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A Histological Study of Pathological Changes in the Rat Thyroid Gland Induced by Chronic Ultraviolet-A (UVA) Radiation Exposure According to Exposure Duration

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دراسة نسيجية للتغيرات المرضية في الغدة الدرقية للجرذان الناتجة عن التعرض المزمن للأشعة فوق البنفسجية من نوع(A– UVA) تبعًا لمدة التعرض

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Abstract

The thyroid gland is one of the most important endocrine glands responsible for regulating metabolism, growth, and physiological homeostasis in the body. With the increasing exposure to ultraviolet-A (UVA) radiation, growing attention has been directed toward investigating its potential effects on biological tissues.

Aim of the Study: This study aimed to evaluate the histological effects induced by ultraviolet-A (UVA) radiation exposure on the follicular structure of the thyroid gland in adult albino rats and to investigate the relationship between these effects and the duration of exposure.

Materials and Methods: Twenty adult male albino rats were equally divided into four groups: Group I**:** Control group. Group II**:** Exposed to ultraviolet radiation for 10 consecutive days at a rate of 8 hours daily. Group III**:** Exposed to ultraviolet radiation for 15 consecutive days at a rate of 8 hours daily. Group IV: Exposed to ultraviolet radiation for 25 consecutive days at a rate of 8 hours daily. At the end of the experiment, the thyroid glands were excised, and tissue specimens were prepared for histological examination using hematoxylin and eosin staining.

Results: The histological examination of the thyroid glands revealed progressive structural alterations in the exposed groups compared to the control group. These changes included disruption of follicular architecture, variation in follicular size, vascular congestion, reduction of colloid content, epithelial cell crowding, and morphological alterations in epithelial cell shape. The severity of these changes increased progressively with longer exposure duration, being most pronounced in the 25-day exposure group.

Conclusion: The findings indicate that chronic exposure to ultraviolet-A (UVA) radiation induces cumulative harmful histological effects on the thyroid gland, with severity increasing in proportion to exposure duration, which may adversely affect its functional efficiency.

Keywords: Ultraviolet-A radiation, Thyroid histopathology, Oxidative stress, Endocrine disruption, Albino rat model, Photo biological toxicity

الملخص

تُعد الغدة الدرقية من أهم الغدد الصماء المسؤولة عن تنظيم عمليات الأيض والنمو والمحافظة على الاتزان الفسيولوجي في الجسم. ومع التزايد المستمر في التعرض للأشعة فوق البنفسجية من نوع A (UVA)، ازداد الاهتمام بدراسة تأثيراتها المحتملة على الأنسجة الحيوية. هدفت هذه الدراسة إلى تقييم التأثيرات النسيجية الناتجة عن التعرض للأشعة فوق البنفسجية من نوع A (UVA) على التركيب الجريبي للغدة الدرقية في الجرذان البيضاء البالغة، ودراسة العلاقة بين هذه التأثيرات ومدة التعرض للإشعاع. تم تقسيم عشرين جرذًا أبيض بالغًا من الذكور بالتساوي إلى أربع مجموعات: المجموعة الأولى: مجموعة السيطرة. المجموعة الثانية: تعرضت للأشعة فوق البنفسجية لمدة 10 أيام متتالية بمعدل 8 ساعات يوميًا. المجموعة الثالثة: تعرضت للأشعة فوق البنفسجية لمدة 15 يومًا متتاليًا بمعدل 8 ساعات يوميًا. المجموعة الرابعة: تعرضت للأشعة فوق البنفسجية لمدة 25 يومًا متتاليًا بمعدل 8 ساعات يوميًا. وفي نهاية التجربة، استُؤصلت الغدد الدرقية، وتم تحضير المقاطع النسيجية للفحص المجهري باستخدام صبغة الهيماتوكسيلين والإيوزين. أظهر الفحص النسيجي للغدد الدرقية تغيرات تركيبية تدريجية في المجموعات المعرضة مقارنة بمجموعة السيطرة. وشملت هذه التغيرات اضطراب البنية الجريبية، وتفاوت أحجام الجريبات، واحتقان الأوعية الدموية، وانخفاض محتوى الغروان، وتزاحم الخلايا الطلائية، بالإضافة إلى تغيرات شكلية في الخلايا الطلائية. وقد ازدادت شدة هذه التغيرات تدريجيًا مع زيادة مدة التعرض، وكانت أكثر وضوحًا في مجموعة التعرض لمدة 25 يومًا. تشير النتائج إلى أن التعرض المزمن للأشعة فوق البنفسجية من نوع A (UVA) يسبب تأثيرات نسيجية ضارة تراكمية على الغدة الدرقية، تزداد شدتها بزيادة مدة التعرض، مما قد يؤثر سلبًا في كفاءتها الوظيفية.

الكلمات المفتاحية: الأشعة فوق البنفسجية من نوع A، التغيرات النسيجية للغدة الدرقية، الإجهاد التأكسدي، اضطرابات الغدد الصماء، نموذج الجرذ الأبيض، السمية الضوئية الحيوية.

1. Introduction

Recent decades have witnessed a significant increase in human exposure to electromagnetic radiation as a result of technological advancement and the expanding medical, industrial, and environmental applications of radiation sources (Ravindran et al., 2010). Among these radiations, ultraviolet radiation (UVR) has attracted increasing scientific interest because of its various biological effects on living cells and tissues (Melnikova & Ananthaswamy, 2005). Ultraviolet radiation is classified into three main types: UVA, UVB, and UVC, which differ in their wavelengths, penetration capacity, and biological effects (Osipov et al., 2022).

UVA radiation is considered the most abundant type reaching the Earth's surface, with wavelengths ranging from 320 to 400 nm (McKenzie et al., 2003). It also possesses a relatively greater ability to penetrate the skin and tissues compared to the other types (Osipov et al., 2022). Exposure to this type of radiation has increased due to natural sources such as sunlight, in addition to certain industrial, medical, and cosmetic sources (Ravindran et al., 2010). Recent studies have demonstrated that chronic or repeated exposure to UVA radiation may lead to the generation of free radicals and oxidative stress within cells, resulting in cellular and functional alterations including DNA damage, disruption of metabolic processes, inflammatory changes, and accelerated cellular aging (Tyrrell, 2011).

The thyroid gland is regarded as one of the organs highly sensitive to environmental and radiation-related factors because of its high metabolic activity and its essential role in regulating metabolism and growth through the secretion of triiodothyronine (T3) and thyroxine (T4) (Larsen et al., 1998). The gland's function mainly depends on the integrity of its follicular structure; therefore, any histological alteration in the follicles may represent an important indicator of functional or cellular dysfunction (Martín-Lacave et al., 2009).

Although numerous studies have investigated the effects of ultraviolet radiation on different body tissues, studies concerning the histological effects of UVA radiation on the thyroid gland remain limited (Turker, 2004). Therefore, the present study aimed to evaluate the histological effects of UVA radiation on the follicular structure of the thyroid gland in rats, as well as to investigate the morphological changes resulting from exposure to this type of radiation. Despite increasing evidence regarding cutaneous UVA toxicity, little is known about its direct

histopathological impact on endocrine tissues, particularly the thyroid gland. This study addresses this knowledge gap.

2. Materials and Methods

2.1 Experimental Animals and Study Design

This experimental study was conducted to investigate the histological effects of ultraviolet A (UVA) radiation on the thyroid gland structure in adult male albino rats. A total of 20 healthy adult male Wistar albino rats, weighing between 200–250 g, were used in the present study. The Wistar rat is considered one of the most commonly used laboratory animals in biological and medical research due to its physiological stability and suitability for experimental studies. The animals were housed individually in well-ventilated plastic cages under standard laboratory conditions at a controlled temperature of (20 ± 2^0 C), with a regular 12-hour light/12-hour dark cycle. Standard laboratory diet and water were provided ad libitum throughout the experimental period. Prior to the experiment, all animals were acclimatized for one week to minimize environmental stress and ensure physiological stability. Before irradiation, the dorsal hair of the animals was carefully shaved to ensure uniform exposure to ultraviolet radiation. The rats were randomly divided into four equal groups (5 rats each). Group I served as the control group and was not exposed to UVA radiation, while Groups II, III, and IV were exposed to UVA radiation for 8 hours daily for periods of 10, 15, and 25 consecutive days, respectively. At the end of each experimental period, the animals were anesthetized by ether inhalation, and thyroid gland specimens were collected for histological examination.

2.2 Ultraviolet A (UVA) Exposure System

Ultraviolet A (UVA) radiation was generated using a fluorescent UVA lamp (Sylvania, 40 W) emitting radiation at a peak wavelength of approximately 368 nm. The irradiation procedure was carried out inside a specially designed exposure chamber with adequate ventilation to minimize heat accumulation and maintain stable environmental conditions throughout the experimental period. The lamp was positioned at a fixed vertical distance of 30 cm above the animal cages to ensure uniform irradiation. The irradiance at the animal surface was measured using a calibrated ultraviolet radiometer and maintained at approximately 3.5 mW/cm², resulting in an estimated cumulative daily radiation dose of 100.8 J/cm² during the 8-hour exposure period. The exposure duration was controlled using an electronic timer to ensure precise daily irradiation. All exposure parameters, including wavelength, irradiance intensity, exposure duration, chamber temperature, and lamp-to-subject distance, were kept constant throughout the experimental study to ensure reproducibility and consistency of UVA exposure conditions among all experimental groups.

2.3 Experimental Grouping

The animals were randomly divided into four experimental groups as follows:

- **Group I (Control Group):** Rats were maintained under normal laboratory conditions without exposure to ultraviolet radiation.
- **Group II (10-Day Exposure Group):** Rats were exposed to UVA radiation for 10 consecutive days at a rate of 8 hours daily.
- **Group III (15-Day Exposure Group):** Rats were exposed to UVA radiation for 15 consecutive days at a rate of 8 hours daily.
- **Group IV (25-Day Exposure Group):** Rats were exposed to UVA radiation for 25 consecutive days at a rate of 8 hours daily.

2.4 Sample Collection and Tissue Preparation

At the end of each exposure period, the animals were properly anesthetized, and the thyroid glands were carefully excised and rinsed with physiological saline solution. The tissue specimens were immediately fixed in 10% neutral buffered formalin for histological processing. Following fixation, the specimens were processed using the conventional paraffin-embedding technique. The tissues were dehydrated in ascending grades of alcohol, cleared in

xylene, and embedded in paraffin wax. Paraffin sections of approximately 5 µm thickness were prepared using a rotary microtome and mounted on clean glass slides. The sections were then stained with hematoxylin and eosin (H&E) for routine histological examination.

2.5 Histological Examination by Light Microscopy

Histological examination was carried out using a light microscope (Olympus BX41, Olympus America Inc.) equipped with a digital camera system for photomicrograph documentation. The stained sections were examined under different magnifications to evaluate structural changes in the thyroid gland tissue. The histological analysis focused on the general architecture of the thyroid follicles, including follicular size and shape, epithelial cell morphology, and colloid content within the follicular lumen. Special attention was given to the integrity of the follicular lining epithelium, vascular congestion, stromal alterations, and any degenerative histopathological changes associated with UVA exposure. Representative photomicrographs were captured for comparison among the experimental groups.

2.6 Histological Evaluation

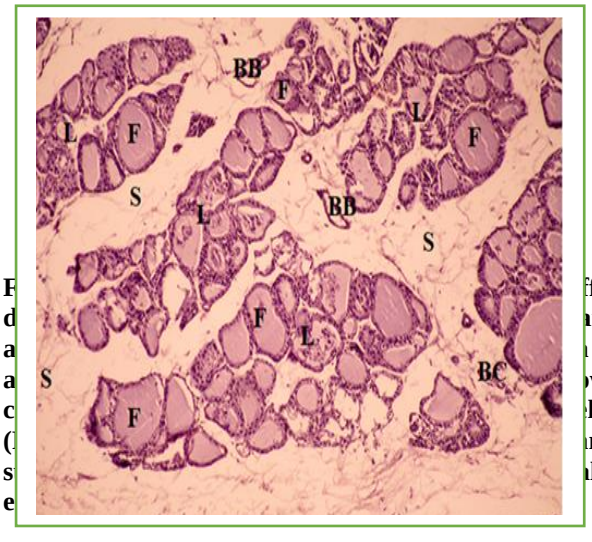
Histological evaluation was performed qualitatively through light microscopic examination of H&E-stained thyroid gland sections. The examined parameters included follicular organization, epithelial cell appearance, colloid distribution, stromal integrity, and vascular changes. Comparisons were made among all experimental groups to assess the progression and severity of histological alterations associated with different durations of UVA radiation exposure. The observed histological changes included variations in follicular size and arrangement, epithelial cell alterations, reduction in colloid content, vascular congestion, stromal edema, and degenerative changes within thyroid tissue. These findings were documented and compared descriptively among the experimental groups.

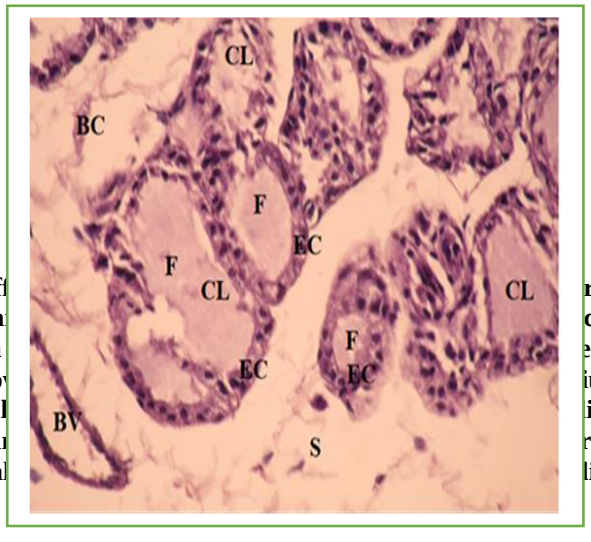
3. Results

The histological changes in the thyroid gland were investigated using light microscopy through examination of paraffin sections stained with hematoxylin and eosin (H&E). The findings demonstrated clear structural differences between the control group and the groups exposed to ultraviolet A (UVA) radiation according to the duration of exposure.

3.1. Normal Thyroid Gland

The examined paraffin sections of the thyroid gland in the control rat demonstrated that the gland was divided into irregular lobular units. Each lobule contained clusters of follicles surrounded by a thin connective tissue rich in fenestrated blood capillaries. The follicular epithelium appeared as a simple epithelium composed of low columnar or cuboidal cells depending on the level of follicular activity. Each follicle contained colloid material of variable amount according to the activity level, appearing as a pale purple substance (Fig1).





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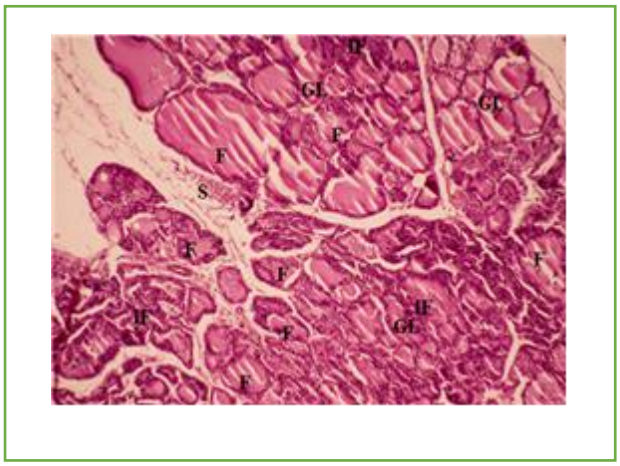
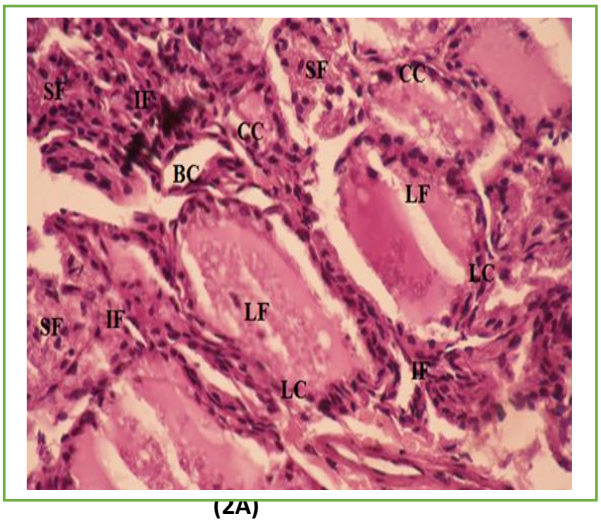
3.2. The 10-Day Exposure Group (8 Hours/Day)

The paraffin sections demonstrated destructive changes in the thyroid gland lobules, accompanied by a reduction in the stromal layer and a decrease in follicular size. An increase in both the number and size of follicles was observed in the peripheral region compared to the central region, along with marked crowding of epithelial cells within the follicles. Severe dilatation and hemorrhage of blood vessels were also observed. Small follicles in the central region lined by cuboidal epithelium were noted, whereas the larger follicles in the peripheral region were lined by cuboidal or low cuboidal epithelium. In addition, proliferation of parafollicular cells within the interfollicular spaces was observed, together with marked dilatation of blood capillaries (Figure 2).



2B))

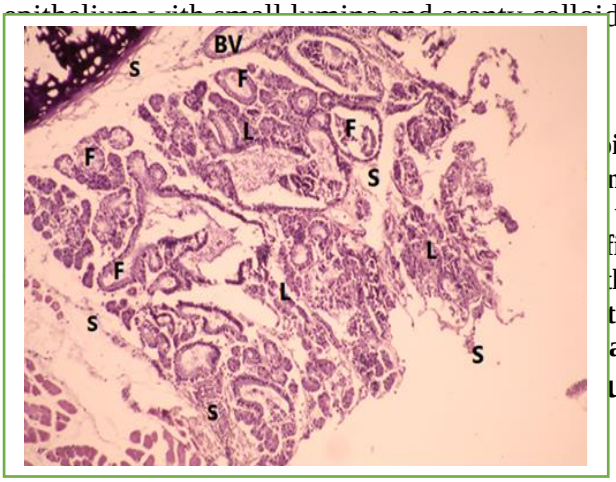


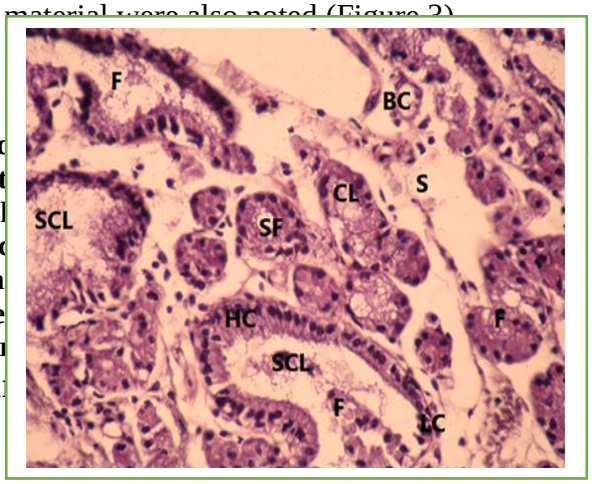
(2A)

Figure (2A) shows a paraffin section of the thyroid gland in a rat exposed to ultraviolet radiation for 10 days, demonstrating destruction of the lobules (GL), reduction of the stromal layer (S), and decreased follicular size (F). An increase in the number and size of follicles in the peripheral region compared with the central region is also evident, together with crowding of epithelial cells within the follicles (IF) and marked vascular dilatation and hemorrhage (BV). (2B) represents a higher magnification of the previous figure, showing small follicles (SF) in the central region lined by cuboidal epithelium, and large follicles (LF) in the peripheral region lined by cuboidal cells (CC) or low cuboidal cells (LC). Proliferation of parafollicular cells within the interfollicular spaces (IF) and severe dilatation of blood capillaries (BC) were also observed.

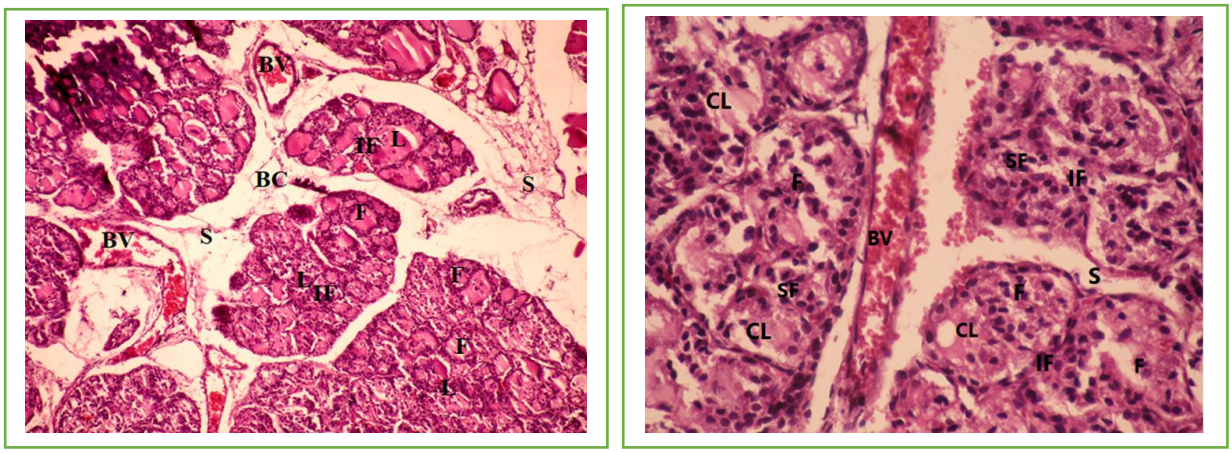
3.3. The 15-Day Exposure Group (8 Hours/Day)

The paraffin sections showed that the gland was divided into irregular lobular units, with each lobule containing clusters of follicles. The follicles were surrounded by irregular epithelial cells within a thin connective tissue stroma rich in fenestrated blood capillaries. Irregularly enlarged follicles with a heterogeneous appearance were also observed, where the follicular epithelium ranged from high columnar cells to low cuboidal cells, accompanied by a marked reduction in the colloid material within the follicles. Areas containing small follicles lined by crowded epithelium with small lumina and scanty colloid material were also noted (Figure 3).





The paraffin sections following 25 days of exposure demonstrated marked destructive changes in the thyroid gland lobules, accompanied by edema and an increase in the stromal layer, together with marked vascular dilatation and hemorrhage. An increase in both the size and number of follicles was also observed, with predominance in the peripheral region compared to the central region, along with crowding of epithelial cells within the follicles. The sections further revealed division of the gland into irregular lobular units surrounded by thin connective tissue rich in blood capillaries. Irregularly enlarged follicles with a heterogeneous appearance were also noted, with the follicular epithelium changing from high columnar to low cuboidal cells, accompanied by a marked reduction in colloid material (Figure 4).



4B 4A

Figure (4A) shows a paraffin section of the thyroid gland in a rat exposed to ultraviolet radiation for 25 days, demonstrating destruction of the lobules (L), edema, and an increase in the stromal layer (S), together with marked dilatation and hemorrhage of blood vessels (BV). An increase in both the size and number of follicles (F) is also observed, along with crowding of epithelial cells within the follicles (IF). (4B) represents a higher magnification, showing a central region containing small follicles (SF) lined by cuboidal epithelium, while other follicles contain proliferative and crowded cells within the lumen associated with scanty colloid material and small lumina (CL). Severe dilatation and hemorrhage of blood vessels (BV) and capillaries (BC) were also observed, together with proliferation of parafollicular cells (IF).

4. Discussion

The thyroid gland is considered highly sensitive to environmental stressors, particularly those associated with oxidative stress and radiation exposure. The present study demonstrated that chronic exposure to ultraviolet A (UV-A) radiation induces progressive histological alterations in the thyroid gland in a duration-dependent manner. Normal thyroid tissue in the control group showed a well-organized follicular structure lined by cuboidal to low columnar epithelial cells and filled with colloid material, reflecting normal functional activity. Following 10 days of UV-A exposure, early histological alterations became evident, including reduction in follicular size, epithelial cell crowding, vascular dilatation, and focal hemorrhage. These findings may represent an early adaptive response to radiation-induced oxidative stress. Similar structural disturbances following ultraviolet exposure were reported by ***Turker (2004***), who demonstrated thyroid follicular irregularities and vascular changes associated with radiation exposure. After 15 days of exposure, the thyroid gland exhibited more pronounced architectural disorganization with marked variation in follicular size and shape accompanied by reduction in colloid content. These findings suggest progressive impairment of thyroid secretory activity and degeneration of follicular cells. The observed alterations may be related to oxidative stress-mediated cellular injury induced by UV-A radiation. ***Osipov et al. (2022)*** reported that prolonged UVA exposure promotes reactive oxygen species (ROS) generation, leading to progressive cellular and tissue damage. The most severe histological changes were observed after 25 days of exposure, including marked edema, stromal expansion, severe vascular congestion, hemorrhage, and

extensive disruption of follicular architecture. The marked depletion of colloid material and severe follicular irregularity may indicate advanced impairment of thyroid gland function. These progressive degenerative alterations are consistent with the findings of ***Alusta et al. (2026),*** who reported significant cellular and tissue damage following chronic ultraviolet radiation exposure, including vascular changes, cellular degeneration, and disruption of normal tissue architecture that increased with prolonged exposure duration. The progressive structural alterations observed in the present study may be explained by the ability of UV-A radiation to generate reactive oxygen species, leading to lipid peroxidation, protein damage, DNA injury, and vascular dysfunction. ***Tyrrell (2011)*** similarly reported that oxidative stress generated by UVA radiation can alter cellular integrity and gene expression, resulting in progressive tissue injury and cellular degeneration. Overall, the findings of the present study indicate that chronic UV-A radiation exposure induces progressive structural damage in thyroid tissue in a time-dependent manner, possibly mediated through oxidative stress pathways and vascular injury mechanisms.

Future studies are recommended to further investigate the molecular pathways involved in UVA-induced thyroid injury, particularly those related to oxidative stress, apoptosis, and inflammatory responses. In addition, evaluating the potential protective role of antioxidants against ultraviolet-induced thyroid damage may provide valuable therapeutic insights. Further research should also include hormonal and biochemical analyses to determine the possible association between histological alterations and endocrine dysfunction of the thyroid gland.

5. Study Limitations

The present study has several limitations that should be acknowledged. The histological evaluation was mainly qualitative and based on light microscopic observations without quantitative morphometric analysis or histopathological scoring. In addition, thyroid hormonal assays such as T3, T4, and TSH were not performed to correlate the structural alterations with functional changes. Furthermore, oxidative stress biomarkers were not assessed to confirm the proposed mechanisms underlying UVA-induced thyroid injury. Therefore, further studies incorporating biochemical, hormonal, and molecular analyses are recommended to provide a more comprehensive understanding of the effects of chronic UVA radiation on thyroid tissue.

6. Conclusion

The present study concluded that exposure to ultraviolet A (UV-A) radiation induces progressive histological effects in the thyroid gland of rats. These effects begin with mild disturbances in follicular and vascular organization and gradually progress, with increasing duration of exposure, into marked structural alterations including loss of lobular organization, variation in follicular size and shape, reduction of colloid material, and the appearance of vascular dilatation and hemorrhage. These findings reflect a progressive deterioration in the functional architecture of the gland. The results highlight the importance of minimizing unnecessary exposure to ultraviolet A radiation, particularly in environments involving similar radiation sources. Furthermore, future studies are recommended to further investigate the molecular mechanisms associated with these alterations, especially the role of oxidative stress, as well as to explore the potential use of antioxidants as protective agents to reduce these harmful effects.

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