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The impact of vitamin D supplementation on dry eye disease and lens clarity in vitamin d deficient university students

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Abstract

Background: To evaluate how well taking oral vitamin D helps reduce symptoms of dry eye disease (DED), increase vitamin D levels in the blood, and improve other eye conditions (like lens clarity and vision) in university students who are low in vitamin D.

Methods: In this pre-post interventional study, 41 vitamin D-deficient university students with dry eye disease (confirmed by OSDI score) received 50,000 IU of oral vitamin D weekly for eight weeks. The outcome measures comprised OSDI scores, serum vitamin D levels, lens clarity, and refractive error, evaluated at baseline and following the intervention. The Wilcoxon Signed Ranks Test and Spearman's correlation were used to do the statistical analysis.

Results: After treatment, there was a significant decrease in OSDI scores (from 33.82 ± 8.47 to 22.68 ± 8.25; Z = -5.59, p < 0.001) and a notable increase in serum vitamin D levels (from 12.70 ± 3.68 ng/mL to 33.09 ± 7.24 ng/mL). Furthermore, a Spearman's correlation coefficient indicated a significant, moderate-to-strong relationship between changes in vitamin D levels and changes in OSDI scores (r = -0.68, p < 0.001). According to the coefficient of determination (R2 = 0.464), the increase in vitamin D levels accounts for approximately 46.4% of the variation in the relief of dry eye symptoms. Additionally, nearly two-thirds of participants (65.85%) met the MCID criteria for clinical improvement. There was also a statistically significant improvement in lens clarity, with values changing from 2.05 ± 0.89 to a post-intervention mean of 1.46 ± 0.78 (where clear lens = 1, mildly cloudy = 2, and moderately cloudy = 3). This change was confirmed by the Wilcoxon signed-rank test (Z = -3.169, p = 0.002).

Conclusion: High-dose vitamin D supplementation effectively addresses vitamin D deficiency, leading to statistically and clinically significant improvements in dry eye symptoms and lens clarity. The inverse relationship between higher serum vitamin D levels and lower OSDI scores suggests that vitamin D may help treat dry eye disease (DED).

Keywords: Dry Eye Disease, Ocular Surface Disease Index, Vitamin D Deficiency, Vitamin D Supplementation, Lens Clarity, University Students, Iraq

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Background

Dry Eye Disease (DED) is a multifactorial disorder of the ocular surface marked by a disruption of tear film homeostasis, leading to symptoms including discomfort, vision impairment, and tear film instability. It is marked by increased tear film osmolarity and inflammation of the ocular surface [1]. DED was formerly believed to predominantly impact elderly individuals; nevertheless, it is more prevalent among younger populations, particularly college students. This alteration is mostly due to persistent environmental and behavioral factors, with prolonged exposure to digital screens having the greatest influence [2]. The use of computers, smartphones, and tablets is essential in contemporary academia and social interactions, leading to a condition commonly referred to as "Digital Eye Strain" or "Computer Vision Syndrome," characterized by reduced blink frequency, increased tear evaporation, and resulting dry eye disease symptoms [3]. At the same time, vitamin D deficiency has been identified as a worldwide public health concern, affecting approximately 1 billion individuals [4]. This insufficiency affects not only the elderly but also young people and adolescents, who are especially susceptible due to indoor lives, diets lacking fortified foods, and inadequate sun exposure [5]. University students are particularly vulnerable due to their extensive indoor activities in lectures, libraries, and studying, as well as their significant screen time [6]. This creates an ideal scenario since those predisposed to digital eye strain due to their

online behaviors are also prone to systemic nutritional deficiencies. A compelling biological rationale suggests a connection between these two conditions. Vitamin D is not merely a vitamin; it is also a secosteroid hormone with potent anti-inflammatory and immunomodulatory properties. It functions by binding to the Vitamin D Receptor (VDR), located in several ocular tissues, including the epithelial cells of the cornea and conjunctiva, as well as the lacrimal gland [7]. Research indicates that vitamin D is crucial for regulating tear formation. It may influence the functionality of the lacrimal gland, which contributes to the formation of a healthy tear film. Furthermore, maintaining the integrity of the ocular surface by augmenting the expression of antimicrobial peptides reinforces the efficacy of the corneal epithelial barrier. It also reduces inflammation, thereby lowering levels of pro-inflammatory cytokines (such as IL-6 and TNF-α), which are crucial to the progression of DED [8]. A vitamin D deficiency can undermine these protective processes, leading to increased ocular surface inflammation, reduced tear film integrity, and the onset or exacerbation of dry eye disease (DED) symptoms. Multiple studies have shown a significant correlation between reduced blood 25-hydroxyvitamin D [25(OH)D] levels and the prevalence and severity of dry eye disease (DED) [9,10,11]. Recent interventional trials provide promising evidence that vitamin D supplementation is a viable management approach for dry eye disease (DED) in individuals with vitamin D insufficiency. Najjaran et al. [12] in 2023 conducted a randomized controlled trial showing that vitamin D-deficient patients with dry eye disease (DED) who were administered a high-dose oral cholecalciferol supplement weekly for 8 weeks showed markedly improved tear break-up time (TBUT) and corneal staining scores compared with the placebo group. Furthermore, this study revealed that vitamin D supplementation significantly reduced ocular surface inflammatory markers. This established a direct correlation between biochemical correction and clinical enhancement [12]. Many individuals perceive the mechanism of this treatment as intricate. Supplementation can restore the immunomodulatory effects of vitamin D on the ocular surface by elevating serum levels to sufficient levels. This involves suppressing critical inflammatory pathways and improving tear film stability and corneal epithelial integrity [13]. This signifies a significant shift in management for university students in the high-risk category who exhibit vitamin D deficiency. Instead of just using artificial tears and changing their lifestyle, screening for and treating the underlying vitamin D deficiency could be a key part of treatment. This study aims to evaluate the potential role of oral vitamin D supplementation in reducing the symptomatology of dry eye disease (DED) and improving other eye conditions (such as lens clarity and vision) among university students with low vitamin D levels.

Methods

Study design and Dataset

Participants in this study were selected from a cross-sectional study of 90 health science students at the University of Duhok, Iraq, aimed at evaluating the prevalence of dry eye disease and its association with vitamin D levels and digital device use [14].

Sample size

Convenience sampling was used to recruit participants. The sample size was calculated using G*Power software based on an anticipated correlation coefficient of 0.3, an alpha error of 0.05, and a power of 80% [15]. Nearly 50% of the participants (n=42) were identified as having vitamin D deficiency (Vitamin D status <20 ng/mL) based on contemporary international consensus cut-offs [16] and exhibited moderate to severe dry eye symptoms (OSDI ≥ 23) [17].

Data processing

In this quasi-experimental study, a single-group design (n=42) with pretest and posttest assessments was used. Only (n=41) of the participants completed the requirements of the study (24 males and 17 females). Under the supervision of an endocrinologist, participants identified as vitamin D-deficient underwent an 8-week supplementation regimen of 50,000 IU of cholecalciferol (Vitamin D_3) by mouth once weekly [18], during which serum vitamin D concentrations and OSDI scores were evaluated. The Minimal Clinically Important Difference (MCID) (a reduction of more than 10 points from baseline OSDI score) was considered a clinically significant change in dry eye disease symptomatology [19]. Data collection took place at two time points: baseline (pre-intervention) and post-intervention. Lens clarity was evaluated by a single highly skilled ophthalmologist using Haag-Streit slit-lamp biomicroscopy under pharmacological mydriasis to assess lens transparency with both direct focal illumination and retroillumination, and the Marco OPD-Scan III to assess refractive errors. Before grading, the ocular surface was examined to rule out corneal pathology or significant tear film instability that might affect transparency measurements [20]. This study used a therapeutically oriented 3-point ordinal scale to emphasize the functional transparency of the ocular media rather than the morphological grading of the Lens Opacities Classification System III (LOCS III). Clarity was divided into: Clear: No obvious opacification. Mildly Cloudy: Early signs of cortical spokes or nuclear haziness, but the retinal detail is still evident. Moderately Cloudy: The opacification is clear, but it reduces the visibility of the back of the eye structures. This method made it easier to see how vitamin D levels affect the clinician's capacity to see the interior eye structures, which is a useful way to quantify clinically important lens alterations. From baseline to the post-treatment follow-up, longitudinal changes in lens status were tracked using this ordinal classification system. Throughout the study, all assessments were conducted by the same examiner under consistent lighting conditions to ensure consistency and reduce inter-observer variability.

Statistical analysis

All statistical analyses were conducted utilizing IBM SPSS Statistics for Windows, Version 26. Continuous data were expressed as mean ± standard deviation (SD). The Shapiro-Wilk test was used to assess the normality of the distributions of all continuous variables. The study utilized a pre-post intervention design with a single group, allowing for within-subject comparisons. Due to the non-normal distribution of the outcome variables (OSDI score, Vitamin D levels, and lens clarity, non-parametric tests were employed for analysis. The alterations in OSDI scores, blood Vitamin D concentrations, and lens transparency from baseline to post-intervention were evaluated by the Wilcoxon Signed-Rank Test. The findings were presented

with the test statistic (Z) and the associated p-value. For all measurements, a two-tailed test was used. The correlation between alterations in serum Vitamin D levels (Δ Vitamin D) and ocular parameters was assessed using a Spearman's rank correlation coefficient to estimate the strength of association. Clinical improvement in dry eye symptoms was based on the Minimally Clinically Important Difference (MCID), which was based on a decrease in the OSDI score of ≥10 points from baseline. Participants were subsequently classified as "Clinical Responder" or "Clinical Non-Responder," and $P < 0.05$ was considered significant for the measured variables.

Results

The participants in this study were health science students from the University of Duhok, Iraq, who demonstrated moderate to severe dry eye symptoms and low serum vitamin D levels, drawn from a cross-sectional analysis of 90 randomly selected participants. The analysis of data from the study group (n=41) demonstrates that vitamin D supplementation had a significant and multifaceted impact on different eye parameters, with notable clinical and statistical outcomes.

OSDI Scores and Serum Vitamin D Levels

A statistically significant improvement was observed in both subjective dry eye symptoms and participants' biochemical status following the intervention, as shown in Figures 1 and 2. The mean OSDI score, which quantifies the severity of dry eye symptoms, decreased substantially and statistically significantly from a baseline of 33.82 ± 8.47 to 22.68 ± 8.25 post-intervention ($Z = -5.59$, $p < 0.001$), indicating a robust reduction in symptom burden. Concurrently, serum Vitamin D levels increase dramatically from a deficient mean baseline of 12.70 ± 3.68 ng/mL to a sufficient mean level of 33.09 ± 7.24 ng/mL after supplementation. This change was also highly statistically significant ($Z = 5.58$, $p < 0.001$).

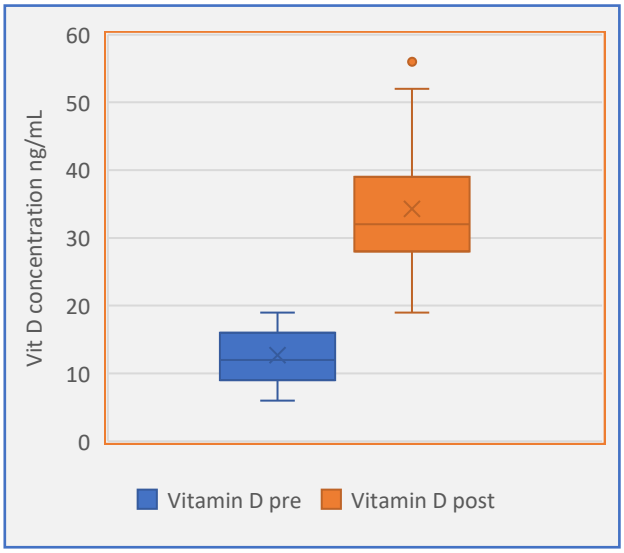

Figure 1. A comparison of the levels of serum vitamin D before and after the intervention. Box plots show the median (the middle line), the interquartile range (the box), and the range (the whiskers) of serum vitamin D levels (ng/mL) in 41 participants. A significant increase in mean serum vitamin D concentration was observed following eight weeks of supplementation (Pre: 12.71 ± 3.68 ng/mL vs. Post: 34.27 ± 10.12 ng/mL), and vitamin D levels rose significantly compared to baseline ($p < 0.001$, Wilcoxon Signed-Rank Test).

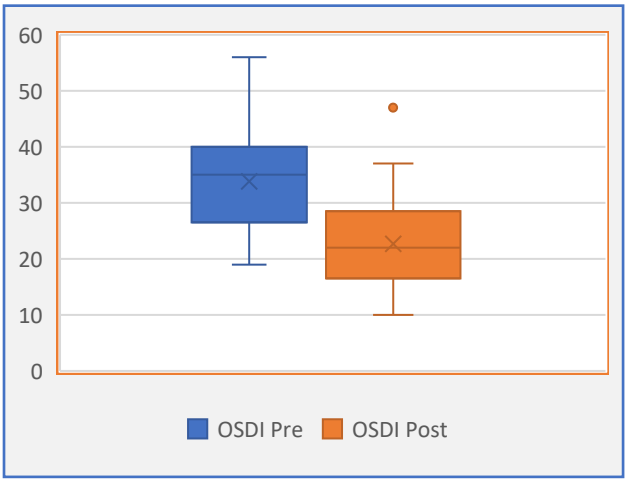

Figure 2. Ocular Surface Disease Index (OSDI) Scores in Participants Before and After Vitamin D Supplementation (N=41). Box plots display the median (horizontal line), interquartile range (box), and range (whiskers) of OSDI scores at baseline and following eight weeks of vitamin D supplementation. A statistically significant reduction in OSDI scores was observed following the intervention (Pre: 33.82 ± 8.47 vs. Post: 22.80 ± 7.65, $p < 0.001$, Wilcoxon Signed-Rank Test).

Correlation Between Changes in Vitamin D and Dry Eye Symptoms

A correlation analysis was performed to investigate the relationship between changes in serum Vitamin D levels (Δ Vitamin D) and changes in OSDI scores (ΔOSDI). After eight weeks of treatment, there was a statistically significant negative correlation between changes in OSDI scores and variation in serum Vitamin D levels. Spearman's correlation coefficient ($r = -0.68$, $p < 0.001$) indicates a moderate to strong, significant negative association. According to the coefficient of determination ($R2 = 0.464$), the increase in vitamin D levels accounts for approximately 46.4% of the variation in the relief of dry eye symptoms. The scatter plot (Figure 3) demonstrates that individuals with the largest drops in OSDI scores also had the largest increases in vitamin D. This inverse relationship indicates that greater increases in serum Vitamin D levels were associated with greater reductions in dry eye symptomatology.

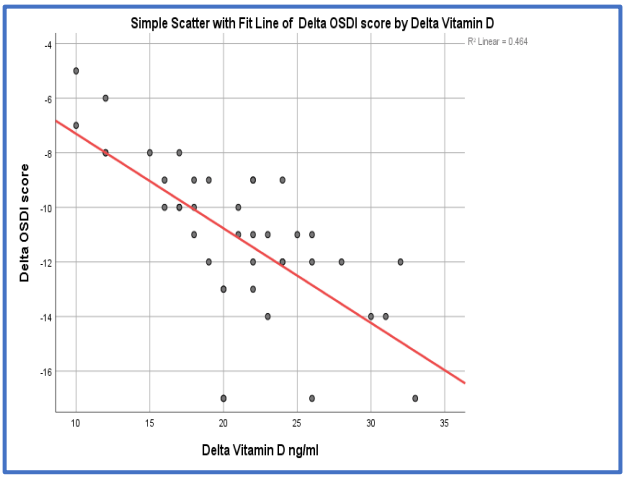

Figure 3. Correlation between the change in serum Vitamin D levels and the change in OSDI scores following 8 weeks of supplementation. The negative slope ($R2 = 0.464$) demonstrates that higher increases in Vitamin D are significantly associated with greater reductions in dry eye symptom severity.

Clinical Efficacy and Its Relationship with Vitamin D Increase

To assess the real-world clinical impact, participants were categorized based on the Minimally Clinically Important Difference (MCID), defined as a reduction of at least 10 points in the OSDI score from baseline. The participants were divided into "Clinical Responders" and "Clinical Non-Responders" groups (Table 1). Every participant in the study experienced a decrease in their OSDI score. The mean score dropped from the "Severe" range (>33) at baseline to the "Moderate/Mild" range after 8 weeks of vitamin D supplementation. Nearly two-thirds of the participants, 65.85% (n=27 participants), experienced clinical improvement according to MCID; however, the other one-third (34.15 %, n=14 participants) did not respond adequately (Improved < 10 points).

Impact of Vitamin D Supplementation on the Lens Clarity

The intervention's effects on specific clinical measures, such as lens clarity and refractive error, were also evaluated (Table 2). The lens clarity data showed a meaningful clinical shift. The number of participants with "Clear" lenses increased by nearly 81% (from 16 at baseline to 29 post-treatment). A statistically significant improvement in lens clarity was observed ($p = 0.002$). The proportion of the participants with clear lenses increased from 39.0% (n=16) at baseline to 70.7% (n=29) post-intervention, while the prevalence of moderate clouding decreased substantially from 43.9% (n=18) to 17.1% (n=7). Lens clarity scores improved from a pre-intervention mean of 2.05 ± 0.89 to a post-intervention mean of 1.46 ± 0.78 (on a scale where 1 = Clear, 2 = Mildly Cloudy, and 3 = Moderately Cloudy). This change was confirmed by the Wilcoxon signed-rank test ($Z = -3.169$, $p = 0.002$). In contrast, no statistically significant change in refractive error was observed. The mean values pre-intervention (1.56 ± 0.84) and post-intervention (1.39 ± 0.70) (on a scale where 1 = No error, 2 = Mild error, and 3 = Moderate error) were nearly identical, and the statistical test indicated this difference was not significant ($Z = -1.213$, $p = 0.317$), suggesting the intervention did not affect refractive error.

Table 1: Clinical Improvement in Dry Eye Symptoms Based on the Changes in OSDI Score.

Parameter	Values	Interpretation
Mean Pre-OSDI Score	33.61 ± 8.27	Moderate to Severe baseline symptoms
Mean Post-OSDI Score	22.41± 8.65	Improvement to the Mild/Moderate range
Average Score Reduction	11.20 points	Exceeds the 10-point MCID*
Clinical Responders	27 (65.85%)	Met or exceeded 10-point improvement
Non-Responders	14 (34.15%)	Improved < 10 points
Maximum Improvement	17 points	Observed in 4 participants
Minimum Improvement	6 points	Observed in 1 participant

* MCID: Minimally Clinically Important Difference, defined as a reduction in the OSDI score of at least 10 points from basal score

Table 2: Effect of Vitamin D Supplementation on Lens Clarity and Refractive Errors in Vitamin D-deficient participants (N=41)

Parameter	Pre-Intervention No. (%)	Post-Intervention No. (%)	Test Statistic [d]	p-value [a]
Lens Clarity				
Clear	16 (39.0)	29 (70.7)	**Z = - 3.169**	**0.002**
Mildly Cloudy	7 (17.1)	5 (12.2)		
Moderately Cloudy	18 (43.9)	7 (17.1)		
Mean Score [b]	2.05 ± 0.89	1.46 ± 0.78		
Refractive Error				
No Refractive Error	28 (68.3)	27 (65.9)	**Z = -1.213**	**0.317**
Mild Refractive Error	2 (4.9)	7 (17.1)		
Moderate error	11 (26.8)	7 (17.1)		
Mean Score [c]	1.56 ± 0.84	1.39 ± 0.70		

a P-values were calculated using the Wilcoxon Signed-Rank Test for paired ordinal data; b Values are presented as Mean ± Standard Deviation (1 = Clear, 2 = Mildly Cloudy, 3 = Moderately Cloudy); c Values are presented Mean ± Standard Deviation (1 = No error, 2 = Mild error, 3 = Moderate error); d Statistical comparisons were performed using the Wilcoxon Signed Ranks Test.

Discussion

Vitamin D and Ocular Surface Health

The results of this study show that taking Vitamin D has a clear, significant positive effect on both subjective symptoms and objective clinical indicators of Dry Eye Disease (DED). After eight weeks of vitamin D supplementation, blood 25(OH)D levels increased rapidly from a deficient baseline (12.71 ng/mL) to a sufficient level (34.27 ng/mL), which was directly connected to the alleviation of dry eye symptoms in this study group ($R = -0.525$, $p < .001$). This beneficial connection backs up the findings of Chen et al. (2024) [21], who found that vitamin D supplementation dramatically improves tear film integrity while decreasing subjective symptom levels in DED patients. Similarly, Gorimanipalli et al. (2023) discovered that vitamin D supplementation improved DED in real-world and clinical trials [22]. Furthermore, Ucakhan et al. (2023) found in a randomized controlled trial (RCT) that antioxidants and vitamins (including Vitamin D) have significant potential to stabilize the tear film and protect the corneal epithelium [23]. The role of vitamin D in ameliorating the symptomatology of DED is most likely multifactorial, probably the most accepted one is likely mediated by the influence of this steroid hormone on Vitamin D receptors, which are expressed in various ocular structures, including the corneal epithelium and are crucial for cellular functions such as

suppressing the expression of pro-inflammatory cytokines (e.g., IL-6, TNF-α) that are elevated on the ocular surface in dry eye disease (DED) and sustain the cycle of ocular surface inflammation [24,25]. In addition, Vitamin D helps the body produce cathelicidin, an antimicrobial peptide that also helps maintain the tear film stability and the corneal epithelial barrier strength [26]. Higher levels of vitamin D may strengthen the lipid layer of the tear film, thereby helping with evaporative dry eye [27]. Vitamin D receptors in the lacrimal gland help control its function. Adequate vitamin D may help the lacrimal gland function better and increase tear production, which is an important part of the pathophysiology of DED [28]. Moreover, recent high-impact research has validated that several ocular tissues, including the corneal epithelium, contain the requisite enzymatic framework, specifically 1α-hydroxylase (CYP27B1), to enable the local transformation of inactive 25(OH)D into its biologically active form, 1,25(OH)2D [29]. This localized autocrine system provides compelling physiological support for the development of topical Vitamin D formulations. These pharmaceutical strategies are proving useful in treating inflammatory eye diseases that do not respond to conventional lubricating or steroid therapy [30]. Therefore, testing vitamin D levels in young people with dry eye might be a new way to improve the health of the eye's surface, and identifying deficiencies facilitates customized supplementation. This might be a way to improve long-term therapeutic outcomes by using a systemic strategy to enhance the efficacy of current topical drugs.

Clinical Significance and MCID

In clinical research, the OSDI is a common tool for measuring patient symptoms and assessing treatment effectiveness [31]. It is now standard practice in medical research to examine both the P value and the effect size to assess their clinical importance [32]. The Minimally Clinically Important Difference (MCID) is a stricter standard because it identifies the smallest change in score that a patient perceives as a real improvement (Miller et al. 2010). The current literature uniformly employs a ≥10-point decrement from baseline OSDI as the standard "responder" threshold in clinical trials [33]. In this study, 27 of 41 participants (65.85%) met the MCID criteria for clinical improvement. This subgroup not only showed a statistically significant decrease in symptoms but also reached a level of relief that led to a noticeable improvement in daily visual function and eye comfort, consistent with recent interventional studies investigating the immunomodulatory role of Vitamin D in ocular surface health. In a recent clinical trial by Samar et al. (2025), oral Vitamin D3 supplementation led to a significant downward shift in disease severity, with many patients surpassing the established MCID of 7.3 to 13.4 points for severe symptoms [34]. This is particularly relevant in younger populations, where Jain et al. (2022) demonstrated that Vitamin D3 acts as a critical adjunct to conventional artificial tears [35]. This "dose-response" pattern strongly reinforces the biological plausibility of Vitamin D as an active therapeutic agent for DED, not just a coincidental nutrient [36]. The biological basis for this 10-point improvement likely stems from Vitamin D's ability to enhance corneal epithelial barrier function since corneas contain mRNA for VDR and 1α-hydroxylase as well as a significant concentration of inactive 25(OH)D3 and its active metabolite 1,25(OH)2D3 [37].

Impact of Vitamin D on Lens Clarity

The observed improvement in lens clarity within our participants suggests a significant relationship between serum 25-hydroxyvitamin D [25(OH)D] levels and the maintenance of the crystalline lens's optical properties. Our observations align with recent large-scale epidemiological data. Notably, a 2025 analysis of the UK Biobank demonstrated a significant inverse relationship between vitamin D levels and cataract risk, specifically highlighting that younger individuals (under 50) may be more susceptible to the ocular consequences of severe deficiency [38]. While vitamin D is traditionally associated with calcium homeostasis, the presence of Vitamin D Receptors (VDR) and the enzyme 1 alpha-hydroxylase within lens epithelial cells indicates that the lens is not merely a passive target but an active site of vitamin D metabolism [39]. The impact of vitamin D on lens transparency likely operates through different pathways, such as vitamin D upregulates antioxidant enzymes and reduces oxidative stress (the primary driver of protein denaturation and "clumping" in the lens), by mitigating the photo-oxidation of lens proteins (crystallins), including superoxide dismutase (SOD) and glutathione peroxidase (GPx). These enzymes are essential for scavenging reactive oxygen species (ROS) that would otherwise damage lens tissue. Vitamin D helps maintain the precise protein arrangement required for transparency [40]. Furthermore, the lens, while avascular, is sensitive to systemic inflammatory markers. Vitamin D suppresses pro-inflammatory cytokines such as IL-6 and TNF-alpha, which can otherwise accelerate degenerative changes in lens fibers [41]. Another possibility is that the lens relies on tight calcium regulation to maintain fiber cell integrity. Vitamin D influences the calcium-sensing receptors and ion channels that prevent intracellular calcium overload, a known cause of lens opacification [42]. While most epidemiological studies focus on the long-term risk of developing mature cataracts, this study is among the first to explore that correcting the deficiency in this younger population may not only prevent future cataracts but also enhance current lens clarity, likely by resolving early-stage subclinical changes such as water clefts or vacuoles that have not yet progressed to formal opacification.

Impact of Vitamin D on Refractive Error

The lack of change in refractive error is expected and serves as an excellent internal control for this study. Refractive error is determined by the anatomical shape of the eye (corneal curvature, axial length) and the power of the lens [43]. There is no known physiological mechanism by which Vitamin D supplementation would alter these fixed parameters. This null finding strengthens the study's validity by demonstrating that the intervention specifically affected dynamic, inflammation-related parameters (symptoms, tear film) rather than causing a non-specific or placebo effect across all measured outcomes.

Limitations and Future Directions

The study's shortcomings include the use of a subjective ordinal scale for lens clarity and a single-group quasi-experimental design. These limitations, in conjunction with environmental confounders such as seasonal fluctuations and psychological variables like placebo effects or behavioral changes, inhibit conclusive causal attribution to the intervention. Furthermore, the small sample size limited the generalizability of these

findings. Future investigations should emphasize objective Scheimpflug-based densitometry and extensive randomized controlled trials with larger sample sizes to delineate the therapeutic efficacy of vitamin D and to validate the durability of these initial clinical advantages.

Conclusion

The findings of this study provide compelling evidence that Vitamin D is a critical modulator of ocular health, particularly among younger adults, including University students. By effectively elevating serum 25(OH)D levels from deficiency to sufficiency, we observed multifaceted improvements in the ocular surface environment and crystalline lens clarity. The achievement of the Minimally Clinically Important Difference (MCID) in 65.85% of our participants, coupled with the dose-response pattern observed, validates Vitamin D as a potent anti-inflammatory and immunomodulatory agent.

Abbreviation

DED: Dry Eye Disease; GPx: Glutathione Peroxidase; MCID: Minimally Clinically Important Difference; OSDI: Ocular Surface Disease Index; SOD: Superoxide Dismutase; TBUT: Tear Break-Up Time; VDR: Vitamin D Receptor.

Declaration

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Availability of data and materials

Data will be available by emailing hishyar.salih@uod.ac

Authors' contributions

All authors contributed equally in the conceptualization, manuscript writing, and interpretation of the findings. The authors read and approved the final manuscript.

Ethics approval and consent to participate

We conducted the research in accordance with the Declaration of Helsinki. Ethical approval for this study was granted by the Directorate General of Health-Research Ethics Committee in Collaboration with the College of Medicine, University of Duhok, Duhok Province, Iraq (Reference number: 25092024-8-20). The study's purpose and procedures were explained to all potential participants. Written informed consent was obtained from each participant prior to enrollment. All data were anonymized and stored securely, ensuring confidentiality.

Consent for publication

Not applicable

Competing interest

The author declares that he has no competing interests.

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