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Effect of short-term exposure of red light on axial length, anterior chamber depth and visual acuity among young myopes

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Purpose: *evaluation of the effects of red-light exposure on vision and ocular measurements after a 3-minute exposure.* ***Material and methods.*** *A Quasi experimental study was conducted. The non-random purposive sampling technique was used. The study included 41 patients with myopia. Both genders were included where the female were 90.24% while male were 9.76%. The mean age for females was 23.15 ± 1.58 (range: 19–24 years) and for males was 23 ± 2.16 (range: 20–25 years). Patient's visual acuity (VA) was assessed with ETDRS chart while axial length (AL), anterior chamber depth (ACD), non-cylcloplegic spherical equivalent refraction (SER), keratometry readings were recorded using IOL Master before and after exposure. To provide exposure an Android mobile application called "SCREEN FLASH" was used in a dark room. The patient was exposed to the Red Screen utilizing 650 nm red light for 3 minutes. SPSS 26 was used for statistical analysis.* ***Results.*** *Significant changes were observed in pre- and post biometric readings. The mean value of VA increased from 0.68 ± 0.33 to 0.58 ± 0.31 log MAR, (p-value < 0.001), AL decreased from 24.54 ± 1.05 to 24.53 ± 1.05 mm (p-value = 0.001), SER decreases from 4.5 ± 0.85 to 4.47 ± 0.97 D (p-value < 0.001) and ACD decreased from 3.64 ± 0.26 to 3.63 ± 0.25 mm (p-value < 0.001) after exposure. For keratometry values, results were insignificant.* ***Conclusion.*** *A notable improvement in VA was found on exposure to red light in young myopic patients and significant reduction in AL, SER and ACD was observed.*

Keywords: myopia; anterior chamber depth; axial length; ocular refraction; red light exposure
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Влияние кратковременного воздействия красного света на аксиальную длину глаза, глубину передней камеры и остроту зрения у лиц молодого возраста с миопией

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Цель *работы — оценка 3-минутного воздействия красного света на остроту зрения и биометрические параметры глаза.* ***Материал и методы.*** *Проведено квазиэкспериментальное исследование с использованием метода неслучайной целевой выборки.*

Обследован 41 пациент с миопией, в том числе 90,24% женщин в возрасте от 19 до 24 лет (в среднем 23,15 ± 1,58 года) и 9,76% мужчин от 20 до 25 лет (в среднем 23,0 ± 2,16 года). Острота зрения (ОЗ) пациентов оценивалась с помощью таблицы ETDRS, длина переднезадней оси (ПЗО), глубина передней камеры (ГПК), нециклоплегический сферический эквивалент рефракции (СЭР) и показатели кератометрии регистрировались до и после воздействия с помощью IOL Master. Для процедуры воздействия использовалось мобильное приложение для Android SCREEN FLASH в темной комнате. Пациент подвергался воздействию красного экрана с длиной волны 650 нм в течение 3 мин. ***Результаты.*** *Отмечены значительные изменения в показателях биометрии до и после процедуры. После воздействия значение ОЗ увеличилось с 0,68 ± 0,33 до 0,58 ± 0,31 log MAR (p < 0,001), ПЗО уменьшилась с 24,54 ± 1,05 до 24,53 ± 1,05 мм (p = 0,001), СЭР уменьшился с 4,5 ± 0,85 до 4,47 ± 0,97 D (p < 0,001), а ГПК уменьшилась с 3,64 ± 0,26 до 3,63 ± 0,25 мм (p < 0,001). Изменения кератометрических показателей оказались незначимыми.* ***Заключение.*** *У молодых пациентов с миопией в результате воздействия красного света заметно улучшается острота зрения, а также снижается величина ПЗО, СЭР и ГПК.*

Ключевые слова: миопия; глубина передней камеры; длина переднезадней оси глаза; рефракция; воздействие красного света

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Myopia is a common progressive ocular condition that can lead to various complications, potentially resulting in blindness [1]. To prevent its progression, it is crucial to explore effective treatment. Although there are many treatment options, they have some drawbacks and a low compliance rate which is the most challenging thing for treating myopia. In early stages of life, alterations occur in the curvature of a cornea, axial length, and refractive power of a lens. Infancy is characterized by decline in lens and corneal power; increase in axial length is believed to be a result of the passive process of emmetropisation. Numerous animal studies and a few human studies indicate that hyperopic defocus facilitates myopic development. Myopia, defined as having a refractive error of 0.50 D or greater, emerged as the pre-dominant cause of distance vision impairment globally in 2010, impacting approximately 1.45 billion [2, 3]. There might exist spectrum of axial lengths within which the cornea can contribute to preventing the myopia progression by promoting emmetropisation. As axial length (AL) progresses beyond a certain point, it is possible that the cornea's ability to flatten further diminishes. Instead, as the AL increases, the cornea might undergo steepening, potentially due to the mechanical stretching of the eyeball causing myopia [3]. There is a growing body of research, encompassing both human and animal studies on refractive error, that suggests that ambient light exposure plays a crucial role in regulating eye growth. Studies indicate that the development of refractive errors in chickens can be influenced by light levels. Chicks raised under high-intensity light (around 10,000 lux) tend to exhibit significantly fewer myopic refractive errors compared to those exposed to daily low light levels (approximately 50 lux). Additionally, exposure to high-intensity light also appears to have a protective effect against the development of form deprivation myopia in both chicks and primates [4]. Many proposals involve delivering light directly to the retina for shorter, repeated durations for myopia control. They used a device emitting red light at a wavelength of 650 nm. The red light (RL) exposure was administered using a desktop light therapy apparatus that emitted red light with a wavelength of 650 nm, providing an illuminance level of around 1600 lux and a power output of 0.3 mW [5, 6].

Myopia has become a major problem with WHO (World Health Organization) projecting an increase from 22% in 2000 to an estimated 52% by 2050 [6, 7]. RL exposure reduces myopia progression by stimulating retinal function, alleviating eye strain, anti-inflammatory effects, and maintaining a melatonin balance [8]. Melatonin plays a role in regulating eye growth, and disruptions in its levels have been linked to myopia. Experimental myopia has been associated with lower levels of dopamine in the eye, and the administration of dopaminergic compounds can inhibit axial elongation. Red light exposure can enhance dopamine levels, which slows down the process of axial elongation [9].

Previous studies were conducted on pediatric age group, to check the effect of low and reduced red light regime exposure on young adults was major concern of this study. This study aimed to discover a more effective approach for managing myopia progression by using RL which would be an effective and well-tolerated treatment for myopia with minimum rebound effects and high compliance issues.

MATERIAL AND METHODS

It was a Quasi-Experimental Study. The study was conducted on patients who had myopia and were aged from 18 to 25 years. The study was conducted in the General Outdoor Patient Department (OPD) of Tertiary Care Hospital, Rawalpindi after approval from Institutional Review Board (IRB) and institutions ethics subcommittee (letter No: XXX/IRB/2020-23). The study duration was 6 months from June 2023 to November 2023. The sample size calculated for this study was 41 and was calculated by the online software 'OpenEpi Version3' by using the odds ratio 8.5. The confidence interval level was set at 95% while a p-value 0.05 was considered clinically significant. The sampling technique was the Purposive non-random Sampling Technique. The patients who had any ocular pathology, history of ocular surgery, refractive error > SER -6.00D, astigmatism > -2.50 D, Anisometropia of > -1.50D were excluded.

The current study highlighted the effects of RL exposure on several ocular parameters in 41 patients with myopia, encompassing a total of 82 myopic eyes. The sample was largely composed of young adult females (90.24%) with an average age of 21.35 years, while the smaller male group (9.76%) had an average age of 23 years. The mean age for females was 23.15 ± 1.58 (range: 19–24 years) and for males was 23 ± 2.16 (range: 20–25 years).

Patients underwent a comprehensive ophthalmic examination, including assessments of visual acuity (VA) in Log MAR with ETDRS chart at distance of 4 m, slit lamp examination, anterior and posterior segment examinations, and measurement of intraocular pressure (Goldman Tonometry). The data collection process was conducted clinically, and demographic information, such as age, was gathered using language that was easy for the participants to understand. Uncorrected VA (UCVA) and best corrected VA (BCVA) were assessed using ETDRS charts monocularly. Objective and subjective refraction tests were performed to determine the refractive status of each patient three days before applying therapy for confirmation of refractive status. Patients with normal findings were chosen for further analysis. The selected patients were positioned comfortably, and biometric measurements were taken using the IOL Master to assess AL, anterior chamber depth (ACD), and k readings. Readings were taken three times from IOL Master and then their average value was considered. Subsequently, the room lights were turned off, and the room was completely darkened. The patient was comfortably seated at 40 cm (about 1.31 ft), which was measured using a measuring tape, red light source, generated by a mobile app called "SCREEN FLASH," was used. After 3 minutes of exposure to the red light, UCVA and BCVA were assessed again, and average biometric readings from the IOL Master were recorded. Before exposure, the patient was counselled to view the screen comfortably without focusing forcefully, just to relax their eyes, and to watch the whole screen.

Full informed consent was obtained from all patients, and their privacy was protected following the principles of the Helsinki Declaration.

Refractive error, spherical equivalent, myopia, red light exposure were the independent variables of this study. UCVA and BCVA, biometric parameters such as AL, ACD and K readings were the dependent variables for this study. Data tab software was used for data analysis. Descriptive statistics were generated for age and gender. Percentage and frequency variables were calculated. Mean and standard deviation, and ranges were generated for continuous variables. As per the Shapiro — Wilk test criteria the data was not normally distributed. Wilcoxon Test was applied to calculate the difference between VA, ACD, AL, SER and K readings base line and after RL exposure and results were interpreted in tabular form.

RESULTS

The demographic profile provides insight into the baseline characteristics of participants, which may help interpret any age or gender-related differences in response to RL exposure. Analysis of ACD revealed a slight but statistically significant reduction after RL exposure. Baseline ACD averaged 3.64 mm (SD ±0.26) with a median of 3.67 mm, which decreased to a mean of 3.63 mm (SD ±0.25) and a median of 3.68 mm post-exposure. The Wilcoxon test showed a significant effect of RL on ACD, with a Z-value of -3.57 and a p-value <0.001. Similarly, AL showed a statistically significant but subtle change, with both baseline and post-RL means close at 24.54 mm and 24.53 mm, respectively, with identical median values of 24.52 mm. The observed Z-value of -3.07 and p-value of 0.001 indicate a minor, yet significant, effect on AL following RL exposure. In contrast, keratometry readings (K) displayed no significant change, as both baseline (43.85 D, SD ±1.08) and post-RL exposure (43.86 D, SD ±1.1) values were nearly identical, with medians of 44.06 and 44.15, respectively, resulting in a non-significant p-value of 0.269 and a Z-value of -1.1 (Table). VA, however, showed a meaningful improvement post-RL exposure. The baseline VA average of 0.68 (SD±0.33) improved to 0.58 (SD ±0.31) post-treatment, with statistical analysis yielding a Z-value of -6.32 and a highly significant p-value <0.001. These findings suggest that while RL exposure may induce slight yet significant changes in ACD and AL, its most substantial positive impact is on VA, with no noticeable effect on keratometry readings. The absence of reported side effects further supports RL exposure as a safe therapeutic option for managing certain aspects of myopia (Table).

Table. Inferential statistics for anterior chamber depth, axial length, keratometry and visual acuity before and after exposure to red light (n = 82)
Таблица. Глубина передней камеры, ПЗО, показатели кератометрии и остроты зрения до и после воздействия красного света (n = 82)

Variables Показатели	Mean ± SD	t-value	p-value
Anterior chamber depth baseline Исходная ГПК	3.64 ± 0.26	3.57	≤.001
Anterior chamber depth after red light exposure ГПК после воздействия красным светом	3.63 ± 0.25		
Axial length baseline Исходная ПЗО	24.54 ± 1.05	3.07	≤.001
Axial length after red light exposure ПЗО после воздействия красным светом	24.54 ± 1.05		
Keratometry readings baseline Исходная кератометрия	43.85 ± 1.08	1.1	0.269
Keratometry readings after red light exposure Кератометрия после воздействия красным светом	43.86 ± 1.1		
Visual acuity baseline Исходная острота зрения	0.68 ± 0.33	6.32	≤.001
Visual acuity after red light exposure Острота зрения после воздействия красным светом	0.58 ± 0.31		
Spherical equivalent refraction baseline Исходный сферический эквивалент	4.5 ± 0.85	2.57	≤.001
Spherical equivalent refraction after red light exposure Сферический эквивалент после воздействия красным светом	4.47 ± 0.97		

DISCUSSION

The study highlights significant findings on the impact of RL exposure on myopic eyes. It explored changes in several ocular parameters, including UCVA, AL, ACD, SER and keratometry readings (K). The observed results align with prior studies, further validating the therapeutic potential of RL exposure in managing myopia. However, it is crucial to address these results in a nuanced manner, considering limitations and prior evidence.

The most pronounced effect of RL exposure was observed in UCVA, which showed a statistically significant improvement (p < 0.001, Z = -6.32). Baseline VA averaged 0.68 ± 0.33, improving to 0.58 ± 0.31 after RL exposure, suggesting a meaningful therapeutic effect. Most participants demonstrated a two-line improvement in visual acuity, a finding consistent with earlier studies where short-term RL exposure improved UCVA in myopic patients [6, 8, 10, 11]. This improvement may be attributed to a temporary modulation of visual functions and reduced strain in myopic eyes. However, long-term impacts remain unexplored and warrant further investigation.

The study noted a minor but statistically significant reduction in AL post-RL exposure (baseline: 24.54 ± 1.05 mm; post-exposure: 24.53 ± 1.05 mm; p < 0.001, Z = -3.07). This subtle change, though small in magnitude, aligns with prior findings demonstrating that RL exposure can decelerate myopic progression by mitigating axial elongation. For example, earlier studies reported weighted mean differences in AL elongation of -0.35 mm over 6 months in the RL intervention group compared to controls [12–14]. Such findings emphasize the potential of RL as a non-invasive strategy to control axial elongation, albeit with variations in efficacy across study designs.

ACD exhibited a slight but significant reduction post-RL exposure (baseline: 3.64 ± 0.26 mm; post-exposure: 3.63 ± 0.25 mm; $p < 0.001$, Z = -3.57). These findings contrast with previous studies, which often reported insignificant changes in ACD following RL therapy [14–16]. The observed reduction may reflect localized alterations in anterior segment dynamics. However, given the lack of significant findings in earlier research, the relevance of this change to myopia control remains uncertain. Keratometry readings showed no significant changes, with baseline and post-exposure means remaining virtually identical (baseline: 43.85 ± 1.08 D; post-exposure: 43.86 ± 1.1 D; p = 0.269, Z = -1.1). These results align with prior studies, which consistently reported no notable impact of RL exposure on corneal curvature [14, 17]. This finding underscores the selective effect of RL therapy, primarily targeting posterior segment parameters like AL while leaving anterior segment parameters like K relatively unaffected.

When compared to other therapeutic interventions for myopia control, such as low-dose atropine (LDA) or peripheral defocus-modifying spectacle lenses, RL therapy demonstrates a relatively modest but significant effect on AL elongation and SER changes. For instance, over 12 months, LDA exhibited a mean AL change of 0.33 mm, significantly higher than the 0.08 mm observed in the RL group. These comparisons highlight RL therapy as a viable, though less aggressive, alternative for managing myopia progression. Controlling AL is crucial in managing myopia progression, as traditional strategies aim to slow AL. Bright light may stimulate retinal dopamine production, inhibiting AL. Myopia progression is linked to inflammation and oxidative stress, with reactive oxygen species (ROS) damaging eye tissues, triggering inflammation, cell death, and structural weakening. Dopamine's antioxidant properties counteract ROS, protecting tissues and potentially slowing myopia. Hypoxic myopia, caused by reduced oxygen supply, exacerbates oxidative stress and scleral weakening, promoting elongation. Hypoxia-inducible factors drive scleral remodeling. RL treatment reduces oxidative stress and inflammation, offering potential myopia control by targeting hypoxia and oxidative damage [18].

Limitations

1. Sample size and gender imbalance: the small sample size and pronounced gender imbalance (90.24% female, 9.76% male) restrict the generalizability of results.

2. Lack of control group: the absence of a healthy control group limits comparative analysis.

3. Short-term effects: the study focused on short-term outcomes, leaving long-term efficacy and safety unexplored.

Future studies should aim to include a larger, more gender-balanced cohort and evaluate long-term effects of RL exposure. Incorporating control groups and comparative analysis with other therapeutic modalities could further elucidate RL therapy's role in myopia management.

CONCLUSION

The study reinforces the therapeutic potential of RL exposure in improving UCVA and slightly mitigating axial elongation, with minimal effects on anterior segment parameters like K readings. While promising, the findings emphasize the need for more robust, long-term studies to establish RL therapy as a cornerstone in myopia control strategies.

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