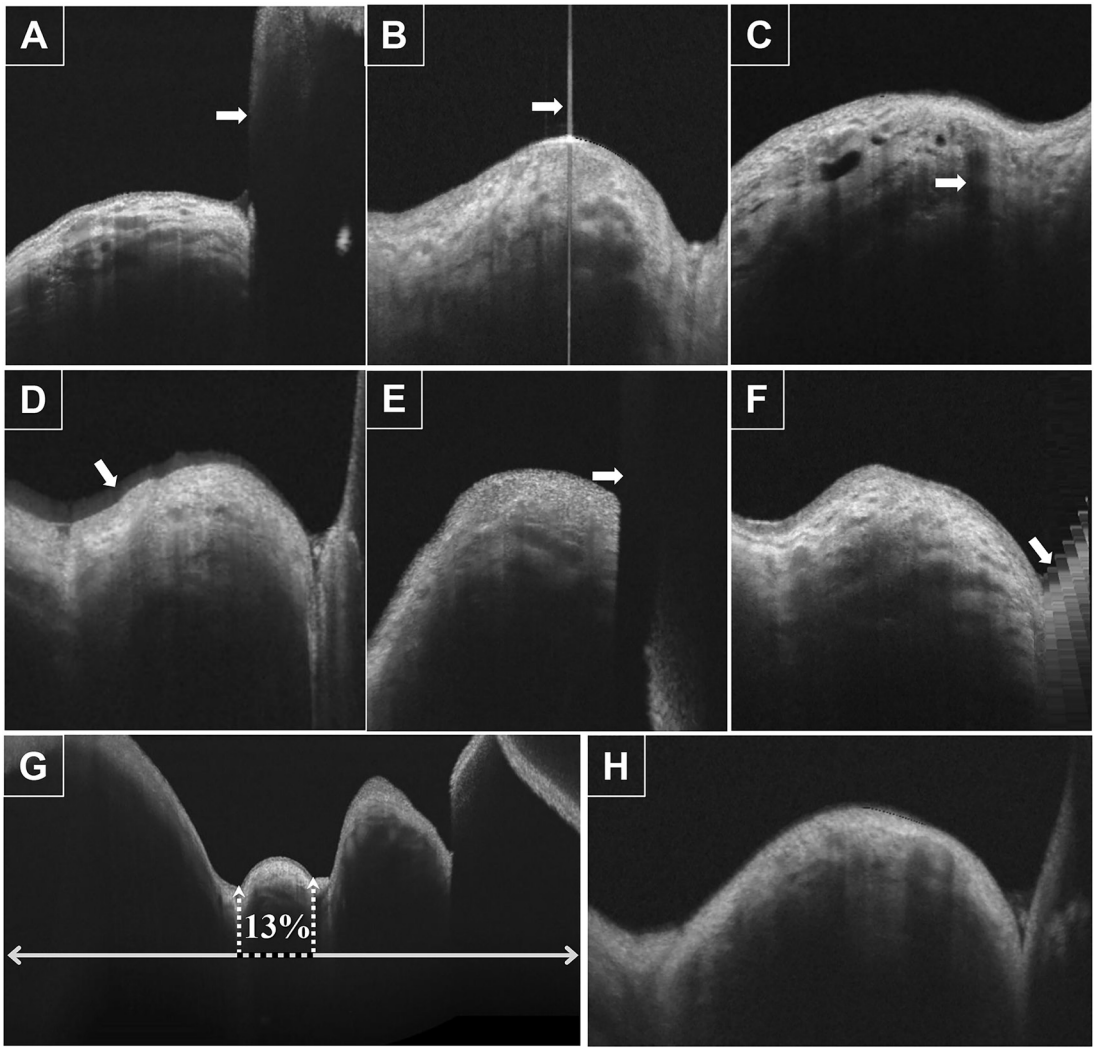

Figure 2 Example of eight lacrimal gland optical coherence tomography artefacts. (A) Cliff (arrow indicates a vertical opacity); (B) reflection (arrow indicates a grey shadow perpendicular to the surface); (C) projection (arrow indicates a tunnel-like shadow with low/high signal intensity); (D) shadow (arrow indicates a low-intensity projection); (E) blink (arrow indicates a black band due to blinking); (F) motion (arrow indicates discontinuity and displacement due to movement); (G) Z-off (13%=the length of the lacrimal gland/the length of the image); (H) defocus.

images in this study. Previous studies have consistently demonstrated the high incidence of artefacts.[12 13 20 21] Even for the widely used and repeatedly optimised posterior segment OCT imaging, the incidence of artefacts is high at 84.7–92%.[12 22] Furthermore, 90.9% of images had at least one artefact type, with 37.5% having severe artefacts, whereas only 8.0% had clinically significant artefacts.[12] The incidence of artefacts could be even as high as 92%.[22] However, no studies have investigated the artefacts in lacrimal gland OCT imaging; therefore, this study fills the gap by defining the artefacts and providing a standard quality control method for high-resolution imaging of the lacrimal gland.

This study observed for the first time that the prevalence of lacrimal gland OCT image artefacts is significantly related to DED occurrence and severity. A potential explanation is that the significantly increased blink frequency of patients with DED could interfere with image acquisition.[23 24] DED is also a risk factor for retinal blood flow imaging artefacts.[23 25] Therefore, whether using posterior or anterior segment OCT or optical coherence tomography angiography imaging, attention is needed to the imaging quality of patients with DED to minimise the interference of artefacts on the interpretation of clinical results. Previous research indicates that artificial tears could enhance the image quality of corneal topography and the accuracy of lens power calculation.[26 27] Future studies on artefacts might explore whether and how artificial tears could improve patient cooperation and reduce artefact occurrence. This study also observed that high IOP is associated with poor image quality, which may be related to the more pronounced discomfort of patients with high IOP during gland exposure and image acquisition.

Participants with severe dry eye symptoms tend to have poorer image quality than those with mild symptoms (online supplemental table 7), though this trend was not statistically significant, possibly due to small subgroup sizes and the subjective nature of the OSDI. We found a significant association between image quality and TFBUT, an objective indicator of DED, suggesting that DED severity may affect image quality. Larger studies are needed to confirm this association.

These eight types of artefacts and their impact on disease diagnosis and lesion identification are similar to those in previous studies on OCT/A.[12 13 20] Reflection can obscure the surface details of the lacrimal gland, making it difficult to identify minute changes, while projection often leads to a loss of detail in deeper gland structures. Defocus reduces reflection intensity

Table 1 Demographics and ocular characteristics of included participants

Characteristic	Overall
No. of subjects (eyes)	151
Age (years)	35.07±8.86
Female (%)	45 (29.80)
Body mass index (kg/m^2)	21.56±3.70
BCVA (logMAR)	0.22±0.19
IOP (mm Hg)	12.25±2.73
OSDI scores	35.38±16.35
Schirmer's test I (mm/5 min)	4 (2,10)
Schirmer's test II (mm/5 min)	4 (2,20)
Tear film breakup time (s)	2.82±1.68
Corneal staining scores	1.07±1.12
Meibomian gland dropout degree (0–3)	1.66±0.77
Meibum expressibility (0–3)	1.35±1.01
Lid margin abnormality score (0–4)	2.53±1.20
Meibum quality score (0–3)	2.20±0.80
Presence of DED*	104 (68.87)
DED syndrome severity† (0–3), mean±SD	2.28±0.90
Meibomian gland function (0–13), mean±SD	7.70±2.99
Systemic immunosuppression use	35 (23.18)

Data are expressed as the mean±SD, median (IQR) or number (%).
*DED was diagnosed as OSDI scores >13 and tear film breakup time <5.
†DED syndrome severity was defined according to the OSDI scores: grade 1 (mild): <13; grade 2 (moderate): 13–22; grade 3 (severe): >23.
BCVA, best corrected visual acuity; DED, dry eye disease; IOP, intraocular pressure; logMAR, Logarithm of the Minimum Angle of Resolution; OSDI, Ocular Surface Disease Index.

and blurs structures, thereby affecting pathological assessment. Cliffs and blinks create opaque areas or black bands, disrupting structural information. Z-off causes image misalignment, which affects the observation of critical areas. Shadow artefacts create low-signal shadows with reduced resolution, complicating the differentiation between the two lacrimal glands. Motion causes image discontinuity and displacement, rendering portions of the lacrimal gland structures uninterpretable. Future research should focus on mitigating the effects of these artefacts to enhance the accuracy and usability of lacrimal gland imaging.

Despite the artefacts affecting image interpretation in research, clinicians can ignore artefacts that have no significant impact on clinical practice. For example, when artefacts cause a minor loss of lacrimal gland structure information, such as shadow, motion, projection and reflection, the decision to recapture lacrimal gland images can be based on clinical needs. However, when artefacts cause significant loss of lacrimal gland structure information (eg, blood vessels, acinar and excretory duct), such as cliff, blink, Z-off and defocus artefacts, it is necessary to recapture them to obtain complete structural information (online supplemental figure 5).

The occurrence of artefacts is primarily related to factors involving the patient, operation and algorithms (online supplemental table 2). The first is patient-related artefacts. Patient movements in different directions during the examination can lead to motion, shadows, defocusing and blink artefacts. Second, operation-related artefacts are due to incomplete exposure of the lacrimal gland, which may lead to cliff artefacts. The misalignment of the central point of the scan with the centre of the exposed lacrimal gland may result in Z-offset artefacts. Third, algorithm-related artefacts may occur due to highly reflective signals (reflections) or less reflective obstructions (projections) caused by the coverage of tears on the surface of the lacrimal gland or superficial blood flow. Therefore, patient education, standardised training of operators and enhanced algorithmic processing may help reduce the occurrence of artefacts.[28]

In evaluating the risk factors for artefact occurrence, this study used two outcome indicators for the artefact occurrence event (amount-based and severity-based image quality indicators). In addition to the significant differences in definitions and measurement methods, the two indicators serve distinct purposes. Amount-based indicators primarily offer a quantitative perspective on the prevalence of artefacts, aiding in understanding their frequency, which is useful for rapid screening. Conversely,

Table 2 Univariate and multivariate logistic regression analysis for the image quality of lacrimal gland in all subjects

	Model 1		Model 2		Model 3	
Variables	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value
Severity-based indicator*						
Presence of dry eye disease	3.32 (1.28 to 8.58)	**0.013**	9.40 (2.40 to 34.71)	**0.001**	9.13 (2.39 to 34.88)	**0.001**
Age (per year increase)	1.02 (0.98 to 1.06)	0.227	–	–	–	–
Female	1.19 (0.55 to 2.59)	0.664	–	–	–	–
Body mass index (per kg/m^2)	0.95 (0.85 to 1.05)	0.270	–	–	–	–
BCVA (per logMAR)	1.15 (0.16 to 8.33)	0.889	–	–	–	–
IOP (per mm Hg)	1.24 (1.08 to 1.42)	**0.003**	1.33 (1.13 to 1.56)	**0.001**	1.34 (1.14 to 1.58)	**<0.001**
Amount-based indicator†						
Presence of dry eye disease	2.27 (0.95 to 5.38)	0.064	3.99 (1.27 to 11.34)	**0.017**	3.88 (1.29 to 11.70)	**0.016**
Age (per year increase)	1.02 (0.98 to 1.06)	0.331	–	–	–	–
Female	1.13 (0.52 to 2.46)	0.755	–	–	–	–
Body mass index (per kg/m^2)	0.97 (0.87 to 1.07)	0.488	–	–	–	–
BCVA (per logMAR)	0.71 (0.10 to 5.24)	0.736	–	–	–	–
IOP (per mm Hg)	1.21 (1.06 to 1.39)	**0.006**	1.27 (1.09 to 1.46)	**0.002**	1.27 (1.10 to 1.48)	**0.002**

Model 1, a crude model; model 2, adjusts for age and gender; model 3, adjusts for age, gender, IOP and BCVA.
Boldface indicates statistical significance at p<0.05.
*Impaired quality is defined as more than 10 severe artefacts on the images.
†Impaired quality is defined as more than 25 any artefacts on the images.
BCVA, best corrected visual acuity; IOP, intraocular pressure; logMAR, Logarithm of the Minimum Angle of Resolution; OSDI, Ocular Surface Disease Index.

Table 3 Multivariate logistic regression analysis for the image quality of the lacrimal gland in all subjects

	Severity-based image quality indicator*		Amount-based image quality indicator†	
Variables	**OR (95% CI)**	**P value**	**OR (95% CI)**	**P value**
Tear film breakup time (s)	0.66 (0.50 to 0.86)	**0.002**	0.71 (0.55 to 0.92)	**0.009**
Meibum quality score (0–3)	2.18 (1.18 to 4.02)	**0.013**	2.86 (1.49 to 5.48)	**0.002**

Model adjusts for age, gender, IOP and BCVA.
Boldface indicates statistical significance at p<0.05.
*Impaired quality is defined as more than 10 severe artefacts on the images.
†Impaired quality is defined as more than 25 any artefacts on the images.
BCVA, best corrected visual acuity; IOP, intraocular pressure.

severity-based indicators provide insights into the impact level of artefacts, offering more detail and depth. This will guide technical improvements and decision-making more precisely. Additionally, sensitivity analyses using these two outcome indicators reinforced the robustness of our findings.

The artefact removal system is a plugin designed to detect and eliminate artefacts in images. It primarily uses filters, machine learning and deep learning techniques for artefact detection, classification, removal and image quality improvement.[28] Our findings provide a basis for improving this system. Future studies should incorporate clinically significant artefact types into artefact removal systems to automatically detect and alert operators to recapture images.

This study's strengths include using SS-OCT equipment with high scanning speed and resolution, the comprehensive analysis based on 1208 lacrimal gland images, the standardised definition of artefact types and the correction of multiple confounding factors when evaluating the risk factors for artefact occurrence. However, this study also has the following limitations. First, only Chinese patients were included in our study. Therefore, the conclusions of this study should be cautiously interpreted when generalising them to other ethnicities. Second, only one type of machine was used in this study. Therefore, this study's image quality control criteria may not apply to other OCT devices. Third, artefacts may be distributed differently in the real world. OCT is an operator-dependent imaging method, and different operator habits may lead to differences in artefact distribution.

In conclusion, this study is the first to identify DED as a risk factor for image artefacts of the lacrimal gland. DED significantly correlates with artefact occurrence. Therefore, establishing a rigorous, standardised image quality control is crucial for harnessing the full potential of SS-OCT in lacrimal gland evaluation.

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Contributors All authors gave their final approval of this version to be published. Lingyi Liang, Longyue Li, and Weijing Cheng participated in the design, data screening and co-wrote the paper. Weijing Cheng and Juejing Chen revised the manuscript. Boyu Yang, Ziyan Chen, Jing Li, Siyi Liu, Feng Gu, Nuan Zhang, and Wenhui Wang performed the data collection. Wei Wang participated in designing. Lingyi Liang is responsible for the overall content as the guarantor. Lingyi Liang participated in final quality control, manuscript revision and supervised the project.

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Competing interests None declared.

Patient consent for publication Consent obtained directly from patient(s).

Ethics approval This study involves human participants and was approved by the Ethics Committee of Zhongshan Ophthalmic Center (approval number: 2019KYPJ135). Participants gave informed consent to participate in the study before taking part.

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REFERENCES

1 Doh SH, Kim EC, Chung SY, *et al*. Optical Coherence Tomography Imaging of Human Lacrimal Glands: An In Vivo Study. *Ophthalmology* 2015;122:2364–6.
2 Singh S, Winter Z, Necker F, *et al*. New insights into lacrimal gland anatomy using 7T MRI and electron microscopy: Relevance for lacrimal gland targeted therapies and bioengineering. *Ocul Surf* 2023;30:204–12.
3 Bingham CM, Harris MA, Realini T, *et al*. Calculated Computed Tomography Volumes of Lacrimal Glands and Comparison to Clinical Findings in Patients With Thyroid Eye Disease. *Ophthalmic Plast Reconstr Surg* 2014;30:116–8.
4 Lecler A, Boucenna M, Lafitte F, *et al*. Usefulness of colour Doppler flow imaging in the management of lacrimal gland lesions. *Eur Radiol* 2017;27:779–89.
5 Kim EC, Doh SH, Chung SY, *et al*. Direct visualization of aqueous tear secretion from lacrimal gland. *Acta Ophthalmol* 2017;95:e314–22.
6 Ali MJ, Singh S. Optical coherence tomography and the proximal lacrimal drainage system: a major review. *Graefes Arch Clin Exp Ophthalmol* 2021;259:3197–208.
7 Timlin HM, Keane PA, Rose GE, *et al*. The Application of Infrared Imaging and Optical Coherence Tomography of the Lacrimal Punctum in Patients Undergoing Punctoplasty for Epiphora. *Ophthalmology* 2017;124:910–7.
8 Hu J, Xiang N, Li G gang, *et al*. Imaging and anatomical parameters of the lacrimal punctum and vertical canaliculus using optical coherence tomography. *Int J Med Sci* 2021;18:2493–9.
9 Ang M, Baskaran M, Werkmeister RM, *et al*. Anterior segment optical coherence tomography. *Prog Retin Eye Res* 2018;66:132–56.
10 Spaide RF, Fujimoto JG, Waheed NK, *et al*. Optical coherence tomography angiography. *Prog Retin Eye Res* 2018;64:1–55.
11 Ho J, Sull AC, Vuong LN, *et al*. Assessment of artifacts and reproducibility across spectral- and time-domain optical coherence tomography devices. *Ophthalmology* 2009;116:1960–70.
12 Han IC, Jaffe GJ. Evaluation of artifacts associated with macular spectral-domain optical coherence tomography. *Ophthalmology* 2010;117:1177–89.
13 Kamalipour A, Moghimi S, Hou H, *et al*. OCT Angiography Artifacts in Glaucoma. *Ophthalmology* 2021;128:1426–37.
14 Clayton JA. Dry Eye. *N Engl J Med* 2018;378:2212–23.
15 Tomlinson A, Bron AJ, Korb DR, *et al*. The international workshop on meibomian gland dysfunction: report of the diagnosis subcommittee. *Invest Ophthalmol Vis Sci* 2011;52:2006–49.
16 Tsubota K, Yokoi N, Shimazaki J, *et al*. New Perspectives on Dry Eye Definition and Diagnosis: A Consensus Report by the Asia Dry Eye Society. *Ocul Surf* 2017;15:65–76.

17 Zhou Y, Murrough J, Yu Y, *et al*. Association Between Depression and Severity of Dry Eye Symptoms, Signs, and Inflammatory Markers in the DREAM Study. *JAMA Ophthalmol* 2022;140:392–9.
18 Lucaya J, Piqueras J, García-Peña P, *et al*. Low-dose high-resolution CT of the chest in children and young adults: dose, cooperation, artifact incidence, and image quality. *AJR Am J Roentgenol* 2000;175:985–92.
19 Motosugi U, Bannas P, Bookwalter CA, *et al*. An Investigation of Transient Severe Motion Related to Gadoxetic Acid-enhanced MR Imaging. *Radiology* 2016;279:93–102.
20 Holmen IC, Konda SM, Pak JW, *et al*. Prevalence and Severity of Artifacts in Optical Coherence Tomographic Angiograms. *JAMA Ophthalmol* 2020;138:119–26.
21 Ghasemi Falavarjani K, Al-Sheikh M, Akil H, *et al*. Image artefacts in swept-source optical coherence tomography angiography. *Br J Ophthalmol* 2017;101:564–8.
22 Hwang YH, Kim YY, Jin S, *et al*. Errors in neuroretinal rim measurement by Cirrus high-definition optical coherence tomography in myopic eyes. *Br J Ophthalmol* 2012;96:1386–90.
23 Napoli PE, Nioi M, Mangoni L, *et al*. Fourier-Domain OCT Imaging of the Ocular Surface and Tear Film Dynamics: A Review of the State of the Art and an Integrative Model of the Tear Behavior During the Inter-Blink Period and Visual Fixation. *J Clin Med* 2020;9:668.
24 Cheng W, Song Y, Lin F, *et al*. Assessment of Artifacts in Swept-Source Optical Coherence Tomography Angiography for Glaucomatous and Normal Eyes. *Transl Vis Sci Technol* 2022;11:23.
25 Cui Y, Zhu Y, Wang JC, *et al*. Imaging Artifacts and Segmentation Errors With Wide-Field Swept-Source Optical Coherence Tomography Angiography in Diabetic Retinopathy. *Transl Vis Sci Technol* 2019;8:18.
26 Kim J, Kim MK, Ha Y, *et al*. Improved accuracy of intraocular lens power calculation by preoperative management of dry eye disease. *BMC Ophthalmol* 2021;21:364.
27 Lee Y, Kim TH, Paik HJ, *et al*. n.d. Artificial Tear Instillation-Induced Changes in Corneal Topography. *Bioengineering (Basel)*11:121.
28 Zhang Y, Liu T, Singh M, *et al*. Neural network-based image reconstruction in swept-source optical coherence tomography using undersampled spectral data. *Light Sci Appl* 2021;10:155.