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Clinical characteristics of dry eye patients with thyroid disorders: a cross-sectional study

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Abstract

Purpose To characterize the clinical findings in dry eye disease (DED) patients with thyroid disorders and explore their associations with DED symptoms and signs.

Methods In this retrospective cross-sectional chart review study, 99 patients who were diagnosed as DED and subjected to thyroid function screening were included. Corneal fluorescein staining (CFS), Schirmer 1 test (S1T), tear meniscus height (TMH), the first noninvasive breakup time (NIBUT-first), the average noninvasive breakup time (NIBUT-avg), and meibomian gland (MG) dropout ratio were tested and their correlations with thyroid function were analyzed.

Results Overall, the average age and gender distribution of DED patients with or without thyroid disorders were similar ($p = 0.391$ and 0.804). DED patients with thyroid disorders had shorter NIBUT-first($p < 0.001$) and NIBUT-avg($p = 0.0042$), and higher MG dropout ratio ($p = 0.001$). Among thyroid function assessments, elevated levels of anti-thyroid peroxidase antibody (Anti-TPO) and anti-thyroglobulin antibody (Anti-Tg) had significant correlation with reduced NIBUT and increased MG dropout ratio. When either NIBUT-first or MG dropout ratio was used as a predicting factor for thyroid disorders, ROC curve demonstrated a cut-off value of 5.255(NIBUT-first AUC 0.770, sensitivity 85.7%, specificity 58.8%, $p < 0.001$) and 0.229 (MG dropout ratio AUC 0.784, sensitivity 70.6%, specificity 79.6%, $p < 0.001$). When combining them together, an AUC area of 0.841(sensitivity 88.2%, specificity 66.2%, $p < 0.001$) was reached.

Conclusion Shorter NIBUT and higher MG dropout ratio correlated with abnormally elevated levels of Anti-TPO and Anti-Tg in DED patients. A combination of NIBUT and MG dropout assessment may have diagnostic potential as a predictive biomarker of possible thyroid disorders.

Keywords Dry eye disease, Thyroid disorders, Meibomian gland, Diagnostic potential, Meibography

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Introduction

Dry eye disease (DED) is a multifactorial ocular surface disorder marked by disrupted tear film homeostasis [1]. Globally, DED prevalence ranges from 5 to 50% [2], with rates escalating due to aging populations and pervasive digital screen exposure [3]. The disease profoundly impacts quality of life through chronic symptoms while imposing significant economic burdens [4], therefore highlighting the imperative to elucidate DED's etiological mechanisms.

Thyroid dysfunction, a prevalent global health issue affecting millions of patients worldwide, is strongly linked to ophthalmic complications [5], with thyroid eye disease (TED) being one of the most frequent and debilitating manifestations [6]. In TED patients, autoimmune-mediated lymphocytic infiltration and inflammation damage the lacrimal glands, impairing their secretory function [7]. Concurrently, widened palpebral fissures and incomplete eyelid closure resulted from proptosis exacerbate tear film evaporation due to increased ocular surface exposure [8]. These combined mechanisms result in significantly reduced Schirmer test values and shortened tear breakup time [9]. Consequently, the disruption of tear film homeostasis predisposes TED patients to a high prevalence of DED [9].

While the association between TED and DED is well-documented, emerging evidence suggests that thyroid dysfunction itself—even in the absence of overt TED—may contribute to DED pathogenesis [8]. Notably, studies report an elevated DED prevalence in patients with hypothyroidism and hyperthyroidism compared to euthyroid individuals [10, 11]. Although the underlying mechanisms linking thyroid dysfunction to DED remain poorly understood, early recognition of thyroid dysfunction and potential thyroid disorders in DED patients is critical for timely intervention [12]. This highlights the necessity for ophthalmologists to screen thyroid function in DED patients with clinical features suggestive of thyroid disorders [13]. Therefore, we performed this cross-sectional study to characterize ocular signs and symptoms in DED patients with thyroid disorders, and evaluate the potential of DED parameters in screening and diagnosis of possible thyroid disorders.

Methods

Study population

This is a retrospective cross-sectional chart review study where all data were obtained from electronically documented medical records. The records of 2306 patients who visited the dry eye clinic of Eye, Ear, Nose & Throat Hospital of Fudan University from September 1st, 2021 to August 31st, 2022 were reviewed. 1642 patients met the diagnostic criteria [14] of DED. Among them, 162(9.9%) were recommended to have thyroid function examination based on clinical suspicion of thyroid disorders according to the advice of a professional ophthalmologist. Of these, 99 patients who had complete medical records (including all required ophthalmic and thyroid function tests) and met the inclusion criteria were enrolled in the final analysis (Fig. 1).

Patients aged between 18 to 85 years old were enrolled. The diagnostic criteria are in alignment with previous

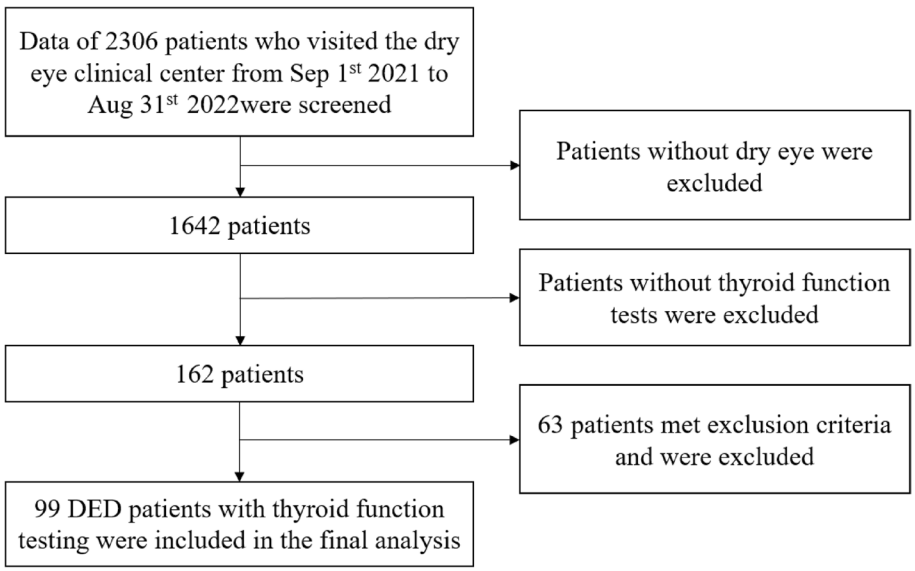

Fig. 1 Flowchart of patient enrollment. Flowchart detailing patient selection process for inclusion in the study on thyroid function and dry eye disease

literature [14]: Patients who were diagnosed as DED should present at least one dry eye symptom such as dryness, gritty eyes and burning sensation. Meanwhile, at least two of the following criteria should be reached: 1) Schirmer 1 test (S1T) < 10 mm/5 min. 2) Fluorescein breakup time (FBUT) < 10 s. 3) corneal fluorescein staining(CFS) score ≥ 1.

Patients who suffered from 1) diagnosed thyroid eye disease (TED) or occult TED according to the diagnostic criteria put forward by Bartley [15]; 2) history of thyroid dysfunction such as hyperthyroidism; 3) history of eye disease, including keratitis, blepharitis, ocular allergic disease, glaucoma and uveitis; 4) previous ocular surgery, trauma and treatment; 5) wearing the contact lenses were excluded.

Clinical evaluation

Ophthalmologic examination

Ophthalmic examinations were performed in all patients in the following strictly standardized order according to the hospital's clinical protocol: visual acuity, a slit-lamp examination including corneal fluorescein staining (CFS), Keratograph 5 M (K5M) (Oculus, Wetzlar, Germany) and Schirmer 1 test (S1T). CFS was evaluated using cobalt blue illumination after applying fluorescein sodium strip to the conjunctival sac. Following established methodology [16], the corneal surface was divided into five segments (central, superior, inferior, nasal, and temporal), with each segment scored from 0 to 3, resulting in a total possible score of 15. K5M was performed in the order of tear meniscus height (TMH), first and average noninvasive breakup time (NIBUT-first and NIBUT-avg), and non-contact meibography, as previously reported [17]. The TMH and NIBUT values were provided by the customized software, while meibography images were further analyzed using ImageJ to calculate the meibomian gland (MG) dropout ratio, as shown in Fig. 2. The method to quantify MG dropout was reported previously [18]. Specifically, intensity threshold segmentation was applied to delineate the areas of gland loss, which were then calculated automatically and expressed as a percentage of the total gland area. S1T was performed in the absence of topical anesthesia by gently placing a Schirmer test strip over the patients' lower eyelids without disturbing the ocular surface to avoid the bias of tearing due to irritation. The wetting length of strip was measured after 5 min. The data from the eye that met diagnostic criteria was included for analysis in unilateral DED patients. For those bilateral DED patients, the right eye was enrolled.

Thyroid function assessment

Blood samples were obtained and serum levels of thyroid stimulating hormone (TSH), total triiodothyronine (TT3), total thyroxine (TT4), free triiodothyronine (FT3), free thyroxine (FT4), anti-thyroid peroxidase antibody (Anti-TPO) and anti-thyroglobulin antibody (Anti-Tg) were tested. The reference range is: TSH: 0.350 ~ 4.940 mIU/L; TT3: 0.54 ~ 296 nmol/L; TT4: 62.68 ~ 150.84 nmol/L; FT3: 2.43 ~ 6.01 pmol/L; FT4: 9.01 ~ 19.05 pmol/L; Anti-TPO: 0 ~ 5.61 IU/ml; Anti-Tg: 0 ~ 4.11 IU/ml. Subjects with all indexes within the

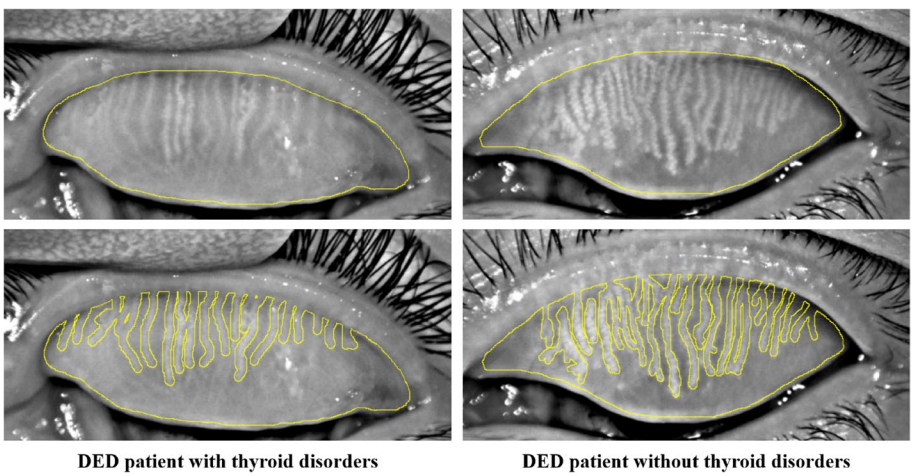

Fig. 2 Comparative imagery of meibomian gland structures in DED patients with or without thyroid disorders. Yellow outlines emphasize the overall shape and intricacies of the gland structures. MG Dropout ratio is calculated by dividing the area of the missing or dysfunctional meibomian glands(bottom) by the total gland area(top). The left panels represent a DED patient with thyroid disorders, showcasing both the general gland structure (top) and detailed gland morphology (bottom). The right panels depict a DED patient without thyroid disorders for comparison

reference range were defined as euthyroidism, otherwise as patients with thyroid disorders.

Statistical analysis

SPSS software (version 21; SPSS Inc, Chicago, IL) was used for statistical analysis. Shapiro–Wilk test was performed to evaluate the normality of age distribution. Data was presented as mean ± SD and analyzed using student t-test for normally distributed continuous variables. Non-normally distributed data were presented as median, 25th percentile (Q1), and 75th percentile (Q3), and Wilcoxon signed-rank test were conducted to compare the DED patients with or without thyroid disorders. Spearman correlation coefficient and Logistic regression analysis were performed to explore the independent variables associated with the thyroid disorders. Receiver operating characteristic (ROC) was analyzed and area under the curve (AUC) was calculated to evaluate the diagnostic accuracy. Two-sided P values < 0.05 were considered statistically significant.

Results

Demographic and clinical characteristics

Among 99 DED patients with thyroid function tests, 79 were female (79.8%) and 20 were male (20.2%). The average age was 45(32, 55) years old. 47 patients (47.5%) had thyroid disorders, while the other 52 patients (52.5%) were euthyroidism. Both age ($P=0.391$) and gender distribution($P=0.804$) were similar between two groups (Table 1). The proportion of patients with systemic autoimmune disease was higher in patients with thyroid disorders, but did not reach statistical significance (46.8% vs 30.8%, $P=0.101$).

Compared to DED patients with normal thyroid function, those with thyroid disorders had shorter NIBUT-first[4.59 s (3.25 s, 6.12 s) vs 7.33 s (5.47 s, 9.13 s), $p<0.001$] and NIBUT-avg[8.13 ± 4.03 s vs 9.78 ± 3.89 s, $p=0.042$]. MG dropout ratio was also significantly higher in DED patients with thyroid disorders [32.99% (21.08%, 55.39%) vs 17.2% (11.2%, 27.1%), $p=0.001$]. Notably, DED patients with thyroid disorders had shorter and thinner meibomian glands and larger intervals, indicating higher degree of gland atrophy (Fig. 2). TMH, S1T and CFS did not have significant differences between two groups. It is notable that the levels of Anti-TPO and Anti-Tg were significantly higher in DED patients with thyroid disorders (Anti-TPO: 8.65 IU/ml vs 0.99 IU/ml, Anti-Tg: 1.94 IU/ml vs 0.82 IU/ml, both $P<0.001$). (Table 1).

Association between thyroid function and DED parameters

Table 2 showed the correlation between DED parameters and thyroid function parameters. It was found

Table 1 Demographic and Clinical Characteristics of DED Patients with or without Thyroid Disorders

	With thyroid disorders ($n=47$, 47.5%)	With euthyroidism ($n=52$, 52.5%)	*P* value
Age (years old)	43.68 ± 13.35	46 ± 13.38	0.391
Gender (male, %)	9 (19.1%)	11 (21.2%)	0.804
With hyperlipemia (n, %)	1 (2.1%)	4 (7.7%)	0.207
With autoimmune diseases (n, %)	22 (46.8%)	16 (30.8%)	0.101
TMH (mm)	0.19(0.16, 0.23)	0.22 (0.18, 0.25)	0.192
NIBUT-first (s)	4.59 (3.25, 6.12)	7.33 (5.47, 9.13)	**< 0.001***
NIBUT-avg (s)	8.13 ± 4.03	9.78 ± 3.89	**0.042***
S1T (mm/5 min)	4.00 (1.25, 5.75)	5.00 (2.00, 8.00)	0.154
CFS (0,15)	9 (7,11)	9 (8,11)	0.241
MG dropout ratio (%)	32.99% (21.08%, 55.39%)	17.2% (11.2%, 27.1%)	**0.001***
TSH level (mIU/L)	1.67(1.12, 2.37)	1.67 (1.23, 2.11)	0.664
T3 level (nmol/L)	1.39 (1.23, 1.49)	1.38 (1.28, 1.49)	0.731
T4 level (nmol/L)	97.58 ± 17.94	98.33 ± 15.47	0.824
FT3 level (pmol/L)	4.16 (3.85,4.40)	4.20 (3.95, 4.39)	0.814
FT4 level (pmol/L)	12.93 ± 1.95	12.90 ± 1.20	0.928
Anti-TPO level (IU/ml)	8.65 (5.63, 20.27)	0.99 (0.54, 2.45)	**< 0.001***
Anti-Tg level (IU/ml)	1.94 (0.89,26.15)	0.82 (0.52, 1.18)	**< 0.001***

Data presented includes median values with interquartile ranges or means ± standard deviations as appropriate. *P* values indicate statistical significance between the two groups

Abbreviations: TMH Tear meniscus height, *NIBUT-first* the first noninvasive breakup time, *NIBUT-avg* the average noninvasive breakup time, *S1T* Schirmer 1 test, *CFS* Corneal fluorescein staining, *MG* Meibomian gland, *Anti-TPO* Anti-thyroid peroxidase antibody, *Anti-Tg* Anti-thyroglobulin antibody

Table 2 Correlation Analysis on DED parameters and thyroid function in DED patients

	Anti-TPO level		Anti-Tg level	
	ρ	*P*	ρ	*P*
NIBUT-first	-0.371	**< 0.001**	-0.279	**0.006**
NIBUT-avg	-0.197	0.053	-0.114	0.268
MG dropout ratio	0.325	**0.001**	0.318	**0.002**

Abbreviations: NIBUT-first the first noninvasive breakup time, *NIBUT-avg* the average noninvasive breakup time, *MG* Meibomian gland

that the level of Anti-TPO and Anti-Tg negatively correlated with NIBUT-first ($p < 0.001$ and $p = 0.006$, respectively), and positively correlated with MG dropout ratio ($p = 0.001$ and 0.002, respectively). NIBUT-avg did not have correlation with thyroid function parameters. Logistic regression analysis showed that patients with either shorter NIBUT-first or larger MG dropout had a higher incidence of thyroid disorders (NIBUT-first: OR 0.643(0.492 ~ 0.840), $P = 0.001$; MG dropout: OR 1.076 (1.036 ~ 1.118), $P < 0.001$).

ROC analysis was then performed to identify the diagnostic potential of NIBUT-first and MG dropout for thyroid disorders in DED patients. Table 3 showed the sensitivity and specificity of using either NIBUT-first alone or MG dropout alone and their cut-off values to predict thyroid disorders. The combination of both parameters had the highest AUC-ROCs (Fig. 3) with the sensitivity of 88.2% and specificity of 66.2%.

Discussion

This study highlights a significant association between thyroid disorders and DED parameters, particularly emphasizing the role of autoimmune thyroid dysfunction in exacerbating ocular surface pathology. The key findings demonstrate that nearly half (47.5%) of DED patients exhibited thyroid disorders, specifically characterized by impaired meibomian gland structure and accelerated tear film breakup compared to euthyroid DED patients, whereas other DED parameters showed no significant association. Although our study is based on a specialized population, this prevalence underscores the widespread relevance of thyroid disorders in DED pathogenesis. These findings align with previous reports linking thyroid autoimmunity and DED severity [19].

The differences in DED parameters between patients with thyroid disorders and euthyroid individuals primarily manifested in NIBUT and MG dropout ratios. While some studies suggest reduced tear secretion in

Table 3 Area under the curve(AUC) and predictive performance of DED parameters

Predictors	AUC	*P* value	Cut-off value	Sensitivity	Specifity
NIBUT-first	0.770	< 0.001	5.255	85.7%	58.8%
MG-dropout ratio	0.784	< 0.001	0.229	70.6%	79.6%
NIBUT-MG dropout ratio	0.841	< 0.001	0.365	88.2%	66.2%

NIBUT-MG dropout ratio: a combined diagnostic index derived from a linear combination of the two diagnostic indicators, calculated as follows: Combined Diagnostic Score = -0.370—0.207*(NIBUT-first) + 0.061*(MG-dropout ratio)

Abbreviations: NIBUT-first the first noninvasive breakup time, *MG* Meibomian gland

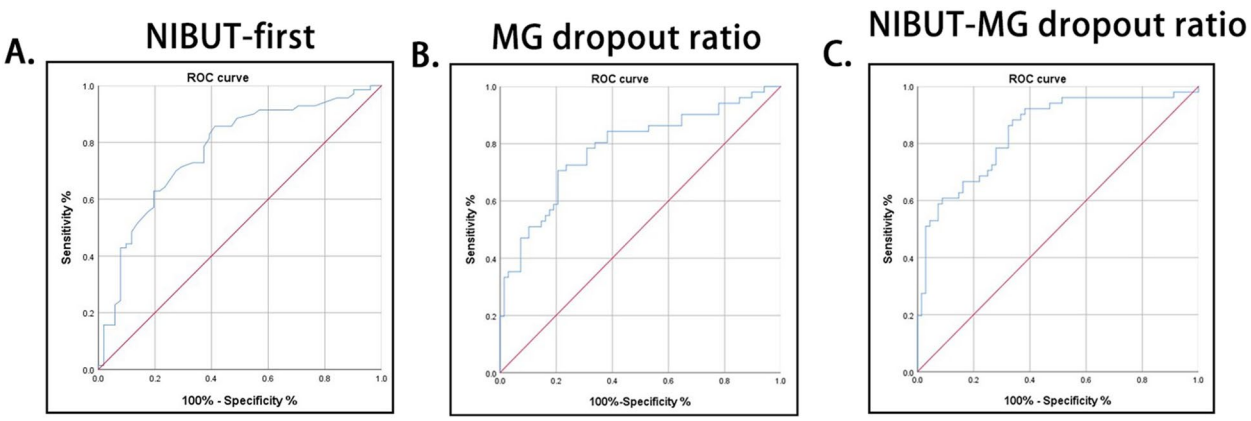

Fig. 3 Receiver operating characteristic (ROC) curve analysis. ROC curve analysis for three DED parameters: NIBUT-first, MG dropout ratio, and NIBUT-MG dropout ratio

TED patients [20, 21], others indicate that TED does not impair tear production [22, 23]. Our findings revealed no significant differences in S1T or TMH between groups, implying that reduced tear secretion is not the sole mechanism driving DED in thyroid dysfunction. Instead, the marked disparities in NIBUT and MG dropout ratios highlight the potential role of evaporative dry eye mechanisms in thyroid-related DED pathogenesis. These observations suggest that thyroid disorders may preferentially disrupt MG integrity prior to clinically apparent lacrimal gland dysfunction.

The relationship between MG and TED has been widely investigated: Park et al. reported greater structural loss of upper eyelid MG in TED patients compared to DED patients with similar dryness severity [8]; Liao et al. identified severe lower eyelid MG dysfunction as a key contributor to tear film instability in TED [22]; Wang et al. observed significantly worse MG dropout in active versus inactive TED [24]. Similarly, our study demonstrated increased MG dropout ratios in DED patients with thyroid disorders, suggesting MG atrophy as a hallmark of thyroid-related DED. Notably, we further identified a significant correlation between elevated Anti-TPO and Anti-Tg antibody levels with increased MG dropout ratios, further supporting the potential role of autoimmune inflammation in MG destruction.

Mechanistically, TSH receptors (TSHR) expressed in the lacrimal gland have been identified as targets for pathogenic autoantibodies that drive inflammatory processes within the gland [25]. A similar pathogenic mechanism might exist in meibomian glands. Although no direct evidence currently confirms TSHR expression in the MG tissues, thyroid hormone responsive spot 14 (THRSP)—a protein that physically and functionally interacts with thyroid hormone receptors [26]—has been detected in human MG tissues [27]. THRSP expression correlates with TSH levels and modulates fatty acid synthesis, a critical process for meibomian lipid secretion [28, 29]. In patients with thyroid disorders, Anti-TPO and Anti-Tg autoantibodies may directly or indirectly interact with THRSP, potentially disrupting its regulatory role and thereby impairing meibomian gland function and structure. Additionally, given the inflammatory state of the ocular surface in patients with thyroid dysfunction [23], MG dysfunction could also arise as a nonspecific consequence of localized inflammation. However, these proposed mechanisms require further experimental validation to establish their causal roles in MG pathology.

Emerging evidence underscores the importance of identifying thyroid disorders in DED patients, as undiagnosed thyroid disorders may exacerbate ocular surface damage and confound treatment outcomes [23, 30]. While current guidelines recommend thyroid screening in DED patients when clinically suspected, the lack of objective criteria often leads to either over testing in low-risk populations or missed diagnoses in asymptomatic cases [13]. In this study, we addressed this gap by developing a novel combined diagnostic model integrating NIBUT-first and MG dropout ratio. This approach achieved an AUC-ROC of 0.84, with 88.2% sensitivity and 66.2% specificity, outperforming individual parameters alone. The model provides clinicians with a reproducible, quantitative framework to prioritize thyroid testing in high-risk DED patients.

This study has several limitations that should be acknowledged. First, the modest sample size may limit statistical power and introduce potential bias, reducing the generalizability of the findings. Additionally, as a retrospective chart review, the study is inherently constrained by the availability and completeness of medical records, which may influence data accuracy. Future studies should prioritize larger and more diverse cohorts to enhance external validity. Furthermore, the observed associations between thyroid disorders and DED parameters, as well as the proposed diagnostic utility of NIBUT and MG dropout ratios as predictive biomarkers, require rigorous validation through multicenter clinical trials or prospective studies. Such efforts are essential to confirm their reliability and applicability in routine clinical practice.

Conclusion

This study reveals that DED patients with shorter NIBUT and higher MG dropout ratios exhibit significant associations with elevated Anti-TPO and Anti-Tg antibody levels. The integration of NIBUT and MG dropout assessments demonstrates promising diagnostic potential as a predictive biomarker for thyroid disorders in DED populations, underscoring the value of ocular surface evaluation in detecting systemic autoimmune disorders. Further research is warranted to validate these findings and refine their clinical utility.

Abbreviations

Anti-Tg	Anti-thyroglobulin antibody
Anti-TPO	Anti-thyroid peroxidase antibody
AUC	Area under the curve
CFS	Corneal fluorescein staining
DED	Dry eye disease
FBUT	Fluorescein breakup time
FT3	Free triiodothyronine
FT4	Free thyroxine
K5M	Keratograph 5 M
MG	Meibomian gland
NIBUT-avg	Average noninvasive breakup time
NIBUT-first	First noninvasive breakup time
ROC	Receiver operating characteristic
S1T	Schirmer 1 test
TED	Thyroid eye disease
THRSP	Thyroid hormone responsive spot 14
TMH	Tear meniscus height

TSH	Thyroid stimulating hormone
TSHR	Thyroid stimulating hormone receptor
TT3	Total triiodothyronine
TT4	Total thyroxine

Authors' contributions
JXH and QHL designed and supervised the study. YTL and XCW analyzed the data and drafted the manuscript. HY, PY, SYZ. ZC. CCX and XJZ contributed to acquisition of data. All authors read and approved the final manuscript.

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Data availability
The datasets generated and analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
This study conformed to the Declaration of Helsinki and was approved by the Ethics Committee of Eye, Ear, Nose and Throat Hospital of Fudan University (EENTIRB-20190301). Informed consent for participation was obtained from all subjects involved in the study.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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References

1. Craig JP, Nichols KK, Akpek EK, Caffery B, Dua HS, Joo CK, Liu Z, Nelson JD, Nichols JJ, Tsubota K, et al. TFOS DEWS II Definition and Classification Report. Ocul Surf. 2017;15(3):276–83.
2. Stapleton F, Alves M, Bunya VY, Jalbert I, Lekhanont K, Malet F, Na KS, Schaumberg D, Uchino M, Vehof J, et al. TFOS DEWS II Epidemiology Report. Ocul Surf. 2017;15(3):334–65.
3. Mehra D, Galor A. Digital Screen Use and Dry Eye: A Review. Asia Pac J Ophthalmol (Phila). 2020;9(6):491–7.
4. Paulsen AJ, Cruickshanks KJ, Fischer ME, Huang GH, Klein BE, Klein R, Dalton DS. Dry eye in the beaver dam offspring study: prevalence, risk factors, and health-related quality of life. Am J Ophthalmol. 2014;157(4):799–806.
5. Karimi F, Kalantarhormozi MR, Dabbaghmanesh MH, Ranjbar Omrani G. Thyroid disorders and the prevalence of antithyroid antibodies in Shiraz population. Arch Iran Med. 2014;17(5):347–51.
6. Bartalena L, Tanda ML. Current concepts regarding Graves' orbitopathy. J Intern Med. 2022;292(5):692–716.
7. Gorimanipalli B, Khamar P, Sethu S, Shetty R. Hormones and dry eye disease. Indian J Ophthalmol. 2023;71(4):1276–84.
8. Park J, Baek S. Dry eye syndrome in thyroid eye disease patients: The role of increased incomplete blinking and Meibomian gland loss. Acta Ophthalmol. 2019;97(5):e800–6.
9. Selter JH, Gire AI, Sikder S. The relationship between Graves' ophthalmopathy and dry eye syndrome. Clin Ophthalmol. 2015;9:57–62.
10. Wang MTM, Vidal-Rohr M, Muntz A, Diprose WK, Ormonde SE, Wolffsohn JS, Craig JP. Systemic risk factors of dry eye disease subtypes: A New Zealand cross-sectional study. Ocul Surf. 2020;18(3):374–80.
11. Kan E, Kılıçkan E, Ecemiş G, Beyazyildiz E, Çolak R. Presence of Dry Eye in Patients with Hashimoto's Thyroiditis. J Ophthalmol. 2014;2014:754923.
12. Hoang TD, Stocker DJ, Chou EL, Burch HB. 2022 Update on Clinical Management of Graves Disease and Thyroid Eye Disease. Endocrinol Metab Clin North Am. 2022;51(2):287–304.
13. Amescua G, Ahmad S, Cheung AY, Choi DS, Jhanji V, Lin A, Mian SI, Rhee MK, Viriya ET, Mah FS, et al. Dry Eye Syndrome Preferred Practice Pattern®. Ophthalmology. 2024;131(4):P1-p49.
14. Le Q, Ge L, Li M, Wu L, Xu J, Hong J, Gong L. Comparison on the vision-related quality of life between outpatients and general population with dry eye syndrome. Acta Ophthalmol. 2014;92(2):e124-132.
15. Bartley GB, Gorman CA. Diagnostic criteria for Graves' ophthalmopathy. Am J Ophthalmol. 1995;119(6):792–5.
16. Zhang H, Wu Y, Wan X, Shen Y, Le Q, Yang P, Zhou S, Zhou X, Zhou F, Gu H, et al. Effect of Hypochlorous Acid on Blepharitis through Ultrasonic Atomization: A Randomized Clinical Trial. J Clin Med. 2023;12(3):1164.
17. García-Marqués JV, Martínez-Albert N, Talens-Estarelles C, García-Lázaro S, Cerviño A. Repeatability of Non-invasive Keratograph Break-Up Time measurements obtained using Oculus Keratograph 5M. Int Ophthalmol. 2021;41(7):2473–83.
18. Osae EA, Ablordeppey RK, Horstmann J, Kumah DB, Steven P. Clinical Dry Eye and Meibomian Gland Features Among Dry Eye Patients in Rural and Urban Ghana. Clin Ophthalmol. 2020;14:4055–63.
19. Lai EW, Tai YH, Wu HL, Dai YX, Chen TJ, Cherng YG, Lai SC. The Association between Autoimmune Thyroid Disease and Ocular Surface Damage: A Retrospective Population-Based Cohort Study. J Clin Med. 2023;12(9):3203.
20. Gürdal C, Saraç O, Genç I, Kırımlıoğlu H, Takmaz T, Can I. Ocular surface and dry eye in Graves' disease. Curr Eye Res. 2011;36(1):8–13.
21. Allam IY, Lazreg S, Shafik Shaheen M, Doheim MF, Mohammed MA. Ocular Surface Changes in Patients with Thyroid Eye Disease: An Observational Clinical Study. Clin Ophthalmol. 2021;15:2481–8.
22. Liao X, Lai KKH, Aljufairi F, Chen W, Hu Z, Wong HYM, Jia R, Wei Y, Tham CCY, Pang CP, et al. Ocular Surface Changes in Treatment-Naive Thyroid Eye Disease. J Clin Med. 2023;12(9):3066.
23. Gupta A, Sadeghi PB, Akpek EK. Occult thyroid eye disease in patients presenting with dry eye symptoms. Am J Ophthalmol. 2009;147(5):919–23.
24. Wang CY, Ho RW, Fang PC, Yu HJ, Chien CC, Hsiao CC, Kuo MT. The function and morphology of Meibomian glands in patients with thyroid eye disease: a preliminary study. BMC Ophthalmol. 2018;18(1):90.
25. Eckstein AK, Finkenrath A, Heiligenhaus A, Renzing-Köhler K, Esser J, Krüger C, Quadbeck B, Steuhl KP, Gieseler RK. Dry eye syndrome in thyroid-associated ophthalmopathy: lacrimal expression of TSH receptor suggests involvement of TSHR-specific autoantibodies. Acta Ophthalmol Scand. 2004;82(3 Pt 1):291–7.
26. Chou WY, Cheng YS, Ho CL, Liu ST, Liu PY, Kuo CC, Chang HP, Chen YH, Chang GG, Huang SM. Human spot 14 protein interacts physically and functionally with the thyroid receptor. Biochem Biophys Res Commun. 2007;357(1):133–8.
27. Liu S, Richards SM, Lo K, Hatton M, Fay A, Sullivan DA. Changes in gene expression in human meibomian gland dysfunction. Invest Ophthalmol Vis Sci. 2011;52(5):2727–40.
28. Chen YT, Tseng FY, Chen PL, Chi YC, Han DS, Yang WS. Serum Spot 14 concentration is negatively associated with thyroid-stimulating hormone level. Medicine (Baltimore). 2016;95(40):e5036.
29. Colbert CL, Kim CW, Moon YA, Henry L, Palnitkar M, McKean WB, Fitzgerald K, Deisenhofer J, Horton JD, Kwon HJ. Crystal structure of Spot 14, a modulator of fatty acid synthesis. Proc Natl Acad Sci U S A. 2010;107(44):18820–5.
30. Vehof J, Snieder H, Jansonius N, Hammond CJ. Prevalence and risk factors of dry eye in 79,866 participants of the population-based Lifelines cohort study in the Netherlands. Ocul Surf. 2021;19:83–93.

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