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REVIEW PAPER

The benefits and limitations of using blue-blocking filters – a review of results of clinical trials

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ABSTRACT

Introduction and aim. Blue light is part of the natural light spectrum and plays a role in regulating the circadian rhythm. However, with the increasing use of electronic devices and energy-efficient lighting emitting high levels of artificial blue light, concerns are raised regarding its potential effect on human health. Blue-blocking filters have been developed and are advertised as a solution to be used in spectacles or intraocular lenses. This review aims to provide an in-depth analysis of the use of blue-blocking filters based on the results of clinical trials.

Material and methods. This review included relevant original papers reporting on clinical trial results from PubMed, Science Direct, and Google Scholar databases using specified keywords.

Analysis of the literature. Trials conducted with patients reveal mixed results, with some showing no significant changes in vision and reading abilities, while others indicating potential limitations such as reduced contrast vision. However, blue-blocking filters have demonstrated potential benefits in improving sleep quality and mood, particularly in patients with sleep disturbances or psychiatric disorders. The efficacy of blue-blocking filters in mitigating symptoms of digital eye strain remains inconclusive.

Conclusion. Overall, this paper provides a comprehensive assessment of the benefits and limitations associated with the use of blue-blocking filters, highlighting the need for further investigation in certain areas.

Keywords. blue light, blue-blocking filters, clinical trials

Introduction

Blue light is an essential part of the natural light spectrum emitted by the sun, which falls within the wavelength range of approximately 400 to 490 nanometers and has high energy. During the day, exposure to natural blue light helps regulate our internal body clock, or circadian rhythm, by signaling wakefulness and alertness.[1] However, the widespread use of electronic devices and energy-efficient lighting has led to increased exposure to artificial sources of blue light. This has raised concerns about its potential effects on human health.

Artificial sources of blue light

Artificial sources of blue light include electronic devices such as smartphones, tablets, computer monitors, televisions, and light-emitting diodes (LEDs).[2] With the ever-increasing reliance on technology, the average person spends a significant amount of time engaging with digital screens. These screens emit blue light at higher intensities compared to other wavelengths, potentially leading to prolonged exposure that exceeds the levels encountered in natural environments.[3] Energy-efficient lighting, such as compact fluorescent lamps and LEDs, has gained pop-

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ularity due to its reduced energy consumption. However, these lighting technologies emit higher levels of blue light compared to traditional incandescent bulbs.[4] The shift towards energy-efficient lighting in residential, commercial, and public spaces has increased overall blue light exposure, particularly during nighttime hours. However, along with the benefits of these technological advancements comes a growing concern regarding the potential health effects of blue light exposure.

The biological impact of blue light

The biological impact of blue light on humans influences the circadian rhythm. Research suggests that excessive blue light exposure can disrupt sleep patterns and lead to sleep disturbances, such as difficulty falling asleep or maintaining deep sleep. Blue light exposure in the evening can suppress the production of melatonin, a hormone that promotes sleep. Consequently, individuals exposed to blue light before bedtime may experience delayed sleep onset and reduced sleep quality.[5-7]

Moreover, blue light has implications for eye health. Even though the research results are not unanimous, prolonged exposure to blue light, especially at close proximity through digital screens, is proposed as a possible risk factor for eye strain, visual discomfort, and eye fatigue.[8,9] There are also concerns about potential long-term effects on retinal health, as studies suggest a possible link between blue light exposure and retinal damage, including macular degeneration. This can be caused by the release of reactive oxygen species in response to blue light absorption.[10] LEDs have been associated with causing damage to photoreceptors and necrosis of the retina.[11]

In addition to sleep and eye-related effects, blue light exposure has been investigated for its impact on mood disorders, such as depression, mania, or bipolar disorder. Even though the results are vague, excessive blue light exposure, particularly during nighttime hours, may disrupt mood regulation and contribute to symptoms of mood disorders.[12-14]

Blue-blocking filters

To address the concerns related to the adverse impact of blue light (which possibly include: sleep disturbances, mood disorders, eye strain, visual discomfort, eye fatigue, and retinal damage), blue-blocking (BB) filters have been developed and incorporated into spectacles and intraocular lenses (IOLs) as a potential solution to reduce the transmission of blue light and mitigate its potential adverse effects.[15] BB filters aim to selectively absorb or reflect short-wavelength light (blue light and shorter wavelengths of 440-500 nm), thereby reducing the amount reaching the retina.[10] However, the efficacy of BB filters in spectacles and IOLs in reducing eye fatigue symptoms when using digital devices, improving sleep quality, and protecting from retinal phototoxicity remains a topic of debate. While some studies suggest potential benefits, others have found limited or inconsistent effects on its supposed potential influence on ocular disorders.[16]

Aim

This review aims to analyze the results of clinical trials investigating the use of BB filters in spectacles and IOLs and their effectiveness in mitigating undesirable symptoms associated with excessive exposure to blue light. By critically evaluating the available evidence, we seek to provide a comprehensive assessment of the benefits and limitations associated with their use.

Material and methods

This narrative review was performed by researching the PubMed, Science Direct, and Google Scholar databases with the keywords "blue light", "blue-blocking filters", "blue light filters", "blue light filters spectacles", "blue light filters lenses" and "clinical trial". The search was performed from May 19th, 2023, through June 8th, 2023. Considered were only original papers that reported on the results of clinical trials, written in English or Polish, and included were those deemed relevant to the analysis by the authors. The exclusion criteria included: preclinical trials, and manuscripts unrelated to the topic. All articles that fit the aim of this review paper were included in the "result" section of the article. The narrative review has been constructed with the use of the scale for the quality assessment of narrative review articles (SANRA).

Analysis of the literature

The results of the reviewed clinical trials were not consistent in all aspects, and some of them concluded that BB filters are not favorable for patients. Different aspects were taken under consideration and the results either supported or disproved the thesis of the trial. The clinical trials also used various outcome measures. The details of each study design can be found in the referenced literature, while this review summarizes the most important conclusions drawn from the studies. The most important advantages and disadvantages of using BB filters are summarized in Table 1.

Table 1. Summary of the advantages and disadvantages of BB filters in IOLs and spectacles*

Advantages	Disadvantages
- may be beneficial as part of the treatment of amblyopia,[26] -improve mood and sleep quality,[28] - may be used as an additive treatment for patients with sleep disturbances in the course of psychiatric disorders,[13,30] - may lead to better reading capacity in children with reading difficulties.[27]	- no influence on contrast vision or visual acuity,[17-20] - do not reduce symptoms of DES,[36,37] - might dysregulate the circadian rhythm,[36] - do not influence mental symptoms and psychiatric disorders in patients after cataract surgeries,[38,39] - do not reduce number of injuries in patients after cataract surgeries,[40] - do not prevent development of AMD.[45-48]

* DES – digital eye strain, AMD – age-related macular degeneration.

The impact of BB filters on vision and reading

Many studies investigated the influence of BB filters on visual function. Up to date, no effect on contrast vision, or visual acuity has been observed.[17-20] Wirtitsch et al. conducted a clinical trial that revealed that the contrast acuity in patients with BB IOLs was lower in comparison to users of ultraviolet-filtering IOLs. The biggest difference in contrast vision was observed in the setting of low-mesopic light (a range of human vision, where both rods and cones are active), where the contrast acuity was tested at low illumination levels (0.5 lux) with different levels of contrast.[21] Also in another work, the researchers found that contrast vision among the patients was worse under lower illumination using the IOLs with BB filters compared to photochromic or clear IOLs.[22] On the other hand, some studies concluded that there is no clinically significant change in contrast vision among patients with BB IOLs, and no difference between BB IOLs in comparison to clear ones regarding mesopic contrast sensitivity nor subjective visual perception.[17,19,20,23,24] Yellow or orange-colored BB IOLs and clear IOLs have similar results in photopic and mesopic contrast sensitivity.[23]

Another important aspect assessed in the clinical trials was color vision reduction. Under mesopic conditions, patients with yellow-tinted IOLs had the least favorable outcomes during the assessment of color perception and made more mistakes during tests.[19,22] Especially, the perception of the color blue has been affected both under mesopic and photopic conditions (a range of human vision, where only cones are active).[20] In another research, there was no significant difference in color sensitivity among the tested groups, but the subjective perception of the colors has been changed and reported by some patients.[18] On the other hand, one clinical trial conducted by Stopyra et al. revealed a possible positive influence of BB filters on color perception.[25]

Another clinical trial assessed the use of BB filters as part of the treatment of amblyopia. Metzler et al. showed, that a BB filter treatment protocol gave better results for treating amblyopia than conventional classic occlusion treatment.[26]

Regarding the influence of BB filters on reading abilities, a clinical trial reported that children with reading difficulties, who wore glasses with blue or yellow filters for 3 months, had a better reading capacity than they did before the start of the clinical trial.[27] A detailed summary of chosen representative clinical trials is shown in Table 2.

The impact of BB filters on sleep disturbances

Many studies suggested that BB filters may have a positive effect on patients with sleep disturbances. Wearing glasses with a BB filter 3 hours before sleep was shown to significantly improve mood and sleep quality in comparison to patients who wore glasses blocking ultraviolet only.[28] In a similar study, after wearing BB glasses 90 min before bedtime a substantial reduction of subjective sleep latency and an increase in subjective total sleep time was observed.[29] Many studies indicated that patients with psychiatric disorders may benefit from BB filters applied in ocular lenses. In one study, patients with bipolar disorder and coexisting circadian rhythm abnormalities who used BB filters in ocular lenses in the evenings presented an improvement in sleeping efficiency.[13] Their use may also be an additive treatment for manic patients in a hospital environment,[30] but no significant changes were seen in patients with depressive symptoms and coexisting sleep onset insomnia.[14] Another group that can be positively influenced is non-sleep-deprived recreational athletes. A clinical trial reported that wearing BB filters in the evening improved the subjective sleep onset latency, sleep quality, and alertness in the morning.[31] Another study stated that the use of amber lenses before bedtime leads to delayed wake time and higher mean subjective total sleep time, overall quality, and soundness of sleep.[32] On the other hand, studies state that long-term blue light reduction might negatively influence mental health.[16] Blue light filtration may negatively affect normal circadian rhythm and sleep, but there is conflicting evidence.[33] Moreover, in a randomized controlled trial BB IOLs lowered nocturnal melatonin secretion in comparison to neutral IOLs, but surprisingly BB IOLs increased sleep efficiency in patients one year after cataract surgery.[34] Another clinical trial also indicated that BB IOLs implantation can be beneficial for patients after cataract surgery in improving the quality of sleep. In the referenced group of patients, blocking the blue light during the day has not had adverse effects, because the amount of light transmitted overall through the lens rises after cataract surgery. The BB IOLs can partially filter purple and blue visible light between 400 and 500 nm, but a residual blue light transmission is still enough to prevent melatonin production during the day. Inhibiting the release of melatonin throughout the day enhances the quality of sleep at night.[35]

The impact of BB filters on the symptoms of digital eye strain

In general opinion, BB lenses are viewed as a tool to prevent computer users from digital eye strain (DES). However, the reviewed clinical trials showed that using BB filters did not reduce the symptoms of DES.[36,37] Additionally, the authors agreed that currently, there is no evidence for using BB filters as a remedy for DES.[36] Furthermore, the usage of BB filters might disintegrate the circadian rhythm. However, it is difficult to conduct a credible clinical trial that would prove that the reduction in the absorption of light impacts the human's sleep schedule.[38]

Table 2. Summary of chosen representative clinical trials that assessed the benefits of using BB filters in glasses and IOLs*

Group of patients	Title of the study	Main objective of the study	Outcome measures	Main outcomes of the trial	References
		Positive effects of BB filters			
Patients with bipolar disorder and insomnia	"A double-blind, randomized, placebo-controlled trial of adjunctive blue-blocking glasses for the treatment of sleep and circadian rhythm in patients with bipolar disorder"	To assess the influence of BB glasses on the change in sleep quality and circadian rhythm	Overall quality of the sleep experience, subjective and objective sleep, circadian rhythm	No difference in sleep quality, but visible changes in actigraphic sleep efficiency	13
Strabismic children with amblyopia aged 3 to 7 years old without previous treatment and a visual acuity up to 0.3	"Blue filter amblyopia treatment protocol for strabismic amblyopia: a prospective comparative study of 50 cases"	To assess the effectiveness of BB IOLs as a treatment method for amblyopia	Visual acuity, fixation behavior, visual evoked potentials	Patients presented with better visual acuity and eye-fixation behavior outcomes	26
Children with reading difficulties aged 7 to 10 years old	"A comparison of two-coloured filter systems for treating visual reading difficulties"	To assess the effectiveness of BB IOLs in treating reading difficulties	Reading and spelling scores, irregular and non-word reading capacity	Patients with visual stress who wore colored filters had better reading and spelling outcomes	27
Patients with insomnia aged 18 to 68 years old	"Amber lenses to block blue light and improve sleep: a randomized trial"	To assess the influence of blocking blue light on improving sleep	Changes in sleep quality	Glasses with BB filters led to improvement of sleep quality and benefited patients' mood	28
Patients with bipolar disorder in a manic state aged 18-70 years old	"Blue-blocking glasses as additive treatment for mania: Effects on actigraphy-derived sleep parameters"	To assess the effectiveness of BB filters on sleep parameters in patients with mania	Actigraphy-derived sleep parameters	The efficiency of sleep was higher, and sleep was more consolidated among patients using BB glasses	30
		Negative effects of BB filters			
Patients with bilateral cataract	"Effects of blue light-filtering intraocular lenses on the macula, contrast sensitivity, and color vision after a long-term follow-up"	To assess side effects and potential protection after implantation of BB IOLs	Contrast sensitivity, color vision, macular findings	No significant influence on color perception, scotopic contrast sensitivity or photopic contrast sensitivity	17
Patients after phacoemulsification and primary posterior curvilinear capsulorhexis	"Intraindividual comparison of color contrast sensitivity in patients with clear and blue-light-filtering intraocular lenses"	To assess the effect of BB IOLs on color contrast sensitivity	Best distance-corrected visual acuity	No change in color contrast sensitivity	18
Patients scheduled for cataract surgery without history of ocular surgery or ocular pathologies	"Comparison of visual performance with blue light-filtering and ultraviolet light-filtering intraocular lenses"	To assess contrast sensitivity, glare, color perception, and visual acuity at different light intensities	Contrast sensitivity, glare, color perception, visual acuity, color discrimination	No significant influence on visual performance	19
Patients with bilateral cataract scheduled for phacoemulsification and posterior IOL implantation in both eyes	"Intraindividual comparison of a blue-light filter on visual function: AF-1 (UY) versus AF-1 (UV) intraocular lens"	To assess the effect of BB IOLs on visual function	Uncorrected and best corrected visual acuities, pupil size, contrast vision, color discrimination	No change in contrast vision and visual acuity, and worse perception of blue color	20
Patients aged between 16 and 27 years old and best corrected visual acuity of at least 20/20	"A double-blind test of blue-blocking filters on symptoms of digital eye strain"	To assess the influence of BB filters on DES symptoms	Pre- and post-reading task symptom scores of DES	No significant change in symptom scores before and after task	36
Healthy young patients	"Blue-blocking filters do not alleviate signs and symptoms of digital eye strain"	To assess whether BB filters are affective in reducing symptoms of DES	Orbicularis oculi muscle activity, visual discomfort	No influence of BB filters on reducing symptoms of DES	37
Cognitively healthy patients scheduled for bilateral cataract surgery	"Blue light-filtering intraocular lenses and post-operative mood: a pilot clinical study"	To assess influence of BB IOLs on post-operative mood and symptoms of depression	Symptoms of depression assessed using geriatric depression scale	BB IOLs did not affect mood differently than untinted IOLs	38
Patients after bilateral cataract surgery	"Association of clear vs blue-light filtering intraocular lenses with mental and behavioral disorders and diseases of the nervous system among patients receiving bilateral cataract surgery"	To assess the development of mental and behavioral disorders and nervous system diseases in patients after cataract surgery	Appearance of mental, behavioral, and nervous system diseases subcategorized by the ICD codes	BB IOLs do not influence the development of mental, behavioral, and nervous system diseases	39
Patients after bilateral cataract surgery	"Association of Blue Light-Filtering Intraocular Lenses With All-Cause and Traffic Accident-Related Injuries Among Patients Undergoing Bilateral Cataract Surgery in Finland"	To assess the influence of BB IOLs on risk of injuries and quality of driving	Kaplan-Meier and Cox regression analyses for the risk of injuries after surgery	BB IOLs did not reduce the risk of injuries and led to worse glare during driving in the dark	40
Patients with bilateral cataract and AMD	"Comparative assessment of the course of age-related macular degeneration in patients after phacoemulsification cataract surgery with implantation of AcrySof Natural SN 60 at and AcrySof SA 60 at lenses"	To assess the influence of BB IOLs on progression of AMD	Ophthalmic examination, fluorescein angiography, multifocal ERG	BB IOLs have no protecting influence on AMD progression	45
Patients who underwent uneventful cataract surgery	"The Effect of Blue-Light Filtering Intraocular Lenses on the Development and Progression of Neovascular Age-Related Macular Degeneration"	To assess the ability of BB IOLs to prevent neovascular AMD after cataract surgery	Kaplan-Meier and Cox regression analyses for overall risk of neovascular AMD development	Study showed no significant benefit of using BB IOLs	46
Patients previously treated for wet AMD and were implanted with BB IOL at least 3 years before	"The Influence of Blue-Filtering Intraocular Lenses Implant on Exudative Age-Related Macular Degeneration: A Case-Control Study"	To assess whether BB IOLs prevent the onset of wet AMD	Monitoring -follow ups	No beneficial change in the occurrence of wet AMD in patients with BB IOLs	47
Patients who underwent cataract surgery in both eyes	"Effect of Blue Light-Filtering Intraocular Lenses on Age-Related Macular Degeneration: A Nationwide Cohort Study With 10-Year Follow-up"	To assess the incidence of AMD after cataract surgery and the incidence of AMD after implantation of BB IOLs and non-BB IOLs	Monitoring – follow ups	No positive influence on the incidence of AMD	48

* BB – blue-blocking, IOLs – intraocular lens, DES – digital eye strain, ICD – International Classification of Diseases, AMD – age-related macular degeneration, ERG – electroretinogram

The impact of BB filters on patients after cataract surgeries

Clinical trials have been conducted to assess the relationship between using BB filters and the outcomes of cataract surgeries. In a study performed by Leruez et al., patients were observed post-surgery to detect mood changes assessed based on the geriatric depression scale, with regard to the type of IOLs implanted. It has been discovered that there is no significant difference in post-operative depression symptoms after implantation of clear IOLs, or BB IOLs.[38] Furthermore, patients who were implanted a BB IOLs after bilateral cataract surgery did not develop any mental and behavioral disorders or diseases of the nervous system.[39] Another study proved that the use of BB IOLs did not reduce the number of injuries and patients with BB IOLs had a worse glare during driving at nighttime, but that did worsen the comfort of driving.[40] Another assessed factor was the influence of BB IOLs on the thickness of the retinal nerve fiber layer (RNFL), and a clinical trial by Kim et al. proved, that BB IOLs did not influence the RNFL after cataract surgery, so there is no additional benefit of using these types of lenses.[41] Also, the type of used lenses does not affect the development of inflammation connected to cataract surgery.[42]

The impact of BB filters on the progression of age-related macular degeneration

Blue light can cause damage to the retina and lead to age-related macular degeneration (AMD).[43] It was suggested that patients with a high risk for the development of AMD could benefit from wearing IOLs with BB filters.[44] However, opposite results were presented by Łak et al., who showed that the implantation of BB IOLs did not stop the progression of AMD, and did not protect the maintenance of contrast sensitivity.[45] In a cohort study, the implementation of BB IOLs did not show any positive effect on the incidence of neovascular AMD and its progression over a non-BB IOLs use in patients after cataract surgery.[46] Moreover, another study found that there is no evidence that BB IOLs prevent the onset of wet AMD.[47] Furthermore, even the use for up to 10 years of BB IOLs had no significant advantage over a non BB IOLs in the incidence of AMD.[48] Another study, which included patients with AMD, assessed the reading rates among patients, and no advantage of using BB filters was proven. Additionally, BB filters users had worse reading rates compared to users of other color filters.[49]

Conclusion

In conclusion, the use of BB filters in spectacles and IOLs has shown mixed results in clinical trials. The impact of BB filters on vision and reading abilities is still a topic of debate, with some studies reporting no significant changes and others indicating potential limitations, such as reduced contrast acuity and color perception. However, BB filters have demonstrated potential benefits in improving sleep quality and mood, particularly in patients with sleep disturbances or psychiatric disorders. The efficacy of BB filters in mitigating symptoms of digital eye strain remains inconclusive, and further research is needed to establish their effectiveness in this area.

Declarations

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Author contributions

Conceptualization, A.P. and E.S.; Methodology, M.D.; Software, P.S.; Validation, A.P., and P.S.; Resources, M.D.; Data Curation, E.S.; Writing – Original Draft Preparation, A.P., E.S., P.S. and M.D.; Writing – Review & Editing, A.P., M.D., P.S., and E.S.; Visualization, M.D.; Supervision, E.S.; Project Administration, P.S.

Conflict of interest

The authors declare no conflict of interest.

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