International Journal of Innovative Technologies in Social Science

e-ISSN: 2544-9435

Scholarly Publisher
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ARTICLE TITLE	DRY EYE DISEASE – RISK FACTORS, PATHOGENESIS, DIAGNOSTIC METHODS, CLINICAL MANIFESTATIONS AND TREATMENT – NEW LITERATURE REPORTS
ARTICLE INFO	Bartłomiej Trzciński, Patryk Kowalczyk, Oliwia Gugała, Igor Winogrodzki, Alicja Stryczek-Schlusche, Aleksandra Magdalena Furczyńska, Wiktoria Socha, Aleksandra Gęsińska, Hanna Paszkiewicz, Kamil Nowak. (2025) Dry Eye Disease – Risk Factors, Pathogenesis, Diagnostic Methods, Clinical Manifestations and Treatment – New Literature Reports. *International Journal of Innovative Technologies in Social Science*. 3(47). doi: 10.31435/ijitss.3(47).2025.3583
DOI	https://doi.org/10.31435/ijitss.3(47).2025.3583
RECEIVED	08 July 2025
ACCEPTED	16 August 2025
PUBLISHED	27 August 2025
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DRY EYE DISEASE – RISK FACTORS, PATHOGENESIS, DIAGNOSTIC METHODS, CLINICAL MANIFESTATIONS AND TREATMENT – NEW LITERATURE REPORTS

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ABSTRACT

Dry eye syndrome (DED) is a prevalent condition, affecting millions of people worldwide. The condition is characterised by a multifactorial disorder of the ocular surface, resulting in the loss of the natural protective barrier of the eyes, known as the tear film, and accompanied by more or less characteristic symptoms. The objective of this article is to present a thorough review of the extant scientific literature, incorporating an exhaustive analysis of the pathogenesis, identification of risk factors, and discussion of diagnostic and therapeutic methods, with consideration given to both conventional approaches and the most recent research findings. Despite ongoing research, the etiology of dry eye syndrome remains unclear. However, various factors have been identified as potential risk elements, including age, gender, environmental influences, ethnics origin, and comorbidities, particularly autoimmune diseases. Tear substitutes remain the primary and most commonly used treatment method, but recent scientific research has focused on drugs that are capable of modifying inflammatory processes to a much greater extent. Lifestyle modifications or the use of increasingly available specialised medications have enabled patients to recover. The condition of dry eye syndrome poses significant challenges in the domains of both ophthalmology and numerous other medical specialties. The effective control of the disease will only be possible with a coordinated approach to the following: symptoms, pathogenesis and patient capabilities. Further research into mechanisms and diagnostic methods is imperative, with the potential to significantly improve the quality of life for millions of patients.

KEYWORDS

Dry Eye, EDE, ADDE, Artificial Tears, Dry Eye Diagnosis, Dry Eye Syndrome Treatment

CITATION

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Introduction.

Dry eye syndrome (DES) is a multifactorial, extensively complex condition.

This disease has a global prevalence, affecting hundreds of millions of people worldwide and representing one of the most common reasons for patients to visit an ophthalmologist. The instability of the tear film underlying DED initiates a vicious cycle of damage to the eye surface and subsequent neurosensory disorders [1].

The condition is characterised by dysfunction of at least one anatomical or physiological structure responsible for the secretion or production of tears with normal composition. The diagnosis of DED is challenging in routine medical practice, as many ophthalmic conditions, some of which may be more serious, can produce similar symptoms. The frequently reported redness of the eyes in dry eye syndrome may coexist with more characteristic symptoms, such as persistent dryness, itching, and a foreign body sensation, particularly described as sand under the eyelids. DED has been demonstrated to exert a detrimental effect on the overall quality of life and well-being of patients. In advanced cases, it can lead to a significant deterioration in mental health [2]. The absence of stable protection from the tear film renders the eyeball more vulnerable to bacterial, viral and fungal infections, microtrauma, and the healing process of wounds on its surface is significantly impeded [26].

It is important to note that dry eye syndrome may also occur in association with other diseases, particularly those of autoimmune or hormonal origin. In many cases, the symptoms of DED require further diagnosis to rule out more serious systemic disorders, and an understanding of the pathophysiology of the mechanisms can significantly accelerate this process [38].

Materials and Methods

A detailed analysis of 44 peer-reviewed scientific articles published between 2020 and 2025 from sources such as PubMed and Google Scholar focused on recent reports on dry eye syndrome.

Risk Factors

The identification of risk factors for DED remains challenging due to the intricacy of the pathophysiological mechanisms that underpin the development of this disease. While contemporary research has enhanced our ability to identify the more or less probable causes of the syndrome, there remains a paucity of information to clearly determine the relationship between risk factors and the development of DED. In this instance, further research is therefore required, extending to a larger number of ethnic groups, patients of different ages and a range of comorbidities, with particular emphasis on autoimmune diseases [3].

2.1 Age

It is an irrefutable fact that the development of dry eye syndrome is contingent on age. The increase in the incidence of the disease after the age of 40 is particularly evident. It is imperative to acknowledge that with advancing age, the patient's exposure to various factors increases. These factors encompass physiological processes, such as natural ageing, and pathological processes, including diseases. Additionally, environmental hazards also contribute to the overall risk profile. At present, DED symptoms are less frequently reported in the paediatric population, but recent studies over the last few years have observed an increase in the incidence of the condition in children, prompting a search for a link between this and generational changes in the amount of time spent in front of computer screens [3, 4, 6].

In the elderly population, irregularities in the structure of the eyelids are more prevalent, leading to exposure of the cornea. Conversely, younger patients tend to exhibit a reduced blink frequency, despite the typical preservation of the number and function of Meibomian glands. The consequence of both mechanisms is the drying of the tear film and disruption of its proper distribution over the surface of the eye [5].

Given the concomitant occurrence of chronic diseases in the elderly population and the increased time spent in front of digital device screens in the younger population, there is a need for more cross-sectional studies that specifically address these factors. The data obtained will be of key importance in clinical practice, enabling faster and more targeted interventions and effective education on eye hygiene [3].

2.2 Female gender

It is hypothesised that the correlation between the increased prevalence and severity of dry eye syndrome symptoms in women is predominantly attributable to the influence of hormonal factors, particularly sex steroids, hypothalamic-pituitary hormones, such as gonadotropin-releasing hormone, luteinising hormone (LH), follicle-stimulating hormone (FSH), and the extensively studied impact of thyroid hormones. The factors under discussion have been shown to alter the functioning of the lacrimal glands and Meibomian glands, although the precise mechanisms by which they do so remain to be fully elucidated. In addition, they may also directly affect the surface of the eye. It is also worth mentioning the positive correlation between the increased incidence of DED and the action of sex chromosomes and specific genes [3, 12].

Furthermore, biological differences between the sexes are also reflected in the development and characteristics of dry eye syndrome symptoms. It has been demonstrated that female patients are more likely to report symptoms and related mood disorders, including depression, than their male counterparts. It is also important to note the higher incidence of autoimmune diseases in women, particularly Sjögren's syndrome, of which DED is a primary and fundamental symptom. The impact of hormonal profile disorders on the development of dry eye syndrome can also be confirmed by changes occurring in women with polycystic ovary syndrome (PCOS), in whom the reported symptoms occur more frequently and are more severe. The composition and quantity of the tear film that covers the surface of the eye undergoes cyclical changes, typical of women of reproductive age. During the ovulation and luteal phases, in comparison to the early follicular phase, an increase in the concentration of inflammatory cytokines such as IL-1β, IL-6 and VEGF was observed. Furthermore, cyclical menstrual changes have been demonstrated to affect the thickness of the cornea, which becomes thinner at the beginning and thicker at the end of the cycle [13].

2.3 Environment

Confirmed external factors causing disturbances in the structure and function of the tear film, especially those that accelerate the evaporation of the aqueous component from the surface of the eye, include dry and windy climates, high air pollution and exposure to smoke [15].

In the contemporary digital era, extensive research has been conducted on the phenomenon of prolonged engagement with mobile phone and computer screens. The incidence of DED is increasingly being observed in younger demographics, which is a worrying phenomenon. Prolonged exposure to displays is a multifaceted factor in the development of the disease, involving structural disturbances such as reduced blinking frequency, leading to tear film instability, reduced tear secretion, and even increased expression of inflammatory cytokines and markers of oxidative stress, such as hexanoyl lysine, 4-hydroxy-2-nonenal, malondialdehyde and 8-oxo-2'-deoxyguanosine [5, 9].

2.4 Genetics

The influence of genetic factors on the development of DED is an intriguing and intricate subject. This poses a significant challenge for researchers, and the identification of specific genetic risk markers will form the basis for the production of modern drugs in the future. At this juncture, the financial burden of these studies is considerable, and gene therapy in this domain is still in its nascent stage. The significance of many DNA variants remains to be elucidated, and the confirmation of any genetic associations appears to be a future prospect that is yet to be realised [3].

2.5 Ethnic origin

This is another risk factor that is largely influenced by specific anatomy, environment and health behaviours. Research indicates that dry eye syndrome manifests more frequently in East Asian populations (16.7-33.4%) than in Caucasian (8.7-11.0%), Indian (26.2%), United States (5.3-14.5%), and African (32.5%) populations. However, it is important to note that the latter value may be overestimated due to the imprecise and limited nature of the studies conducted thus far. This underscores the necessity for further verification of these data. The higher incidence of DED in the East Asian population may be attributable to both anatomical variations in the eyeball, which result in greater eyelid tension, potentially contributing to incomplete blinking and accelerated tear film drying, as well as behavioural factors. A substantial body of research has demonstrated that children of Asian descent are exposed to digital screens for a greater proportion of their time than their counterparts from other ethnic groups [4, 6, 42].

2.6 Systemic Diseases

A multitude of systemic diseases have been observed to induce or exacerbate the symptoms of dry eye syndrome. A proportion of these are directly related to the anatomical structures of the eye, tear secretion mechanisms, or inflammatory mediators. Autoimmune diseases have been demonstrated to be particularly associated with dry eye syndrome, given that they result in infiltration and damage to the glands responsible for tear secretion, as well as those that contribute to maintaining the proper composition of the tear film [3].

Although a number of autoimmune diseases, including rheumatoid arthritis, systemic lupus erythematosus, systemic sclerosis, recurrent chorditis and ankylosing spondylitis, have been demonstrated to contribute significantly to the development of dry eye disease (DED), it is well established that Sjögren's syndrome has been historically associated with the development of dry eye syndrome since as early as 1933 [20, 26]. It is a systemic autoimmune disease that causes inflammatory infiltration of the exocrine glands, including the lacrimal gland and the salivary gland. The pathogenesis of this condition is multifactorial in nature, involving a combination of genetic predisposition, female gender, previous viral infections, activation of B lymphocytes, Th1 and Th17 lymphocytes, and increased concentrations of pro-inflammatory cytokines such as extracellular matrix metalloproteinases (MMPs) [8, 20].

It is evident that diseases associated with hormonal changes are also listed as a direct cause of DED development. Thyroid hormone deficiency in cases of hypothyroidism or other pathologies has been shown to be associated with a decrease in the activity of the lacrimal glands, which in turn contributes to the loss of the aqueous component of the tear film [3]. Quantitative changes in androgens, which regulate both tear secretion and the composition of the lipid component that contributes to the reduction of tear evaporation from the surface of the eye, may explain the more frequent occurrence of DED in diseases such as PCOS or during adrenal dysfunction [13].

Furthermore, diabetes and the cross-reaction of antigens associated with the development of dry eye syndrome are also prevalent in the population and are significant risk factors. A plethora of symptoms may be attributable to alterations in microcirculation and neuropathy. Autonomic neuropathy, characterised by a reduction in corneal sensation, has been demonstrated to limit the reflex production of the tear film and, on occasion, the frequency of blinking. This, in turn, has been shown to result in damage to the corneal epithelium [3, 10].

The aetiology of dry eye syndrome encompasses a wide range of potential causes, including but not limited to mood disorders, depression, post-traumatic stress disorder (PTSD), sleep apnea, migraine, asthma, chronic obstructive pulmonary disease (COPD), allergies, hypertension and coronary artery disease [8].

A decrease in blood vitamin D levels has been demonstrated to be a contributing factor to the development of dry eye syndrome. It has been demonstrated that vitamin D has the capacity to inhibit corneal inflammation by affecting Langerhans cells and the production of pro-inflammatory mediators such as interleukins and TNF-α via the vitamin D receptor (VDR). Consequently, it appears imperative to assess its levels in cases of treatment-resistant dry eye syndrome [15].

2.7 Medicines

The development of dry eye syndrome is influenced by a number of systemic medications. Anticholinergics, encompassing antihistamines, antidepressants and anxiolytics, function as antagonists at muscarinic receptors, a class of neurotransmitter receptors. The mechanism of blocking these receptors has been shown to reduce the activity of the glands; in the case of the lacrimal gland, this results in a decrease in tear production, and in the case of goblet cells, a decrease in mucin production. Furthermore, a group of antidepressants that increase serotonin availability may affect the nerve sensitivity of the cornea and thus be responsible for the deregulation of tear secretion [3]. Research has indicated that there is an approximate threefold increase in the likelihood of developing DED when a patient is prescribed a single anticholinergic drug [11].

The potential for the development of dry eye syndrome has also been identified as a consequence of hormone replacement therapy (HRT). This phenomenon can be attributed to the inhibitory effect of oestrogens on the synthesis of the lipid component of the tear film within the Meibomian glands [3].

Reduced tear secretion may also result from the use of pharmaceuticals such as antihypertensive agents, diuretics, oral steroids and antiglaucoma drugs [6, 15].

2.8 Ophthalmic Conditions

The advent of novel ocular surgical techniques has engendered the capacity to treat ophthalmic conditions that heretofore were considered to be beyond the scope of medical intervention. However, even with the employment of contemporary microsurgical techniques, the interference with such diminutive and intricate structures carries the risk of damaging the natural protective structures of the eye surface. The following surgical procedures have been identified as those which carry an elevated risk of developing dry eye disease (DED): cataract surgery, pterygium removal, strabismus treatment, glaucoma surgery, eyelid surgery and laser vision correction (LASIK, PRK). It is important to note that the majority of these procedures are associated with transient symptoms of dry eye syndrome. However, in a subset of patients, these symptoms can be so debilitating and persistent that they result in a marked diminution in satisfaction with the surgical outcome. Appropriate education and effective treatment of dry eye syndrome symptoms have been shown to be beneficial in reducing postoperative discomfort. Furthermore, such treatment has been demonstrated to improve patient satisfaction with the results of the procedure and psychological comfort [7].

It is imperative to acknowledge the significance of prolonged or erroneous contact lens usage as a pivotal risk factor. This results in the division of the tear film into two distinct regions, thereby promoting its instability and causing a disturbance in the proper distribution of tears across the surface of the cornea [3, 6].

Pathogenesis

The multifactorial aetiology of dry eye syndrome, i.e. the occurrence of the condition due to a number of unrelated factors, means that current research is unable to fully explain the complex mechanisms and processes that cause it. The majority of studies into the aetiology of DED categorise the condition into two primary classifications: aqueous tear-deficient dry eye (ATDDE), with a prevalence of 6.2%, and evaporative dry eye (EDE), with a prevalence of 64.2%. The coexistence of both forms has been observed in approximately 11.1% of patients, resulting in a more complex clinical picture. The accurate classification of patients with dry eye syndrome is challenging, with incorrect diagnoses made in up to 18.5% of cases. The accurate determination of the primary cause of DED is of crucial importance when selecting the most appropriate treatment plan [12, 14].

3.1 Aqueous Tear-Deficient Dry Eye (ATDDE)

The primary catalyst for this progression is a multifaceted sequence of inflammatory responses, initiated by hyperosmotic stress arising from elevated tear osmolarity, predominantly during diminished production of the aqueous component. Although hyperosmolarity can be caused by a number of independent factors, the common consequence is a disturbance in the maintenance of a stable tear film on the surface of the cornea and conjunctiva. Aqueous component deficiency syndrome (ACDS) is characterised by a reduced tear meniscus height (TMH) of less than 0.2 mm [12, 14]. In the context of chronic hyperosmotic stress in tears, there is evidence of increased expression of Interleukin-20 (IL-20). This stress has been shown to affect other inflammatory factors, including IL-1β, IL-6, IL-8, TNF-α, and extracellular matrix metalloproteinase (MMP-9). Furthermore, it has been demonstrated that this stress can induce cell apoptosis. This process is pivotal in the development and progression of dry eye syndrome [1, 16].

ATDDE can be categorised as either comprising an aqueous component deficiency associated with Sjögren's syndrome, or not associated with Sjögren's syndrome [8].

3.1.1 Sjögren's syndrome

It is a systemic autoimmune disease in which immune system cells infiltrate the exocrine glands, principally the lacrimal and salivary glands. Damage to the former results in symptoms of dry eyes, and in the case of salivary gland involvement, also to dry mouth (known as sicca syndrome). The manifestation of Sjögren's syndrome is characterised by a plethora of symptoms, including but not limited to: joint and muscle pain, chronic fatigue and lymphadenopathy. The co-occurrence of the disease with rheumatoid arthritis (RA) is a common occurrence. Sjögren's syndrome manifests more frequently in women, individuals with genetic predispositions, and following viral infections. In recent studies, the influence of inflammatory factors and the role of the gut microbiome in its pathogenesis have also been described [8]. Androgen deficiency in Sjögren's syndrome is also of significance. These hormones have been shown to stimulate genes that produce and transport lipids in the Meibomian glands [13].

3.1.2 Water component deficiency not associated with Sjögren's syndrome

The etiology of the condition is divided into two broad categories: congenital and acquired. Congenital absence of tears is an uncommon condition, characterised by an absence of tear production from birth. It is associated with underdevelopment of the lacrimal gland or a disorder in the structure of the tear ducts. The acquired causes of ATDDE include conditions such as Stevens-Johnson syndrome (SJS), mucous membrane pemphigoid and graft-versus-host disease (GvHD). The fundamental mechanism of these diseases is an immune response. Although the subsequent stages of DED symptom development differ from each other, they can be described collectively as a process involving pro-inflammatory cytokines, microorganisms (including viral infections), and drug-induced mechanisms leading to the deposition of neutrophils in body tissues. These changes result in scarring of the structures surrounding the eyelids and conjunctiva, which consequently impedes tear secretion. A number of other factors have been identified as possible causes of acquired ATDDE. These include mechanical trauma, exposure to ionising radiation, previous ocular surgery and the use of certain pharmaceuticals [8].

3.2 Evaporative Dry Eye (EDE)

The primary cause of this condition is a disruption or reduction in the function of the lipid layer of the tear film, with the tear gland function typically remaining unaffected. In this case, a characteristic feature will be a reduction in the number of Meibomian glands by more than 28%, a lipid layer thickness (LLT – in interferometric examination, assessed on the Guillon-Keeler scale) below three, and tear evaporation above 46g/m2 per hour [12, 14, 15].

Therefore, in contradistinction to dry eye syndrome resulting from a deficiency of the aqueous component, excessive evaporation (EDE) will be predominantly associated with increased loss of meibum, an oily substance whose function is to reduce evaporation of the tear film [14]. This component of tears is produced by the Meibomian glands, which are located in the area adjacent to the edge of the eyelids. The aetiology of atrophy or obstruction of these glands is multifactorial and may be primary or secondary to inflammation [12, 22]. The loss of meibum leads to increased evaporation and loss of the aqueous component of the tear film. As with ATDDE, this condition leads to tear hyperosmolarity, which in turn results in the development of chronic inflammation and apoptosis of the epithelial cells of the eye surface [22].

Furthermore, excessive evaporation of the tear film from the surface of the eye can also occur during the loss of goblet cells. The mucin they produce is essential for ensuring adequate adhesion of the aqueous layer to the surface of the eye. In the event of a deficiency, the cornea becomes hydrophobic, which significantly accelerates tear evaporation [6].

A number of factors have been identified as contributing to the development of EDE. These include infrequent blinking, incomplete closure of the eyelids (lagophthalmos), anatomical disorders of the accessory organs of the eye, vitamin A deficiency, wearing contact lenses, and even environmental factors such as low air humidity or high air flow [6, 12].

Clinical Manifestations

The initial presentation of symptoms encompasses complaints pertaining to abnormalities in the production, composition or stability of the tear film. The most common symptoms are permanent or temporary redness and irritation of the eyes. It is important to note that these symptoms may also be manifestations of various ophthalmic conditions, such as allergy, infection, epithelial erosion, anterior segment inflammation, scleritis or episcleritis, or even increased intraocular pressure. Due to the non-specific nature of the symptoms, in clinical practice, dry eye syndrome should only be diagnosed after other potentially serious causes have been ruled out [39].

A significant proportion of patients may report ocular discomfort of varying intensity. The aetiology of this condition may be attributed to nociceptive, neuropathic or psychogenic reactions. The potential for analysis of alterations in tear evaporation from the ocular surface by the body's physiological responses may provide a rationale for heightened sensitivity during instances of excessive tear loss. It has been demonstrated that certain receptors are adapted to respond to mechanical stimuli arising during friction movements, with their activity being particularly intensified when the eye loses its natural lubricating layer. However, the majority of receptors are polymodal and possess the capacity to respond to mechanical, thermal and chemical stimuli, as well as to the hyperosmolarity of tears [17].

The loss of tear film integrity is also accompanied by a range of symptoms, including a burning sensation, the presence of a foreign body, sand in the area or under the eyelids, dryness and itching. Despite an increase in tear secretion, the absence of sufficient tear components results in inadequate protection of the eyeball. Despite the paucity of research conducted on paediatric subjects, preliminary findings suggest that the presentation of symptoms in children may mirror that observed in adults [18, 20, 40, 41].

A further group of symptoms is characterised by a reduced capacity of the eye to accommodate. The overloading of ocular mechanisms during extended periods of focal attention to a single point has been demonstrated to induce symptoms including secondary visual impairment, difficulties in re-focusing on distant objects and diplopia. A correlation has been demonstrated between the accelerated progression of refractive eye diseases, such as myopia, and the onset of DED. The final group encompasses symptoms manifesting extraocularly, predominantly attributable to improper body posture, for instance, during extended periods of work in front of a computer. The aetiology of this condition is most often musculoskeletal, with the reported symptoms including headaches, shoulder pain, neck pain and back pain resulting from neck stiffness. The majority of patients will report the co-occurrence of symptoms from different groups, and less frequently, the occurrence of only one symptom [30, 39, 41].

The transition in lifestyle patterns subsequent to the emergence of the novel Coronavirus (SARS-CoV-2) has precipitated an augmentation in the duration of time patients allocate to digital screens, a phenomenon that has engendered a reportage of challenges pertaining to extended periods of digital screen usage. In consideration of the aforementioned symptoms, it can be posited that this may represent a further, equally significant step towards the early detection of DED. Moreover, the presence of persistent ocular inflammation has been demonstrated to result in a substantial decline in quality of life, thereby contributing to the emergence of mental health disorders [24, 40].

In severe cases, dry eye syndrome can lead to structural changes in the corneal and conjunctival epithelium, causing corneal epithelial exfoliation, fibrillary keratopathy, and even significant scarring of the conjunctiva [18, 19].

A less common set of symptoms reported by patients includes difficulty in wearing contact lenses, a reduced blink rate, twitching or a feeling of heavy eyelids, and difficulty opening the eyes. Furthermore, the condition may be accompanied by sharp or dull pain in the retro-orbital area, and in severe cases, an inability to cry may also be observed [12, 26].

Diagnosis

The prevalence of DED ranges from 5 to 50% in population studies. The broad spectrum of outcomes can be attributed, in part, to the absence of universally applicable criteria and diagnostic tests that would facilitate a definitive diagnosis of the condition. In view of the fact that DED has been observed to occur in association with the use of certain medications, due to environmental factors, and as a manifestation of other diseases, especially autoimmune diseases, diagnosis should not be based solely on the assessment of dry eye symptoms, but also on determining the direct cause. Consequently, it is imperative to meticulously collect information regarding the patient's health and symptoms of dry eye, encompassing their nature, frequency, severity, and impact on daily functioning. The administration of bespoke questionnaires, such as the Ocular Surface Disease Index (OSDI), the Dry Eye Questionnaire (DEQ), and the SPEED questionnaires, is utilised for this purpose [24, 25, 39].

The diagnosis is thus formulated on the basis of a combination of subjective symptoms reported by the patient, an objective ophthalmological examination, and diagnostic tests designed to detect DED [20].

The absence of universal diagnostic criteria signifies that the diagnosis of DED may vary depending on the classification employed. For instance, the TFOS DEWS II criteria include a score of ≥6 reported using the DEQ-5 questionnaire or a score of ≥13 for the OSDI questionnaire, in addition to at least one positive homeostasis marker. These are defined as: tear break-up time (NIBUT or fluorescein <10 s), tear osmolarity above 308 mOsm/l, interocular difference of 7 mOsm/l, or staining of the eye surface using, for example, the Oxford or Efron scales. The Asia Dry Eye Society (ADES) criteria define dry eye disease (DED) as an Ocular Surface Disease Index (OSDI) score of ≥13 and a Tear Breakup Time (TBUT)/NIBUT ≤5 seconds. In turn, the Japanese Dry Eye Society (JDES) criteria require the presence of symptoms included in the Dry Eye Quality of Life Scale (DEQS), tear abnormalities (Schirmer test ≤5 mm or TBUT/NIBUT ≤5 seconds) and damage to the surface of the eye (determined by staining, where a score greater than 3 points out of 9 is considered positive) [20].

5.1 Tear film break-up time assessment

In clinical practice, the methods employed are primarily those that are widely available to medical professionals and well tolerated by patients. The diagnosis of tear film disorders is achieved through the utilisation of ophthalmic dyes, the administration of tear osmolarity tests, and the Schirmer test. Of these, the most frequently used are diagnostic dyes such as fluorescein, lysamine green and, less commonly, rose bengal. The distribution of these dyes on the surface of the cornea and conjunctiva is then assessed using a slit lamp with an appropriate filter [20, 25].

A fundamental diagnostic method is the measurement of tear break-up time (TBUT), which is observed as the spreading of a dye, most commonly fluorescein, on the surface of the cornea using a slit lamp with a cobalt (blue) filter. In the case of fluorescein, the normal TBUT value is above 15 seconds. Values between 10 and 15 seconds are considered borderline, while results below 10 seconds may indicate an abnormal balance between the mucinous-aqueous layer and the lipid layer of the tear film. Tear haemostasis disorders are also indicated by the presence of >9 spots during conjunctival staining using special lysamine green or staining of the eyelid margin (Lid Wiper Epitheliopathy – LWE) using fluorescein and/or lysamine green with a length of ≥2 mm and a width of ≥25%. Alternatively, tear film stability can be assessed using the NIBUT (non-invasive TBUT) method, e.g. interferometry, which determines changes in light reflection on the tear film and allows indirect assessment of its stability without the use of dyes [12, 25].

5.2 Assessment of tear production capacity

The Schirmer test is the most common method employed to assess the quantity of tears secreted. The procedure entails the placement of a specially designed strip of filter paper within the crease of the lower eyelid, with the objective of quantifying the lacrimation rate of the eye. The successful execution of the test is contingent upon experience and expertise, as minor irritation of the cornea can induce reflexive and excessive tear secretion, thereby distorting the measurement. The test result is read after a period of five minutes and indicates the length of the moistened strip in millimetres. Values of 15 mm or more are considered normal, while a result between 10 and 15 mm indicates a mild decrease in tear production. The diagnosis of dry eye syndrome is determined by the presence of results falling below 5 mm or 10 mm, as indicated by the established criteria. Such a decrease is indicative of the loss of an adequate amount of the aqueous component of the tear film [12, 21].

In less common instances, a cotton thread soaked in phenol red (PRT) is utilised to assess tear secretion. As with the Schirmer test, the thread is placed in the lower conjunctival sac, but the test is conducted for a shorter duration of 15 seconds. Subsequent to this period, the length of the reddened section is measured. A value of less than 10 mm is significant in the diagnosis of DED [12].

5.3 Tear film assessment

Increased tear osmolarity has been identified as one of the fundamental mechanisms responsible for the pathophysiology of dry eye syndrome. It has been observed that an increase in tear osmolarity is associated with a deterioration of the condition. Tests designed to assess tear osmolarity are commercially available, yet their utilisation within routine ophthalmic practice remains limited. This is primarily attributable to the substantial expense associated with the requisite equipment and the paucity of reimbursement options. Consequently, they are predominantly employed in scientific research or as a subsequent stage in clinical diagnosis. In accordance with the established threshold values, a positive result is indicated by a threshold that exceeds 308 mOsm/l or the presence of a substantial interocular osmolarity difference that surpasses 7 mOsm/l. Bedside tests measuring matrix metalloproteinase 9 (MMP-9) levels, which increase in the tears of people with dry eye syndrome, can also be considered for tear film assessment. However, as with tear osmolarity tests, these are not yet as widely available as other diagnostic methods [12, 24, 25].

5.4 Assessment of the cornea and conjunctiva

Redness, a burning sensation, and the sensation of sand in the eye are frequently reported symptoms in cases of erosion of the corneal or conjunctival epithelium. The utilisation of dyes that have the capacity to deposit at the site of the defect is advantageous for the purpose of determining the severity of the disease. The most common method of administration of fluorescein for this purpose is by means of a specially stained leaflet. The assessment is performed under a slit lamp using a cobalt filter, and the presence of staining in a minimum of five points is considered a positive result. Conversely, lisamine green staining is predominantly utilised in the diagnosis of conjunctival and eyelid margin damage. In this case, a positive result is indicated by the presence of a minimum of nine staining points on the conjunctiva. Eyelid margin staining (LWE) is considered positive if the stained area is ≥ 2 mm in length or if its sagittal width exceeds $\geq 25\%$ [12].

5.5. Assessment of the activity and functionality of the Meibomian glands

The condition is characterised by the absence of meibum, the fundamental component of the lipid layer in the tear film, which functions to minimise evaporation from the surface of the eye. The function of the Meibomian glands, responsible for the production of meibum, can be determined visually using a slit lamp or a handheld light source with magnification. A combination of an assessment of the appearance and a patency test using pressure around the edge of the eyelids can provide preliminary information about the proper functioning of the glands. The absence of resistance to the flow of clear secretion is indicative of the efficacy of the procedure. In the event of cloudy, sticky mucus that is difficult to expel, further diagnostic procedures may be indicated. A more advanced method is meibography, which involves the assessment of the meibomian glands using special infrared systems. During the examination, both the upper and lower eyelids are subjected to quantitative and qualitative assessment, and the result can be presented using a digital image. The thickness of the lipid layer can also be examined using broad-spectrum white light interferometry [12, 25].

5.6 Laboratory tests

Currently, there are no laboratory methods that can clearly and unambiguously confirm the diagnosis. Nevertheless, the diagnostic approach should involve actively searching for the cause of DED. Given that dry eye syndrome symptoms occur in many diseases, it seems appropriate to use laboratory parameters that can identify the direct cause. Measuring the concentration of cholesterol, testosterone, dehydroepiandrosterone (DHEA), sex hormone-binding globulin (SHBG) and ultrasensitive estradiol in serum may be helpful. In cases of suspected Sjögren's syndrome, serological markers such as anti-Ro (SSA) and/or anti-La (SSB) should be tested for [22, 23].

5.7 Biomarkers

Recent studies have indicated a correlation between the development of dry eye syndrome and elevated levels of inflammatory mediators, including interleukins (IL-1β, IL-2, IL-4, IL-6, IL-9, IL-12 and IL-17A), interferon gamma (IFN-γ), tumour necrosis factor alpha (TNF-α), chemokines (e.CCL2, CCL3, CCL4 and

CXCL8), metalloproteinase-9 (MMP-9), fibroblast growth factor (FGF), vascular endothelial growth factor (VEGF-A) and neurotrophic factors such as NGF, substance P and serotonin. Soluble receptors including sICAM-1 and sTNFR1 have also been implicated. Reduced levels of IL-7, IL-17F, CXCL1, CXCL10, EGF and lactoferrin have also been reported. Increasing access to specialised testing for these biomarkers could be extremely useful for diagnosing, monitoring, and evaluating the effectiveness of treatment for dry eye disease (DED). Currently, these markers are mainly used in scientific research. They are not yet routinely used in clinical practice [24, 32].

Treatment - General Principles and New Directions

The aetiology of dry eye syndrome (DED) is still being studied, and treatment requires an individual approach. This is due to the complexity of the underlying pathophysiological mechanisms, the wide range of clinical symptoms, and the frequent occurrence of comorbidities that exacerbate the progression of the disease. Taking into account environmental influences, health behaviours and individual preferences is crucial for therapeutic success. Many products and therapeutic methods are currently available, with others remaining at the stage of intensive clinical research [26]. The primary goal of treating dry eye syndrome is to break the cycle of inflammation, improve tear composition, and restore normal meibomian gland function. At the same time, improving the patient's quality of life is extremely important, as the disease may be accompanied by mood disorders [1, 2].

In mild cases, basic recommendations such as patient education, eliminating risk factors, practising proper eye hygiene, using topical lubricants and applying warm compresses to the eyelids to unblock the Meibomian glands are usually sufficient. Oral supplementation with omega-3 fatty acids, which have anti-inflammatory properties and support tear film stability, may also be recommended [1, 12].

For more severe cases, alongside the use of preservative-free artificial tears, additional methods may be appropriate, such as intense pulsed light (IPL) therapy or thermally assisted Meibomian gland cleansing using specialised devices. Where active inflammation is present, topical antibiotics may be necessary, either alone or in combination with corticosteroids. In some cases, immunomodulatory drugs (e.g. cyclosporine A), LFA-1 antagonists (lifitegrast) and oral antibiotics from the macrolide or tetracycline group may be advisable, as well as topical secretagogues such as rimonabant [1, 26].

Some patients, particularly those with chronic conditions or those who have not responded to previous treatment, may benefit significantly from the temporary or permanent closure of the tear ducts, special therapeutic lenses that offer protection and moisture, or ophthalmic surgery [1, 12].

6.1 Preliminary treatment and lifestyle modification.

The first and most important stage in treating dry eye syndrome is talking to the patient. This should involve explaining the nature of the condition, discussing potential risk factors, and presenting a treatment plan. Educating patients increases their involvement in the therapeutic process and facilitates long-term compliance with recommendations. Exposure to environmental factors that exacerbate symptoms should be limited, such as dry air, cigarette smoke, wind and air conditioning. Any medications used to treat other conditions should be chosen to minimise the risk of exacerbating DED symptoms. There is increasing emphasis on hygiene when using digital devices. It is recommended that you limit your screen time to a maximum of 4 hours per day and implement the 20-20-20 rule: take a 20-second break every 20 minutes to look into the distance at a distance of 20 feet (about 6 metres) while blinking intensively. Adequate indoor humidity can also help alleviate symptoms. To protect your eyesight, it is also recommended that you use blue light filter glasses and monitors with an anti-reflective coating [1, 41].

6.2 Local moisturising of the eye surface

Artificial tears applied to the surface of the eye are the basic and most common method of treating DED at all stages of the disease. Their main task is to ensure adequate lubrication of the eye surface, stabilise the tear film and reduce the osmolarity of the corneal surface, thereby indirectly reducing inflammation. Thanks to these properties, they prevent microdamage to the corneal epithelium. However, it should be noted that artificial tears do not directly contribute to the prevention of the disease, but are mainly responsible for reducing the severity of symptoms. These preparations differ in composition and mechanism of action. Some of them contain hydrophilic agents, such as carboxymethylcellulose, dextran 70 or glycerine, which protect the epithelial cells from hyperosmolarity. Others consist mainly of lipid substances, such as linseed oil or mineral oil, which help to rebuild the tear film by reducing evaporation. The common function of these

preparations is to protect, support the regeneration of the eye surface and alleviate the symptoms of DED. When using artificial tears, preservative-free products are preferred for long-term treatment as they do not cause additional irritation. Since the tear film consists of aqueous, lipid and mucin components, the use of artificial tears that reproduce only one component may not be sufficient. Therefore, multi-component tear substitutes or eye surface modulators are increasingly being developed, depending on their effect on the components of the tear film and epithelial functions [1, 26, 27].

6.3 Antiflammatory and Immunomodulatory Therapies

The key to treating DED is to stop and control inflammation. Topical immunomodulatory and immunosuppressive drugs, such as corticosteroids, cyclosporine A and the LFA-1 antagonist lifitegrast, can be used for this purpose. In cases of suspected infection, antibiotics from the tetracycline or macrolide group can be used, as these also have anti-inflammatory properties by inhibiting the activity of metalloproteinases (MMP-9) [1, 6].

Corticosteroids are used in short cycles, mainly during exacerbation periods, as chronic therapy can cause side effects such as increased intraocular pressure and cataract development [28].

Cyclosporine A works by blocking the calcineurin-phosphatase pathway, thereby inhibiting T-cell activity and reducing the production of inflammatory cytokines (IL-2 and IL-6). It increases the number of goblet cells, thereby increasing tear production and regenerating the eye surface. Clinical improvement can be observed after just four weeks of use, while objective improvement, as assessed by corneal staining and the Schirmer test, appears after several months of therapy. The most common side effects are a burning sensation, a foreign body sensation, itching and hyperaemia [27, 28].

The LFA-1 antagonist lifitegrast blocks the binding of the ICAM-1 molecule to LFA-1, reducing T-cell activation and lowering pro-inflammatory cytokine levels (including IFN-γ, IL-1β and IL-10). This reduces inflammation of the eye surface and alleviates the symptoms of the disease [27, 28].

Using omega-3, hyaluronic acid, tacrolimus or non-steroidal anti-inflammatory drugs may also help. Omega-3, when used both orally and topically, acts as an inflammatory mediator by converting into anti-inflammatory lipid mediators. It improves the quality of the tear film and reduces subjective symptoms. However, its bioavailability following topical administration is limited, and research into new delivery systems is ongoing [8, 34].

Thanks to its water-binding properties and protection against oxidative stress, hyaluronic acid is used in preparations that support epithelial regeneration. While its effectiveness has been confirmed, further research is needed to determine the optimal dosage [30, 33].

Topical tacrolimus has an immunosuppressive effect, inhibiting T lymphocytes and reducing the release of inflammatory cytokines (IL-3, IL-5, IL-8 and IFN-gamma), and can be used in cases that are resistant to standard methods [44].

Topical non-steroidal anti-inflammatory drugs (NSAIDs) relieve pain, burning sensations and the gritty feeling, but their use is limited due to possible side effects including corneal epithelial cell damage, inhibition of wound healing and, in rare cases, ulceration of the eye surface [44].

6.4 Treatment of Meibomian Gland Dysfunction

For patients with chronic Meibomian gland dysfunction (MGD), improving gland patency and secretion quality is an important part of treatment. Basic methods include massage and warm compresses, which dissolve retained meibum. However, the optimal temperature required to soften the secretion is 41.5 °C, so home remedies may be ineffective in maintaining this temperature for long enough [29]. Modern techniques include intense pulsed light (IPL), LipiFlow technology and near-infrared light (NIL). These therapies induce a photothermal effect, warming the glands and improving secretion flow and the lipid composition of the tear film. The advantage of these techniques is that the effects last longer than with traditional methods, although several treatment sessions are usually required, offering promising long-term benefits [29, 36, 37].

6.5 Advanced treatment and invasive procedures

In resistant cases, invasive and semi-invasive methods are employed, including therapeutic lenses and punctal plugs, as well as less common procedures such as amniotic membrane transplantation, tarsorrhaphy and minor salivary gland transplantation (MSGT).

Therapeutic lenses, including soft contact lenses, scleral lenses and PROSE (Prosthetic Replacement of the Ocular Surface Ecosystem) lenses, can alleviate the symptoms of severe dry eye syndrome, particularly in

cases of advanced tear film deficiency accompanied by autoimmune conditions such as Stevens–Johnson syndrome (SJS). These specialised lenses are filled with fluid to ensure adequate lubrication of the eye surface. However, their widespread use is limited due to their high cost, limited availability, and the need for training in their use [8].

Punctal plugs are placed in the lacrimal puncta to temporarily or, less commonly, permanently close the anatomical tear drainage pathways. This is intended to prolong the duration of the tear film on the surface of the eye. Their effectiveness depends on appropriately selecting the material and location, including determining whether to block both the upper and lower lacrimal puncta. Visible effects are seen after just a few days, but a full assessment of the therapeutic benefits is usually possible after at least three months [36].

Other, less common methods, particularly for severe dry eye syndrome, include amniotic membrane transplantation and tarsorrhaphy. Amniotic membrane transplantation improves the regeneration of corneal tissue and reduces inflammation. Tarsorrhaphy involves surgically suturing the eyelids to reduce the width of the palpebral fissure and minimise tear evaporation. This technique is reserved for the most resistant cases involving significant damage to the eye's surface. Amniotic membrane transplantation and tarsorrhaphy can be used together to speed up epithelialisation [29, 43].

Another surgical technique is minor salivary gland transplantation (MSGT), which is used to treat severe ADDE. It involves transferring tissue from under the mucous membrane of the labia to the back of the eyelid or eyeball. Before and after the procedure, fluorescein tests are performed to evaluate secretory activity and determine the optimal site for gland harvesting. MSGT is not recommended for patients with Sjögren's syndrome as the disease affects the salivary and lacrimal glands directly [8].

6.6 New and Experimental Therapies

RGN-259 (Tymozona β4) is currently undergoing clinical trials. It is an experimental solution containing a 43-amino acid protein that plays a role in wound healing and the immune response [28].

Autologous serum, obtained from the patient's blood, supports epithelial regeneration thanks to its growth factor content (e.g. EGF and TGF-β), as well as its vitamin A and lysozyme content. However, due to the costs associated with preparing the serum under specialised conditions, its use is limited to severe, resistant cases [31].

Recombinant human growth factor (rhNGF) and vitamin B12 supplementation are known to have neuroprotective properties. NGF accelerates regeneration and partially restores function to damaged nerves. Receptors sensitive to this factor have been found on the surface of the eye. This study aims to understand the mechanisms of neurodegeneration and determine their significance in supporting the regeneration of nerve fibres on the surface of the eye during dry eye syndrome treatment. NGF often causes side effects such as hyperaemia and pain. Additionally, due to the high cost of therapy, its use will be limited for the time being [29].

A new, non-invasive method of supporting lacrimal gland function is transcutaneous nerve stimulation (TENS), which increases tear secretion in patients with impaired neurogenic function [29].

Substances that modulate nerve transmission, such as GABA and pain receptor agonists, were previously mainly used in the treatment of neuropathic pain. However, new studies are evaluating their potential use in treating dry eye syndrome, particularly in patients who visit their doctor complaining of pain [35].

Secretagogues are a new class of drugs that stimulate lacrimal gland receptors. This group includes drugs such as tetrasodium diclazuril, rebamipide, cewimeline and oral pilocarpine. When administered as 3% eye drops, tetrasodium diclazuril acts on P2Y2 receptors in the conjunctiva, meibomian glands, and lacrimal glands. This increases intracellular calcium levels, thereby enhancing tear secretion. Rebamipide, on the other hand, supports mucin secretion by stimulating goblet cells, while also having an anti-inflammatory effect by influencing cytokines and prostaglandins. Cevimeline and pilocarpine are muscarinic receptor agonists that stimulate the lacrimal and salivary glands. This supports the lubrication of the surfaces of the eyes and mouth, which is important for patients with Sjögren's syndrome (SS) [8].

Therapies involving the use of mesenchymal stem cells (MSCs) and the bioengineering of lacrimal glands that can produce tears similar in composition to natural tears are still in the experimental stage, but are developing rapidly. Recent studies have shown that it will be possible to produce three-dimensional human lacrimal glands. Although the results are promising, these methods are still awaiting clinical application [8, 29].

An innovative alternative is faecal microbiota transplantation (FMT). Given the role of the gut microbiome in the pathophysiology of ocular surface diseases, it is believed that rebuilding the microbiota could be therapeutic. So far, the results suggest that FMT has positive effects in patients with immunological dry eye syndrome, but further research is needed to confirm the safety and durability of these effects [8].

Conclusions

Dry eye disease (DED) is a significant public health problem that is leading to an

increasing number of ophthalmological consultations. It is estimated that DED symptoms affect 10–20% of people over the age of 40, a figure which is partly due to an ageing population. While this condition primarily affects adults, symptoms are increasingly being observed in younger patients, potentially due to the increased time spent in front of electronic device screens.

Current research focuses on identifying modifiable and non-modifiable risk factors and predispositions for the development of DED. Attention is also drawn to the important role of environmental factors and comorbidities. In ageing societies, the number of people with dry eye syndrome is expected to continue increasing, so rapid diagnosis and the implementation of effective therapies based on both existing and newly developed methods are crucial.

Dry eye syndrome often coexists with other diseases, making diagnosis and treatment difficult. Therefore, a clinical approach that considers not only ocular symptoms, but also potential systemic causes, is important. This can benefit not only the patient's quality of life, but also their overall health and life expectancy.

Despite the availability of numerous diagnostic methods, many of these require specialised equipment, experience, and reagents that are not commonly available in primary care. In this context, a promising development is the use of new technologies, including artificial intelligence-based systems which have achieved high diagnostic accuracy in studies (e.g. 91.91%) [6].

Therapy advances include improvements to moisturising preparations and the development of modern treatment methods, such as biological drugs and stem cell therapies. Further research should focus on improving our understanding of the pathogenesis of DED; the standardisation of diagnostic criteria; and the development of consistent therapeutic algorithms that are accessible to both general practitioners and specialists.

Disclosures

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All authors have read and agreed to the published version of the manuscript.

Funding Statement: The author received no external funding for this work.

Institutional Review Board Statement: Not applicable; this review included only published data.

Informed Consent Statement: Not applicable.

Data Availability Statement: All supporting data are available within the cited peer-reviewed literature.

Acknowledgments: The author acknowledges the contribution of investigators and data curators whose high-quality research underpins the advances reviewed herein.

Conflict of Interest Statement: The author declares no conflict of interest.

Declaration of the use of generative AI and AI-assisted technologies in the writing proces

In preparing this work, the authors used ChatGPT for the purpose of improving language and readability. After using this tool, the authors have reviewed and edited the content as needed and accept full responsibility for the substantive content of the publication.

REFERENCES

1. Zemanová M. (2021). DRY EYE DISEASE. A REVIEW. SYNDROM SUCHÉHO OKA. přehled. *Ceska a slovenska oftalmologie: casopis Ceske oftalmologicke spolecnosti a Slovenske oftalmologicke spolecnosti*, *77*(3), 107–119. https://doi.org/10.31348/2020/29
2. Sheppard, J., Shen Lee, B., & Periman, L. M. (2023). Dry eye disease: identification and therapeutic strategies for primary care clinicians and clinical specialists. *Annals of medicine*, *55*(1), 241–252. https://doi.org/10.1080/07853890.2022.2157477
3. Britten-Jones, A. C., Wang, M. T. M., Samuels, I., Jennings, C., Stapleton, F., & Craig, J. P. (2024). Epidemiology and Risk Factors of Dry Eye Disease: Considerations for Clinical Management. *Medicina (Kaunas, Lithuania)*, *60*(9), 1458. https://doi.org/10.3390/medicina60091458
4. McCann, P., Abraham, A. G., Mukhopadhyay, A., Panagiotopoulou, K., Chen, H., Rittiphairoj, T., Gregory, D. G., Hauswirth, S. G., Ifantides, C., Qureshi, R., Liu, S. H., Saldanha, I. J., & Li, T. (2022). Prevalence and Incidence of Dry Eye and Meibomian Gland Dysfunction in the United States: A Systematic Review and Meta-analysis. *JAMA ophthalmology*, *140*(12), 1181–1192. https://doi.org/10.1001/jamaophthalmol.2022.4394
5. Barabino S. (2022). Is dry eye disease the same in young and old patients? A narrative review of the literature. *BMC ophthalmology*, *22*(1), 85. https://doi.org/10.1186/s12886-022-02269-2
6. Kwon, J., Moghtader, A., Kang, C., Bibak Bejandi, Z., Shahjahan, S., Alzein, A. i Djalilian, AR (2025). Przegląd choroby suchego oka dla lekarzy podstawowej opieki zdrowotnej. *Medicina (Kowno, Litwa)*, *61* (3), 460. https://doi.org/10.3390/medicina61030460
7. Qian, L., & Wei, W. (2022). Identified risk factors for dry eye syndrome: A systematic review and meta-analysis. *PloS one*, *17*(8), e0271267. https://doi.org/10.1371/journal.pone.0271267
8. Doctor, M. B., & Basu, S. (2022). Lacrimal Gland Insufficiency in Aqueous Deficiency Dry Eye Disease: Recent Advances in Pathogenesis, Diagnosis, and Treatment. *Seminars in ophthalmology*, *37*(7-8), 801–812. https://doi.org/10.1080/08820538.2022.2075706
9. Talens-Estarelles, C., García-Marqués, J. V., Cerviño, A., & García-Lázaro, S. (2022). Dry Eye-Related Risk Factors for Digital Eye Strain. *Eye & contact lens*, *48*(10), 410–415. https://doi.org/10.1097/ICL.0000000000000923
10. Mangoli, M. V., Bubanale, S. C., Bhagyajyothi, B. K., & Goyal, D. (2023). Dry eye disease in diabetics versus non-diabetics: Associating dry eye severity with diabetic retinopathy and corneal nerve sensitivity. *Indian journal of ophthalmology*, *71*(4), 1533–1537. https://doi.org/10.4103/IJO.IJO_2680_22
11. Katipoğlu, Z., & Abay, R. N. (2023). The relationship between dry eye disease and anticholinergic burden. *Eye (London, England)*, *37*(14), 2921–2925. https://doi.org/10.1038/s41433-023-02442-x
12. Golden, M. I., Meyer, J. J., Zeppieri, M., & Patel, B. C. (2024). Dry Eye Syndrome. In *StatPearls*. StatPearls Publishing.
13. Gorimanipalli, B., Khamar, P., Sethu, S., & Shetty, R. (2023). Hormones and dry eye disease. *Indian journal of ophthalmology*, *71*(4), 1276–1284. https://doi.org/10.4103/IJO.IJO_2887_22
14. Vidal-Rohr, M., Craig, JP, Davies, LN i Wolffsohn, JS (2024). Klasyfikacja podtypów zespołu suchego oka. *Soczewki kontaktowe i przedni odcinek oka: czasopismo Brytyjskiego Stowarzyszenia Soczewek Kontaktowych*, *47* (5), 102257. https://doi.org/10.1016/j.clae.2024.102257
15. Rolando, M., & Barabino, S. (2023). Dry Eye Disease: What Is the Role of Vitamin D? . *International journal of molecular sciences*, *24*(2), 1458. https://doi.org/10.3390/ijms24021458
16. Wang, HH, Chen, WY, Huang, YH, Hsu, SM, Tsao, YP, Hsu, YH i Chang, MS (2022). Interleukina-20 jest związana z zespołem suchego oka i stanowi potencjalny cel terapeutyczny. *Journal of biomedical science*, *29* (1), 36. https://doi.org/10.1186/s12929-022-00821-2
17. McMonnies CW (2021). Dlaczego objawy i obiektywne oznaki zespołu suchego oka mogą nie być ze sobą powiązane. *Journal of optometry*, *14* (1), 3–10. https://doi.org/10.1016/j.optom.2020.10.002
18. Barabino, S. i Benítez-Del-Castillo, JM (2024). Patogeneza i objawy kliniczne zespołu suchego oka: poszukiwanie korelacji w praktyce klinicznej. *European Review for Medical and Pharmacological Sciences*, *28* (5), 1881–1890. https://doi.org/10.26355/eurrev_202403_35602
19. Yan Z. P. (2020). Dry eye symptoms and signs in children wearing OK lenses for six months in China. *Journal francais d'ophtalmologie*, *43*(3), 211–215. https://doi.org/10.1016/j.jfo.2019.07.029
20. Stapleton, F., Velez, F. G., Lau, C., & Wolffsohn, J. S. (2024). Dry eye disease in the young: A narrative review. *The ocular surface*, *31*, 11–20. https://doi.org/10.1016/j.jtos.2023.12.001
21. Yu, K., Bunya, V., Maguire, M., Asbell, P., Ying, G. S., & Dry Eye Assessment and Management Study Research Group (2021). Systemic Conditions Associated with Severity of Dry Eye Signs and Symptoms in the Dry Eye Assessment and Management Study. *Ophthalmology*, *128*(10), 1384–1392. https://doi.org/10.1016/j.ophtha.2021.03.030
22. Khoo, P., Groeneveld, T., Boyle, F., O'Neill, S., Forster, B., & Watson, S. L. (2022). Dry eye signs and symptoms in patients on aromatase inhibitor therapy. *Eye (London, England)*, *36*(4), 766–772. https://doi.org/10.1038/s41433-021-01538-6
23. Bjordal, O., Norheim, K. B., Rødahl, E., Jonsson, R., & Omdal, R. (2020). Primary Sjögren's syndrome and the eye. *Survey of ophthalmology*, *65*(2), 119–132. https://doi.org/10.1016/j.survophthal.2019.10.004

24. Narang, P., Donthineni, P. R., D'Souza, S., & Basu, S. (2023). Evaporative dry eye disease due to meibomian gland dysfunction: Preferred practice pattern guidelines for diagnosis and treatment. *Indian journal of ophthalmology*, *71*(4), 1348–1356. https://doi.org/10.4103/IJO.IJO_2841_22
25. Wolffsohn, J. S., Travé-Huarte, S., Stapleton, F., Downie, L. E., Schulze, M. M., Guthrie, S., Stahl, U., Wang, M. T. M., & Craig, J. P. (2025). Relative importance of tear homeostatic signs for the diagnosis of dry eye disease. *The ocular surface*, *36*, 151–155. https://doi.org/10.1016/j.jtos.2025.01.010
26. Mohamed, H. B., Abd El-Hamid, B. N., Fathalla, D., & Fouad, E. A. (2022). Current trends in pharmaceutical treatment of dry eye disease: A review. *European journal of pharmaceutical sciences: official journal of the European Federation for Pharmaceutical Sciences*, *175*, 106206. https://doi.org/10.1016/j.ejps.2022.106206
27. Barabino, S., Benitez-Del-Castillo, J. M., Fuchsluger, T., Labetoulle, M., Malachkova, N., Meloni, M., Utheim, T. P., & Rolando, M. (2020). Dry eye disease treatment: the role of tear substitutes, their future, and an updated classification. *European review for medical and pharmacological sciences*, *24*(17), 8642–8652. https://doi.org/10.26355/eurrev_202009_22801
28. Periman, LM, Perez, VL, Saban, DR, Lin, MC i Neri, P. (2020). Podstawy immunologiczne zespołu suchego oka i aktualne opcje leczenia miejscowego. *Journal of ocular pharmacology and therapeutics: oficjalne czasopismo Association for Ocular Pharmacology and Therapeutics*, *36* (3), 137–146. https://doi.org/10.1089/jop.2019.0060
29. Mittal, R., Patel, S., & Galor, A. (2021). Alternative therapies for dry eye disease. *Current opinion in ophthalmology*, *32*(4), 348–361. https://doi.org/10.1097/ICU.0000000000000768
30. Rolando, M., & Merayo-Lloves, J. (2022). Management Strategies for Evaporative Dry Eye Disease and Future Perspective. *Current eye research*, *47*(6), 813–823. https://doi.org/10.1080/02713683.2022.2039205
31. Vazirani, J., Sridhar, U., Gokhale, N., Doddigarla, V. R., Sharma, S., & Basu, S. (2023). Autologous serum eye drops in dry eye disease: Preferred practice pattern guidelines. *Indian journal of ophthalmology*, *71*(4), 1357–1363. https://doi.org/10.4103/IJO.IJO_2756_22
32. Kumar, N. R., Praveen, M., Narasimhan, R., Khamar, P., D'Souza, S., Sinha-Roy, A., Sethu, S., Shetty, R., & Ghosh, A. (2023). Tear biomarkers in dry eye disease: Progress in the last decade. *Indian journal of ophthalmology*, *71*(4), 1190–1202. https://doi.org/10.4103/IJO.IJO_2981_22
33. Yang, Y. J., Lee, W. Y., Kim, Y. J., & Hong, Y. P. (2021). A Meta-Analysis of the Efficacy of Hyaluronic Acid Eye Drops for the Treatment of Dry Eye Syndrome. *International journal of environmental research and public health*, *18*(5), 2383. https://doi.org/10.3390/ijerph18052383
34. Paik, B., & Tong, L. (2022). Topical Omega-3 Fatty Acids Eyedrops in the Treatment of Dry Eye and Ocular Surface Disease: A Systematic Review. *International journal of molecular sciences*, *23*(21), 13156. https://doi.org/10.3390/ijms232113156
35. Aragona, P., Giannaccare, G., Mencucci, R., Rubino, P., Cantera, E., & Rolando, M. (2021). Modern approach to the treatment of dry eye, a complex multifactorial disease: a P.I.C.A.S.S.O. board review. *The British journal of ophthalmology*, *105*(4), 446–453. https://doi.org/10.1136/bjophthalmol-2019-315747
36. McCann, P., Kruoch, Z., Lopez, S., Malli, S., Qureshi, R., & Li, T. (2024). Interventions for Dry Eye: An Overview of Systematic Reviews. *JAMA ophthalmology*, *142*(1), 58–74. https://doi.org/10.1001/jamaophthalmol.2023.5751
37. Ren, X., Chou, Y., Wang, Y., Chen, Y., Liu, Z., & Li, X. (2021). Comparison of intense pulsed light and near-infrared light in the treatment of dry eye disease: a prospective randomized study. *Acta ophthalmologica*, *99*(8), e1307–e1314. https://doi.org/10.1111/aos.14833
38. Huang, R., Su, C., Fang, L., Lu, J., Chen, J., & Ding, Y. (2022). Dry eye syndrome: comprehensive etiologies and recent clinical trials. *International ophthalmology*, *42*(10), 3253–3272. https://doi.org/10.1007/s10792-022-02320-7
39. Chatterjee, S., Agrawal, D., Sanowar, G., & Kandoi, R. (2021). Prevalence of symptoms of dry eye disease in an urban Indian population. *Indian journal of ophthalmology*, *69*(5), 1061–1066. https://doi.org/10.4103/ijo.IJO_1796_20
40. Kunboon, A., Tananuvat, N., Upaphong, P., Wongpakaran, N., & Wongpakaran, T. (2024). Prevalence of dry eye disease symptoms, associated factors and impact on quality of life among medical students during the pandemic. *Scientific reports*, *14*(1), 23986. https://doi.org/10.1038/s41598-024-75345-w
41. Kaur, K., Gurnani, B., Nayak, S., Deori, N., Kaur, S., Jethani, J., Singh, D., Agarkar, S., Hussaindeen, J. R., Sukhija, J., & Mishra, D. (2022). Digital Eye Strain- A Comprehensive Review. *Ophthalmology and therapy*, *11*(5), 1655–1680. https://doi.org/10.1007/s40123-022-00540-9
42. Britten-Jones, A. C., Wang, M. T. M., Samuels, I., Jennings, C., Stapleton, F., & Craig, J. P. (2024). Epidemiology and Risk Factors of Dry Eye Disease: Considerations for Clinical Management. *Medicina (Kaunas, Lithuania)*, *60*(9), 1458. https://doi.org/10.3390/medicina60091458
43. Ozcan, A. A., Ulas, B., & Ciloglu, E. (2022). Tarsorrhaphy with Sutureless Amnion Transplantation: Practical Management of Ocular Surface Pathologies. *Beyoglu eye journal*, *7*(4), 313–319. https://doi.org/10.14744/bej.2022.10327
44. Nguyen, A., Kolluru, A., & Beglarian, T. (2023). Dry eye disease: A review of anti-inflammatory therapies. *Taiwan journal of ophthalmology*, *13*(1), 3–12. https://doi.org/10.4103/2211-5056.369606