Title: “Effect of blue light filters on tear and contrast sensitivity in individuals using electronic devices”

Running short title: “Blue light, tear and electronic devices”

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ABSTRACT

Objetives: To investigate the effect of contact lenses with blue light filter on contrast sensitivity and any alteration in tear quantity and quality.

Method: This prospective longitudinal pilot study required three visits by each participant. Monocular visual acuity, contrast sensitivity, phenol red thread test, and tear break-up time were measured at each visit.

Results: There were significant differences in logarithmic contrast sensitivity (LogSC) between the groups. The BUT was significantly lower after use video display terminals than before ($p<0.05$).

No differences in BUT were found between groups video display terminals and contact lenses having the blue filter ($p>0.05$). However, higher mean values were observed in the group after video display terminals use with contact lenses having the blue filter than with standard contact lenses ($p>0.05$ in both groups).

No significant differences were found between the groups in tear secretion ($p>0.05$). However, the mean value of phenol red thread test on group after video display terminals use with contact lenses having the blue filter was lower than group before use it.

Conclusion: The results establish a relationship between the symptoms of computer vision syndrome, tear stability, improved contrast sensitivity, and the use of a blue filter in contact lenses.

Key words: blue light, tear, contrast sensitive, electronic devices.

Our current lifestyle has been heavily influenced by the use of and dependency on electronic devices. The flat screen displays of mobile phones, tablets, laptops, and televisions are directly affecting visual perception. Blue light (380–495 nm), belonging to the 380–780 nm visible spectrum, increases oxidative damage. Thus, at a corneal level, it causes inflammation of the corneal epithelium in addition to a decrease in the number of cells and xerophthalmia or ocular damage, which is supplemented by vitamin A deficiency (1). Oxidative stress also contributes to yellowing and the appearance of cataracts in the lens (2,3). Oxidative processes and the creation of free radicals, produced by blue-violet light (380–450 nm), alters the function and morphology of retinal structures, causing age-related macular degeneration, AMD, and photoreceptor cell death (4). On the other hand, blue-turquoise light (450–495 nm), when affecting the retinal ganglion cells, specifically melanopsin, allows circadian rhythm regulation and pupillary response, among other important biological functions. Melanopsin is a photosensitive pigment with a maximum peak of light absorption between 470–480 nm (5).

Visual acuity is the most important data obtained from a visual examination because the ability to see is quantified in high-contrast conditions. However, certain visual losses due to lesions at the level of the retina may go unnoticed; this becomes apparent when measuring the sensitivity to contrast or the ability to discriminate between differences in the illumination of adjacent areas, and hence measuring the quality of vision (6,7).

The main characteristic of blue light filters is the reduction of the spectral transmittance of blue light radiations of short wavelengths. However, finding a balance between reducing the harmful effects of this radiation without interfering with the essential functions controlled by blue light remains challenging (8,9). It is interesting to study the effect of filters on visual performance, since any alteration in the light that affects the retina can cause alterations in perception (10). Although most studies on the effect of filters have been performed with intraocular lenses in patients operated for cataracts, their results can be interpolated to the effect produced by filters with similar characteristics in contact lenses (11). Many of these studies have analyzed contrast sensitivity and color vision, without finding significant differences between conventional intraocular lens and those with selective filters. However, a decrease in the contrast sensitivity of intraocular lens with filters compared to the conventional intraocular lens is found, especially in mesopic conditions (12). In addition, improvements in contrast sensitivity with the use of filters have also been reported (13).

This study aimed to investigate the effect of contact lenses with blue light filters on contrast sensitivity and any alteration in tear quantity and quality, beyond what may be produced with contact lenses without the blue light filter.

METHODS

Participants

Twenty students of the University of Seville (mean age, 22,27 ± 2,05 years) participated in this study. The study was carried out at the Faculty of Pharmacy of the University of Seville (Optics and Optometry department) from February to April 2019, and was approved by the Ethics Committee of the University of Seville. It was performed according to the principles of the Helsinki Declaration, and informed consent was obtained from the participants after being informed about the study verbally and in writing. Inclusion criteria were age between 18 and 40 years and at least 20/20 uncorrected visual acuity. Individuals with alterations in the eye surface that could influence the characteristics of the tear film, those with a systemic disease, or those undergoing treatment with any medication that could affect tear production were excluded.

Study protocols

This prospective longitudinal pilot study required three visits by each participant. Monocular visual acuity, contrast sensitivity, phenol red thread test, and tear break-up time (TBUT) were measured at each visit. On the first visit, participants were asked not use any digital devices 3 hours prior to the study, and the Standard Patient Evaluation of Eye Dryness questionnaire was given. On the second visit, participants were asked to use some type of digital device continuously during the 3 hours leading up to the study. On the last visit, participants were asked to come with 3 hours of contact lens support and continued use of some type of digital device. In the right eye, the contact lens was placed without a filter (CL 1), and the contact lens in the left eye had a blue light blocking filter (CL 2). Monocular visual acuity and contrast sensitivity were measured first, following which the contact lenses of both eyes were removed, and tear film was measured for further tests.

Measurements

TBUT

Tear film quality was measured by TBUT using a fluorescein strip impregnated with one drop of saline and inserted into the upper bulbar conjunctiva. Participants were instructed to blink several times and the time between the last blink and the appearance of dark areas in the tear film was measured (in seconds) under the cobalt blue illumination of the slit lamp. TBUT was the average of the three measures of each eye.

Phenol red thread test

Tear film secretion was measured using the phenol red thread test. It consists of a cotton thread impregnated with phenol red that changes color from yellow to red when moistened by tears because of the pH changes caused by tears. A 3-mm portion of thread was folded and inserted into the temporal third of the lower eyelid for 15 seconds, the participants were asked to keep their eyes closed. After 15 seconds, the thread was removed, and the red colored portion was measured. This procedure was performed first in the right eye and then in the left eye.

Contrast sensitivity

Contrast sensitivity was measured using the CSV 1000-E test (Vector Vision, Inc., Ohio, USA) at 2.50 meters under mesopic conditions. The test consists of four spatial frequencies: 3, 6, 12, and 18 cycles/degree (CPD) with eight contrasts levels and has its own lighting system, with a luminance of 85 lx/m^2. Participants were instructed to choose between two targets presented on different rows (one with sinusoidal modulation and the other with a solid grey). The results were collected in the data record sheet provided by the manufacturer; the maximum level of contrast that the participant was able to perceive in the four spatial frequencies was noted. Values were transposed to logCS by the table listed on the company's website (http://www.vectorvision.com/csv1000-norms/) for curve fitting and analysis.

Contact lenses

Two neutral monthly silicone hydrogel contact lenses provided by the Mark'Ennovy Laboratory were used in the study. Contact lens 1 (Saphir Rx©) was placed in the right eye and did not incorporate filters, and contact lens 2 (Blue:gen©) was placed at the left eye with an incorporated Class I UV filter and a selective filter for blue light that blocked 14% of the harmful blue-violet light. The contact lens parameters are listed in Table 1.

Statistical analysis

Statistical analysis was performed with the Statgraphics Centurion VXI program using ANOVA variance analysis with a 95% confidence level (p-value < 0.05). Spatial frequencies of contrast sensitivity (3 CPG, 6 CPG, 12 CPG and 18 CPG), tear film quality, and tear film secretion were considered as the dependent variables. The following four factors were considered: eyes rested, digital devices (DD), DD, and contact lenses with Blue-blocking Filters, DD, and contact lenses. The homogeneity of the sample was confirmed by the Levene's test.

RESULTS

Contrast sensitivity

There were significant differences in logarithmic contrast sensitivity (LogSC) between the groups (Table 2) (p). Group 3 (video display terminals [VDT] + contact lenses having the blue filter) showed the highest mean value of LogSC at all spatial frequencies.

LogCS in VDT + C-L with blue filter (group 3) was significantly better than in normal eyes (group 1) and VDT (group 2) at spatial frequencies of 3c/deg, 6c/deg, and 12c/deg ($p \leq 0.05$). Group 3 showed better LogSC than VDT + C-L without blue filter (group 4) at 6c/deg, 12c/deg, and 18c/deg too ($p<0.05$).

Tear film stability

Figure 1 shows mean values of the time-break-up (BUT) measured for each group.

The BUT in group 2 (5.21±2.87 sec after VDT use) was significantly lower than that in group 1 (7.10±2.48 sec. before VDT use) ($p<0.05$).

No differences in BUT were found between groups 3 and 1 ($p>0.05$). However, higher mean values were observed in group 3 (8.47±2.63 sec. after VDT use with contact lenses having the Blue Filter) than in groups 2 and 4 (6.42±1.54 sec. after VDT use with standard contact lenses) ($p>0.05$ in both groups).

Tear secretion

Figure 2 shows mean values of tear secretion on each group.

No significant differences were found between the groups in tear secretion ($p>0.05$). However, the mean value of phenol red thread test on group 3 (23.06±1.56 mm after VDT use with contact lenses having the Blue Filter) was lower than group 1 (26.92±5.92 mm before VDT use) and similar to group 2 (25.59±5.77 mm after VDT use) and group 4 (25.00±6.42 mm after VDT use with C-L standard).

DISCUSSION

Our study aimed to evaluate the volume and time of tear breakage among users with contact lenses, with and without a blue light filter exposed to VDT, and analyzes the influence of these filters on the visual performance of an individual in terms of contrast sensitivity under mesopic conditions.

In some studies, relationships between the use of contact lenses and computer vision syndrome were studied in workers exposed to the continuous use of these devices (14–17); however, contact lenses with blue light filters were not included in any case. The reduction of short-wavelength light on the ocular surface and retina through the use of contact lenses with a blue light blocking filter could improve visual perception and reduce the possible adverse effects on the anterior surface of the eye and retina (18). Our study compares a silicone hydrogel contact lens that combines a Class I UV filter with a selective blue light filter to protect the eye against more than 99% of UVB rays, 93% of UVA rays and 14% of harmful blue-violet light with an unfiltered silicone hydrogel lens.

The results of this study demonstrating the relationship between the use of contact lenses and the tendency to increase computer vision syndrome are in line with those of previous studies

(16). In addition, several studies have reported on the alteration of stability (19) and secretion (20,21) (22) among VDT users without contact lenses.

The use of VDT produces an alteration in the act of blinking that affects the cornea and favors a greater evaporation of tears (22–26). Our study shows a tendency to alter the tear film and ocular surface without contact lenses. In this research, three different appointments were made for each participant. At the first appointment, participants were asked to stay for 3 hours prior to the appointment, avoiding the use of any type of digital screen (BUT = 7.10 ± 2.48 sec and 26.92 ± 5.92). At the second appointment, the participants had to exhibit 3 hours of continuous VDT use prior to the visit (BUT = 5.21 ± 2.87 sec and 25.59 ± 5.77 mm). In the third appointment, the tear film was compared between users of contact lenses, with and without a blue light filters, exposed to continuous VDT use. This trend suggests that lenses with a blue light blocking filters improve tear stability (8.47 ± 2.63 sec) compared to those without a filter (6.42 ± 1.54 sec). The use of hydrogel lenses with high water content is reportedly associated with dry eye symptoms (27). Dehydration of contact lenses caused by evaporation from the front surface of the lens produces thinning of an individual's tear film. Hydrogel lenses with high water content were compared in this study. Filtered lenses have water content 52% and unfiltered lenses 55%, this small difference could account for the higher tear stability (BUT) in blue light filter lens wearers.

Light is essential for visual perception; however, it can also be dangerous. The anterior structures of the eye limit the amount of harmful ultraviolet radiation that can reach the retina. The cornea absorbs UV radiation below 300 nm, and the lens blocks most of the light between 300 and 400 nm. With age, the lens loses transparency and the transmittance of short-wavelength light that reaches the retina decreases. Thus, aging lenses show greater blue light filtering properties than younger lenses that allow more short-wavelength visible light to be transmitted to the retina (18).

The increased use of electronic light-emitting devices has changed indoor lighting perception (28) as short-wavelength blue-violet light causes glare due to direct or reflected bright light. Thus, several studies have examined efficacy intraocular lenses that incorporate blue light filters (29).

Our study aimed to investigate whether the selected individuals could benefit from the use of blue light blocking filter contact lenses in terms of contrast sensitivity and glare. These filters contained chromophores that block wavelengths between 400 and 500 nm, generally classified as blue blockers (which absorb visible light in the blue part of the spectrum, around 450 to 500 nm) and violet light blockers (absorbing only the violet part of the spectrum, around 410–440 nm, but transmitting blue light) (30). Contact lenses used with a blue light filter were found to improve contrast sensitivity by counteracting a part of the dazzling blue-violet radiation and providing favorable conditions for encoding visual signals from photoreceptors. The results of the contrast sensitivity analysis shown in Table 2. Significant statistical differences were observed between the studies groups measured under mesopic conditions.

CONCLUSION

In conclusion, our results establish a relationship between the symptoms of computer vision syndrome, tear stability, improved contrast sensitivity, and the use of a blue filter in contact lenses, although no statistical significance has been shown in our study, this finding could be considered a starting point in future research.

Regarding the limitations of our study, it is important to emphasize the small sample size and characteristics of the optometric cabinet where the measurements were taken have not been considered in this study. It has been shown that ambient humidity, temperature, and ventilation could contribute to increasing the signs of eye irritation and tear stability (31).

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Figure legends

Figure 1. Tear film stability measured by time-break-up. The mean values and the 95% Fisher confidence interval on each group have been shown.

Figure 2. Tear secretion measured by phenol red thread test. The figure shows the mean values and the 95% Fisher confidence interval on each group.

Table 1

Contact lenses used in the study (Mark'Ennovy laboratory)

	Contact lens 1	**Contact lens 2**
Commercial name	Saphir Rx©	Blue:gen©
Material	Methafilcon A	Filcon IV 1
Base curve (mm)	8.70	8.70
Diameter (mm)	14.40	14.40
Oxygen transmissibility (Dk/t)	60	60
Water content (%)	75	75
Modulus (MPa)	0.29	0.25
Blue light-blocking filter	No	Yes

Table 2

Table 2: Logarithmic Contrast Sensitivity values at the four spatial frequencies in each group.

	Group 1: Normal (n=40)			**Group 2: VDT (n=40)**			**Group 3: VDT + Contact lens with blue filter (n=20)**			**Group 4: VDT + Contact lens (n=20)**			
		95% Fisher CI			95% Fisher CI			95% Fisher CI			95% Fisher CI		
	Mean±SD	Low	High	Mean±SD	Low	High	Mean±SD	Low	High	Mean±SD	Low	High	P*
3c/deg	1.41±0.35	1.330	1.482	1.35±0.35	1.274	1.426	1.61±0.27	1.505	1.720	1.44±0.36	1.330	1.545	.050
6c/deg	1.42±0.40	1.345	1.493	1.46±0.35	1.382	1.530	1.69±0.28	1.583	1.792	1.44±0.34	1.333	1.542	.026
12c/deg	1.46±0.40	1.385	1.540	1.49±0.33	1.416	1.571	1.76±0.32	1.653	1.872	1.51±0.31	1.403	1.622	.016
18c/deg	1.60±0.34	1.527	1.673	1.48±0.36	1.402	1.548	1.78±0.26	1.672	1.878	1.48±0.29	1.372	1.578	.006

* ANOVA (Statistically significance p≤0.05)

CI=Confidence Interval; c/deg=circles/degree; SD=Standard Deviation

Figure 1

Click here to access/download;Figure (1 per file. Do Not Embed in TEXT);Figure 1.tif

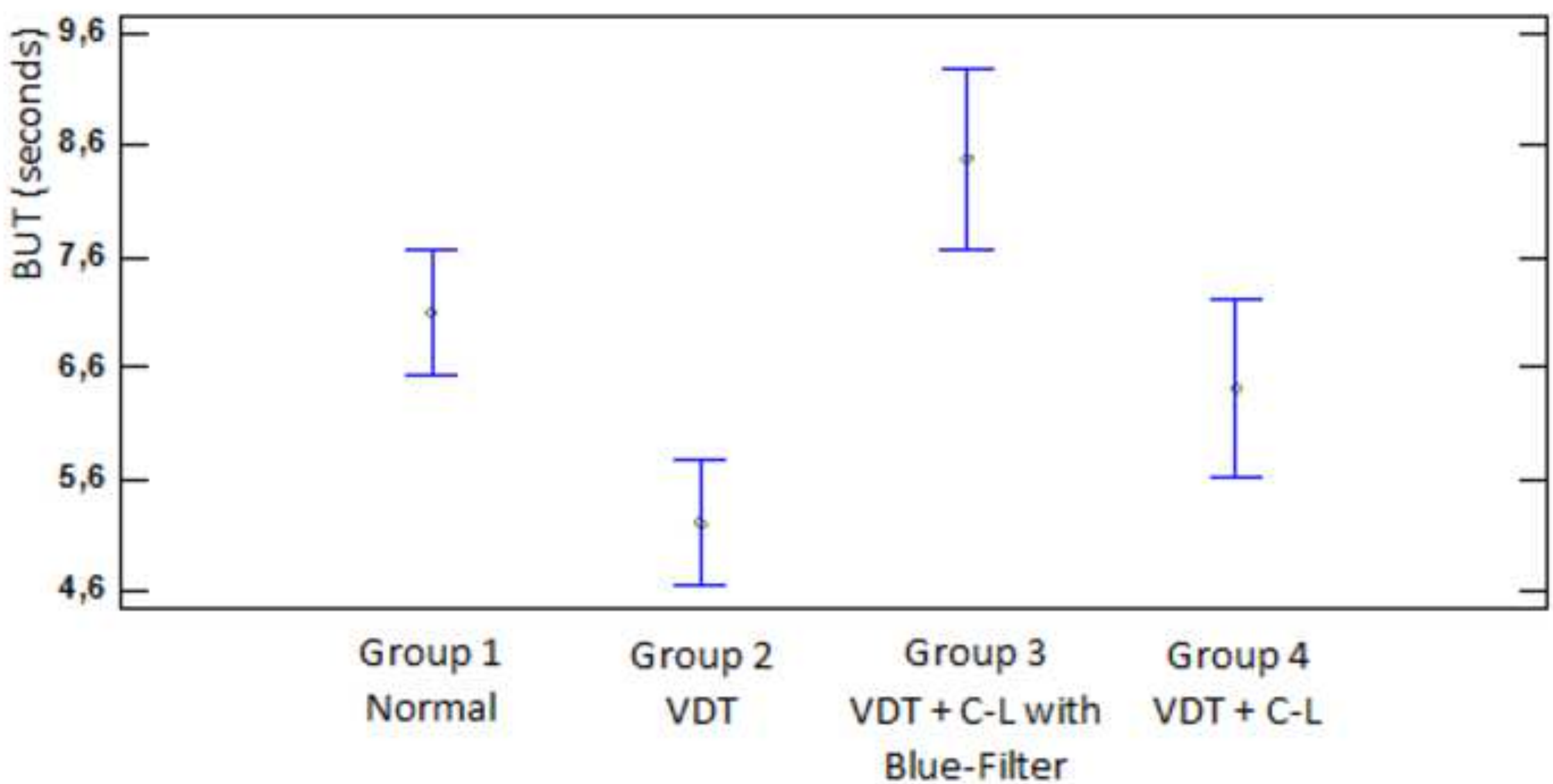
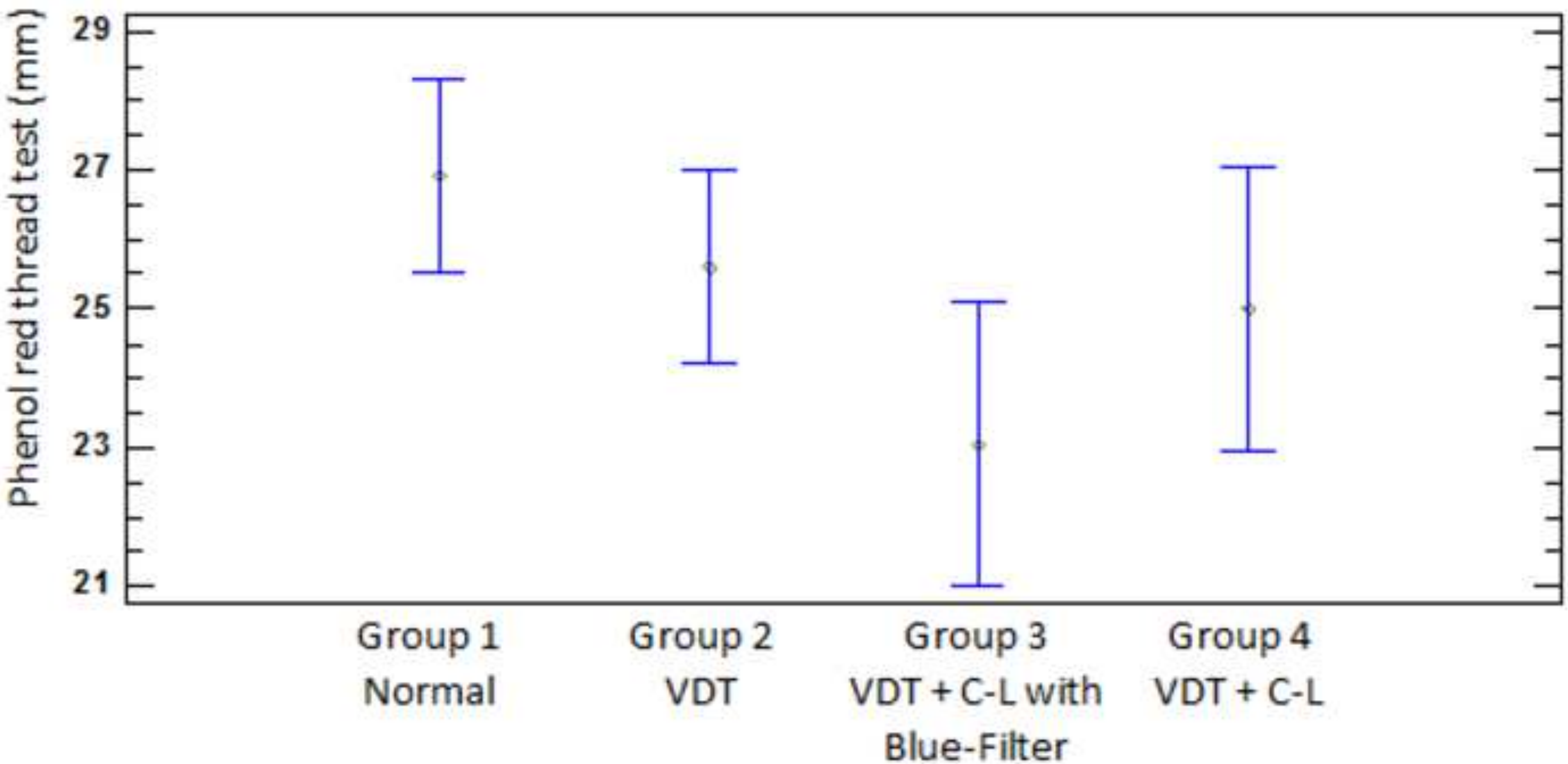


Figure 2


Phenol red thread test (mm)
29
27
25
23
21
Group 1
Normal
Group 2
VDT
Group 3
VDT + C-L with
Blue-Filter
Group 4
VDT + C-L