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Effect of Ultraviolet Radiation from Welding Activities on Ocular Tissues of Albino Rats

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Ultraviolet radiation (UVR) causes acute eye injuries such as photokeratitis with accompanying symptoms such as ocular pain, tearing, and a sensation of sand in the eye. This research aimed to assess the impact of ultraviolet radiation on ocular tissues due to the use of various welding machines in some welding workshops within Ogbomoso. This research is crucial for understanding and mitigating the ocular risks of UV radiation exposure in welding, enhancing occupational safety and guiding protective equipment standards. Fifteen male albino rats were grouped into cages A, B and C of five rats each. Group A served as the control group, Group B was exposed to UVR from

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imported welding machine while Group C was exposed to UVR from locally constructed welding machine for 4 hours at 25 cm distance for 7 days consecutively. The rats were sacrificed by cervical dislocation and their eyes fixed in 10% formalin for histological examination of ocular tissues: sclera, uvea, cornea retina, lens and conjunctiva. The histological examination of ocular tissues from albino rats in Groups B and C showed significant damage, including the fragmentation of eye tissues, indicating severe cellular disruption. Hemorrhaging of blood vessels was observed, with blood leaking into surrounding tissues, suggesting trauma and potential vision impairment. The presence of edema indicated swelling due to fluid accumulation, which can increase eye pressure and damage delicate structures. Additionally, the retina showed irregular thickening, a sign of chronic inflammation or stress, potentially disrupting normal vision. These implies that activities of locally and imported welding machines may pose radiological damage to the eyes of welders and cause severe damage to the tissue of the eyes. By specifically targeting ocular health, the research addresses a critical but often overlooked aspect of occupational safety, with findings that highlight the need for improved protective measures for welders. Hence, workplace safety and the use of personal protective equipment such as welding helmet, goggles and face shields should be enforced to minimize UV radiation exposure

Keywords: UV radiation; ocular tissues; albino rats; welding activities; histology.

1. INTRODUCTION

Light is one of the most important elements for human survival since it allows us to see and understand our surroundings [1]. From low energy radio waves with wavelengths measured in meters to high energy gamma rays with wavelengths less than 1 x 10^{-11} meters, the electromagnetic spectrum as a whole is incredibly vast. As the name implies, electromagnetic radiation explains variations in the electric and magnetic fields that carry energy across a vacuum at the speed of light, or around 300,000 km/sec. Ultraviolet (UV) light is the term for electromagnetic waves with wavelengths between 10 nm and 400 nm [2,3].

Even though infrared and ultraviolet radiations (UVR) are invisible, they share many physical characteristics with visible. Moreover, these three distinct radiation kinds are referred to as "optical radiation" as they frequently happen together. According to Julie et al*.,* [4], this radiation is referred to as "hazardous optical radiation" when its intensity poses a risk of harm. Ultraviolet light falls between visible light and X-rays in the electromagnetic spectrum. The wavelength ranges from around 380 nm (0.000015 inches) to approximately 10 nm (0.0000004 inches), with frequencies ranging from $8×10^{14}$ Hz to $3×10^{15}$ Hz. Sunlight contains ultraviolet light, which is invisible to the naked eye [5].

In contrast to ionizing radiation, which has the potential to be far more hazardous than non-ionizing radiation, optical radiation is a type of non-ionizing radiation [6]. Since optical radiations do not penetrate deeply, the organs that should be concerned are the skin and the eyes [7]. UV light exposure produces a number of harmful health effects, the most common of which is photokeratitis. The fabrication technique of welding involves utilizing heat to fuse two or more pieces together. A metal bond is formed when two pieces that need to be linked melt together under pressure, heat, or both, with or without metal attached [8]. Numerous workers are at danger of ultraviolet radiation exposure from the high levels of UVR emitted by the arcs used in arc welding. These include workers who perform tasks like assembly, arc air gouging, can fabrication, crane operation, oxygen cutting, sheet metal work, slinging, and chipping, in addition to professional welders and workers who conduct welding operations on occasion [9].

The entire UVR spectrum, including UVA (400–315 nm), UVB (315–280 nm), and UVC (280–100 nm), is produced by arc welding. UVA is less likely to cause DNA damage than UVB or UVC, although it enters the skin more deeply [10]. Nonetheless, epidemiological evidence suggests UVA might play a significant role in the emergence of malignant melanoma [11]. According to Gallagher and Lee [12], UVB is to blame for erythema, the majority of DNA damage that occurs within skin cells, and the majority of skin malignancies that follow. Since solar UVC is easily absorbed in the atmosphere before it reaches the earth's surface, humans are rarely exposed to UVC. On the other hand, welders might also be subjected to UVC since there might not be enough space for the welder's skin to absorb the majority of the UVC [13].

UV radiation from the sun or artificial sources such arc welding activities can have harmful effects on human skin and eyes. The skin, as the body's outermost layer, serves as the first line of defense against various environmental factors, including microbes, particulates, irritants, allergens, and UV radiation radiation [14,15]. Due to this role, the skin is frequently exposed to UV rays. Such effects on the skin include sunburns, premature ageing, skin cancer and suppression of the immune system [16,17]. Research has also shown that certain doses of UV radiation can trigger photosensitivity reactions in some individuals, leading to symptoms such as itching, rashes, blisters, and pain. The eye area is particularly vulnerable, with an increased risk of developing cataracts and macular degeneration [18]. Additionally, UV exposure can cause dryness, pain, and inflammation of the eye's surface.

The aim of this study therefore, is to investigate the effects of ultraviolet (UV) radiation emitted during welding activities on the ocular tissues of albino rats. By focusing on the eye tissues, including the cornea, lens, and retina, this research seeks to understand the extent of damage and potential protective mechanisms.

The research innovation of this study lies in its focused investigation of ultraviolet (UV) radiation effects from welding machines on ocular tissues using albino rats. By comparing the impact of radiation from both an imported MMA 250 welding machine and a locally constructed machine, the study provides unique insights into potential differences between these sources. The controlled exposure methodology, with precise distance and duration settings, ensures consistent and replicable results. By specifically targeting ocular health, the research addresses a critical but often overlooked aspect of occupational safety, with findings that highlight the need for improved protective measures for welders. The use of albino rats as an animal model allows for detailed histological examination, offering valuable data applicable to human health risks in welding environments, ultimately contributing to the development of better safety guidelines and personal protective equipment (PPE) standards.

2. MATERIALS AND METHODS

2.1 Sources of Radiation

The study sources of ultraviolet radiation are from locally constructed welding machine and imported welding machine (MMA 250) located in various welding workshops in Ogbomoso, Oyo State, Nigeria. These machines emit ultraviolet radiation as a by-product of their operation.

The MMA 250 welding machine is a versatile manual metal arc (MMA) welder, also known as a stick welder, designed for various welding tasks in both professional and DIY settings. It operates with a maximum output of 250 amps, allowing it to weld thicker materials and accommodate electrode sizes ranging from 1.6mm to 5.0 mm. The machine can be powered by either single-phase or three-phase electricity, typically between 220V and 380V, and often features a duty cycle of 60% at 250 amps, meaning it can weld continuously for 6 out of every 10 minutes at full output without overheating. Its robust construction includes thermal overload protection and a cooling fan, ensuring durability and safety during operation. Additionally, features like adjustable arc force and hot start enhance the welding experience by providing a stable arc and preventing the electrode from sticking. Despite its power, the MMA 250 is designed to be lightweight and portable, making it ideal for on-site welding jobs across various applications, including construction, fabrication, and maintenance.

2.2 Experimental Rats

For this study, fifteen male albino rats were employed. The rats were obtained from a breeding stock kept in the animal house at the College of Medicine, Ladoke Akintola University of Technology, Ogbomoso, Oyo State. Prior to the start of the trials, they were housed in conventional laboratory circumstances with a 12-hour daylight cycle, access to food and water, and three weeks to get acclimatized to the environment. Using a weighing balance, the animals' weight was estimated at the time of procurement, during acclimatization, at the start of the experiment, and twice more during the course of the study. Ladoke Akintola University of Technology, Ogbomoso, Faculty of Basic Medical Science provided ethical approval for the animal sacrifice.

These rats were randomly divided into three groups of five rats each and they were housed separately in three cages under the same condition of atmosphere, same food and water. The albino rats were systematically exposed to ultraviolet (UV) radiation during the welding process using an MMA 250 welding machine to investigate its effects on ocular tissues. Group A served as the control group with no exposure, while Groups B and C were exposed to radiation from an imported MMA 250 welding machine and a locally constructed welding machine, respectively. The rats in Groups B and C were placed at a fixed distance of 25 cm from the radiation source, considered the ‘near point,’ and were exposed for four hours daily over seven consecutive days in a controlled welding workshop environment. After the exposure period, the rats were sacrificed, and their eyes were preserved in 10% formalin for histological examination to assess structural changes in the ocular tissues. This method ensured consistent and controlled exposure, allowing for a detailed comparison of the impact of UV radiation from different welding machines on the rats' ocular health.

2.3 Animal Sacrifice and Harvesting of the Organ

At the time of sacrifice, all rats were weighed and then sacrificed via cervical dislocation, and the eyes were carefully harvested. Each animal's eye was weighed using an electronic, sensitive analytical balance, and the eyes were then promptly fixed in 10% formosaline for histological examination of the ocular tissues such as; sclera, uvea, cornea, retina, lens, and conjunctiva.

2.4 Tissue Processing (Histological Slide Preparation)

2.4.1 Fixation

The tissues that had been treated in 10% formosaline were moved to an ethanol series that was graded. For one hour each, they were submerged in 70%, 90%, ABI, and ABII absolute alcohol. This was done in order to get rid of the water that was in the tissues. After one hour, two changes of molten paraffin wax were made, and the tissues were blocked out and embedded in the wax. Make that the mounted pieces to be cut with the rotary microtome are aligned perpendicular to the testes' long axes before embedding.

A solid block of tissue was cut into serial sections, each 5 µm thick. The sections were then floated out on a warm water bath and picked by a clean slide that had been coated with Mayer's egg albumin to suitably cement the sections to the slides. They were exposed to alcohol and xylene, and they were then stained with eosin and haematoxylin after being cleared in xylene. The slices were then dried at a temperature between 35 and 40 °C. For a histological assessment, the slides were examined under a research microscope that was linked up to a computer display.

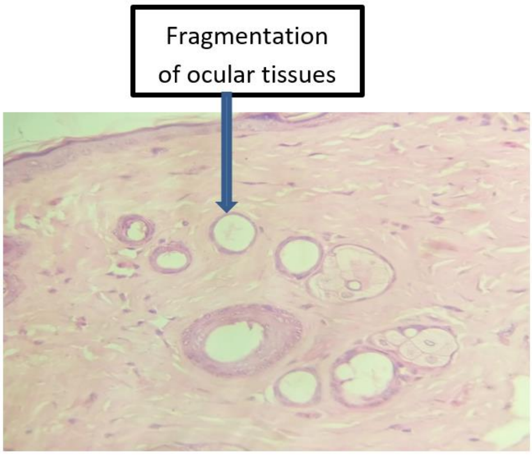
3. RESULTS AND DISCUSSION

3.1 Histology

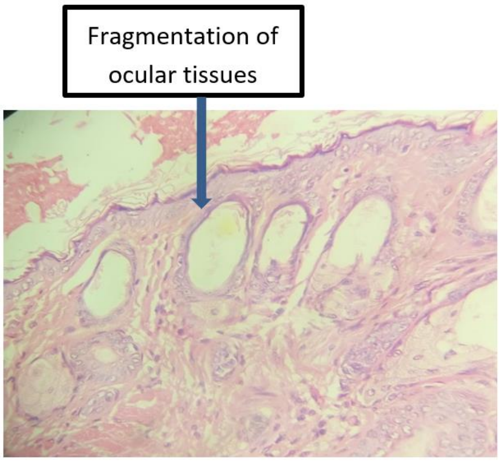
In the process of the exposure to ultraviolet radiation, it was observed that all the rats developed a pink pigment in their eyes, this pink pigment is called “photokeratitis” which was caused by light arc. Albino rats do not have this pigment in their eyes or fur; therefore, this pink pigment was caused by light bouncing off the blood vessels in their eyes. On the first day of exposure to ultraviolet radiation, some of the albino rats developed a pink pigment in their eyes and this pigment disappeared some hours later after the exposure to ultraviolet radiation. On the second day of exposure, this pink pigment reappeared few hours after been exposed to ultraviolet radiation and it also disappeared few hours later after the exposure. These changes were constant for the first 3 days of exposure. On the fourth day of the exposure, the pink pigment become permanent on some of the rats eyes and more reddening than before due to the consistent exposure to ultraviolet radiation. The histopathological changes increased along with irradiation intensity and exposure. The injury caused by UV irradiation to the cornea is called “photokeratitis” which is characterized by exfoliation of the cornea epithelium.

A normal histological feature in both cross and transverse sections characterised by the present of the sclera, cornea, uvea and retina layers were observed in histological feature of group A. Also seen are palpebral conjunctivas with overlying skin and adnexal structures, extra skeletal muscles, and adipocytes. The histological sections of Group B (rats exposed to radiation from MMA 250) and Group C (rats exposed to radiation from locally constructed welding machine) revealed the following:

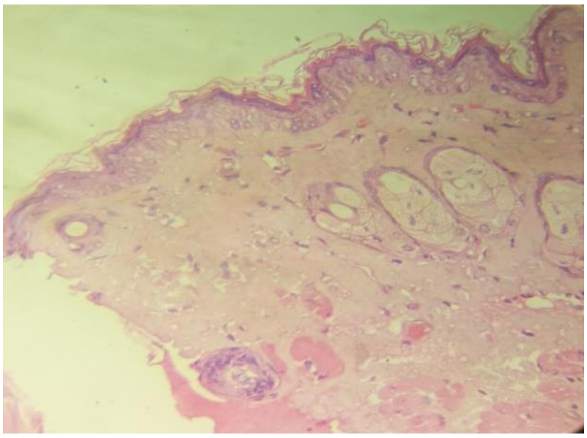
3.1.1 Fragementation of Ocular Tissue



a: Group C



b: Group B



c: Group A- Non-radiated

Plate 1. Fragmentation of ocular tissues

Plate 1 (Group B and C): Section shows ocular tissue in fragments with eosinophilic bodies. Also seen are palpebral conjunctivas with overlying skin and adnexal structures. Section (c) shows normal ocular tissues

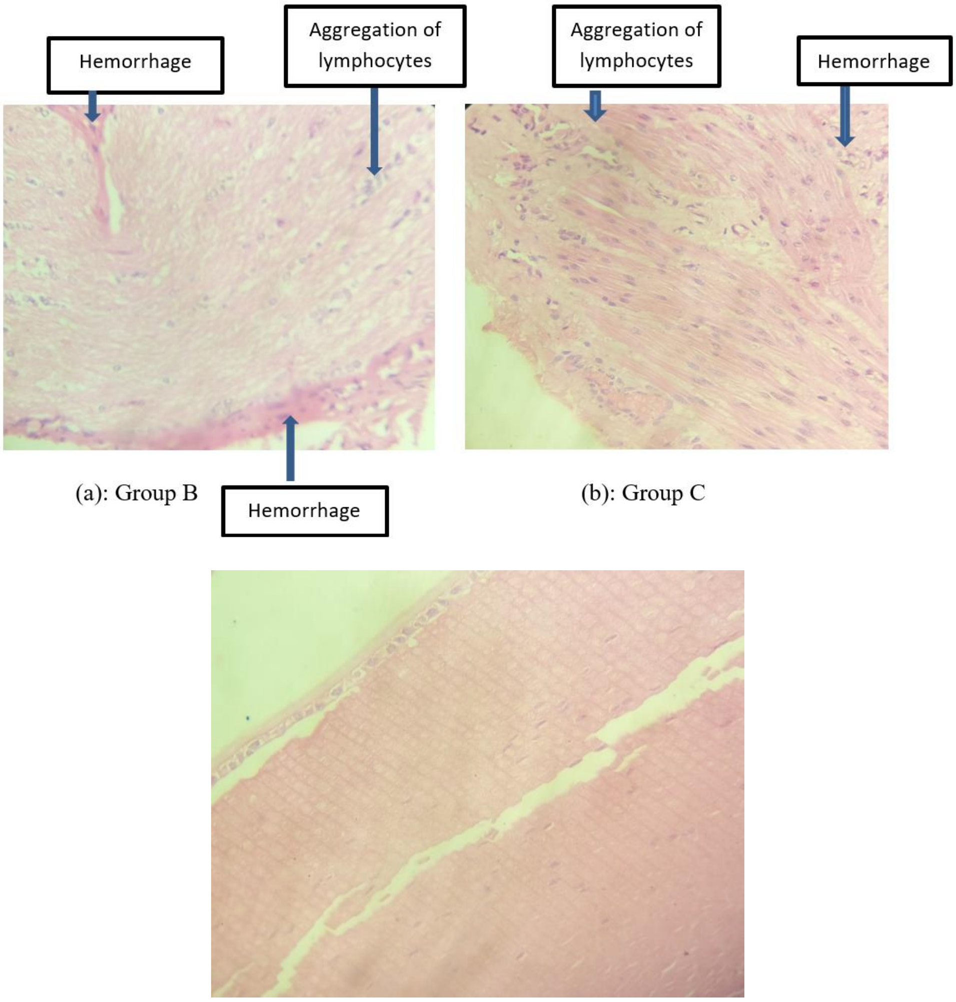
Fragmentation of cornea, uvea, sclera, and retina was revealed in the left eye longitudinal section of rats exposed to radiation from both source (group B and C) as shown in Plate 1. The cornea and lens of the eye are especially vulnerable to UV radiation. The outer tissues of the eye can be penetrated by UV radiation, particularly UVA and UVB rays. "Fragmentation of ocular tissue" refers to the disruption or degradation of the normal structural integrity of eye tissues, and chronic exposure can cause a variety of eye problems. The long-term detrimental effects of UV light may be the cause of this. Various eye troubles could result from the tissues weakening and breaking apart. When UVR with a wavelength of 300 nm or longer is partially transmitted through the cornea and absorbed in the lens, it results in ocular tissue with amorphous eosinophilic bodies. The original description's reference to eosinophilic bodies raises the possibility that some cellular alterations or anomalies resulted from UV exposure. Eosinophilic bodies may be a sign of certain cellular responses or eye injury. This area appears to encompass not only intraocular tissues but also the surrounding components of the eye due to the palpebral conjunctiva, skin covering, and adnexal structures. Prolonged exposure to UV radiation can harm and cause inflammation in the skin and conjunctiva surrounding the eyes, among other problems.

3.1.2 Aggregates of Lymphocytes and Haemorrhage

Aggregates of lymphocytes and areas of haemorrhage seen in Sclera, uvea and retina layers of the left eye longitudinal section of the exposed rats was as a result of chronic exposure to UV radiation. This may result in cellular damage to the eye, which will set off an immunological response. The immune response frequently entails lymphocyte infiltration into the afflicted tissues. The lymphocyte aggregates demonstrate the body's attempt to counteract UV-induced damage. Additionally, direct UV radiation damage to blood vessels within the eye can result in microhemorrhages seen in Plate 2 (sclera, uvea, and retina), and among other layers of the eye. This is known as ocular blood vessel hemorrhage. The weakening of blood vessel walls as a result of UV-induced inflammation and damage may be the cause of these hemorrhages. According to Magovern et al*.,* [19], bleeding around the blood vessel was generated by an increase in UVB radiation intensity from 0.045−0.36 J/cm2 and an increased exposure length from 47 seconds to five minutes in their histological findings in the cornea of experimental rats exposed to UVB radiation.

3.1.3 Edematous of the Conjunctiva, Degeneration and loss of Epithelial Cells

The exposed rats eye revealed that the Palpebral Conjunctiva was edematous and with scanty lymphocytic infiltration as seen in Plate 3. The term "edematous" describes a swelling or puffiness of the palpebral conjunctiva, the inner lining of the eyelids. Strong UV exposure could be the cause of this edema. Likewise, the palpebral conjunctiva of group C's right eye showed a dense infiltration of lymphocytes;



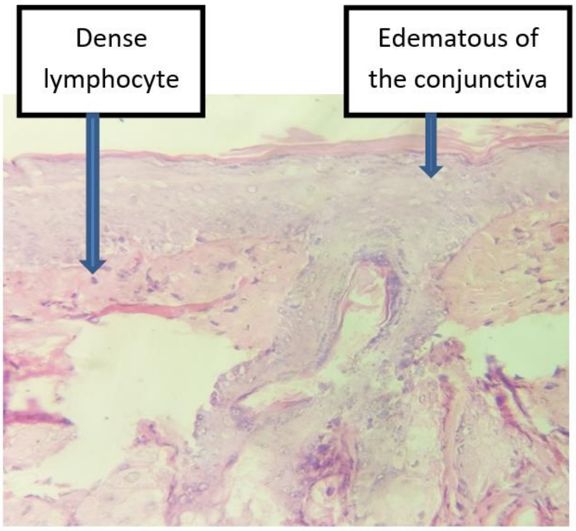
(a): Group B

(b): Group C

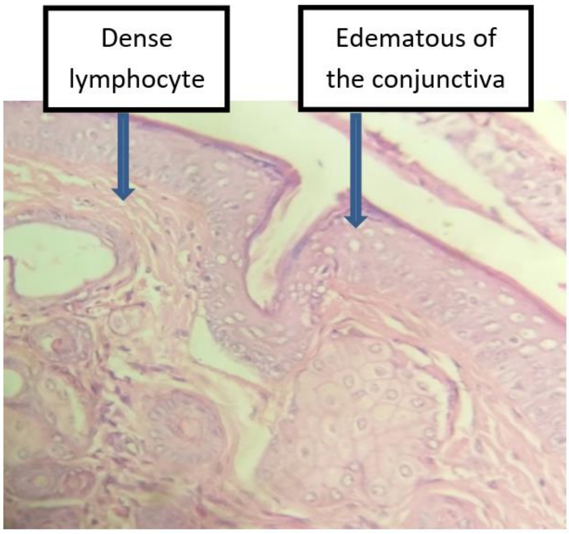
(c): Group A- Non-radiated

Plate 2. Aggregates of Lymphocytes and Haemorrhage

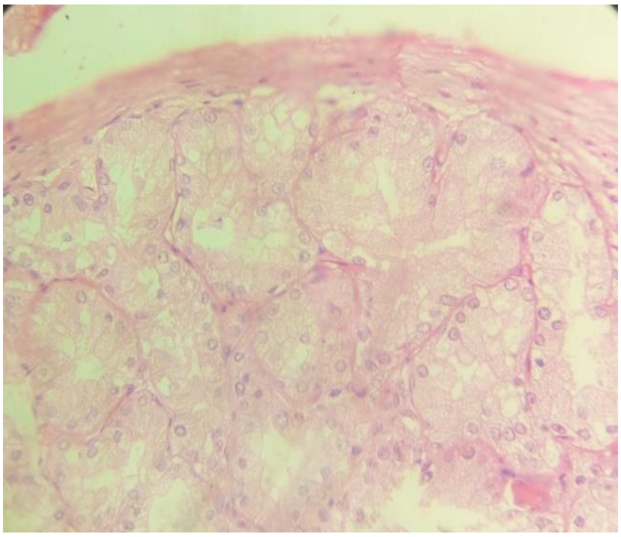
Plate 2: Left eye (Group B and C): Section shows ocular tissues containing aggregates of lymphocytes. Areas of hemorrhage are also seen in Sclera, uvea and retina layers. Section (c) shows normal tissues



(a): Group B



(b): Group C



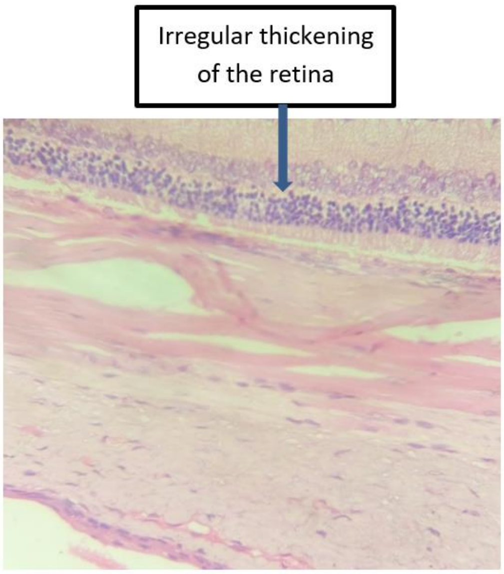
(c): Group A**-** Non-radiated

Plate 3. Edematous of the conjunctiva, degeneration and loss of epithelial cells

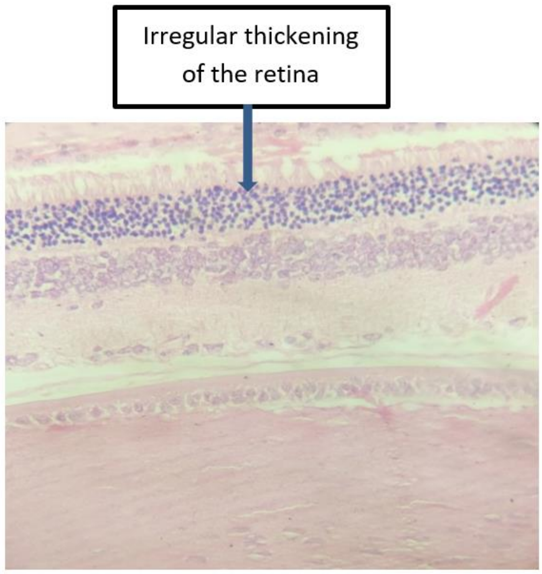
Plate 3: Right eyes (Group B and C): section shows areas of dense lymphocytic infiltration within palpebral conjunctiva. Also, the palpebral conjunctiva is edematous with scanty lymphocytic infiltration. Section (c) shows normal tissues

this condition can be linked to ultraviolet B radiation and induce immunological reactions and inflammation in ocular tissues, including the conjunctiva. Degeneration and loss of epithelial cells as revealed in group C right eye might be due to oxidative stress caused by UVB [20]. The loss of dead cells resulting from cellular degeneration and the sluggish rate of cellular growth and regeneration could be the cause of epithelial thinning. As keratocytes are responsible for maintaining and synthesizing stromal collagen, prolonged exposure to UV radiation may prevent the replacement of keratocytes. Consequently, the loss of keratocytes would lead to a decrease in collagen production, which would ultimately cause the loss of stromal collagen and consequent corneal thinning [21]. Bergmanson and Sheldon, [22] discovered that in an unprotected rabbit eye exposed to light from a UV radiation lamp; there was full thickness epithelial loss, as well as loss of keratocytes and endothelial cells. Over time, damage can occur to the retinal cells, namely to the photoreceptor cells that are in charge of absorbing light and sending visual signals to the brain. Vision issues may be the outcome of this damage.

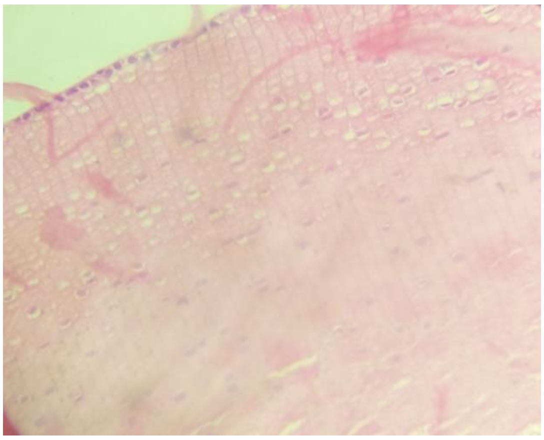
3.1.4 Irregular Thickening of the Retina



(a): Group B



(b): Group C



(c) Group A- Non-radiated

Plate 4. Irregular thickening of the retinal

Plate 4: Right eye (Group B and C): section shows irregular thickening of the retina. Section (c) shows normal retina tissue

Irregular thickening of the retinal in group B and C was caused by prolonged exposures of intense UV light to the retinal. According to Wang et al*.,* [23], mice that were exposed seemed to develop retinal samples with somewhat greater levels of damage from oxidative stress on DNA and lipids. According to Niguse et al*.,* [20], there is a correlation between UVB radiation and elevated oxidative damage to DNA and lipids in the retinal tissues of mice.

4. CONCLUSION

This study provides clear evidence of the detrimental effects of ultraviolet radiation (UVR) emitted from both local and imported welding machines on ocular tissues. The histological analysis of ocular tissues from albino rats in Groups B and C revealed severe damage, including tissue fragmentation, which points to significant cellular disruption. Blood vessels within the eye were ruptured, leading to hemorrhaging and potential impairment of vision. Swelling, or edema, was also present, indicating fluid buildup that could increase pressure and harm the eye's delicate structures. Furthermore, the retina displayed abnormal thickening, suggesting chronic inflammation or stress that could interfere with normal visual processing. The findings demonstrated that exposure to

UVR, whether from imported or locally constructed welding machines, can lead to significant histological damage in the eyes, as evidenced by the fragmentation of ocular tissues, hemorrhaging of blood vessels, edema, and irregular thickening of the retina in albino rats. These results suggest that welders, who are routinely exposed to such radiation, may be at risk of serious eye injuries and long-term ocular damage if adequate protective measures are not implemented. The study highlights the critical need for strict enforcement of workplace safety protocols, including the mandatory use of personal protective equipment such as welding helmets, goggles, and face shields. By reducing exposure to harmful UV radiation, these measures can significantly lower the risk of ocular injuries among welders, ensuring better occupational health and safety.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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