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VETERINARIA

Light therapy in veterinary dermatology

This review examines the application of light therapy, including photobiomodulation, fluorescent biomodulation, and photodynamic therapy, in veterinary dermatology. It explores the mechanisms of action, key treatment parameters, and clinical applications, focusing on how light absorption influences tissue healing and other biological processes. Dermatological indications supported by existing studies and case reports such as wound healing, bacterial skin infections, and other conditions are highlighted. Finally, this review outlines future research directions, emphasizing the need for large-scale, randomized controlled trials and standardized treatment protocols to establish the long-term efficacy of light therapy in veterinary medicine.

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INTRODUCTION

Electromagnetic radiation (EMR) spans a broad spectrum, including gamma rays, X-rays, ultraviolet radiation (UVR), visible light (VL), infrared (IR), microwaves, and radio waves. Among these, UVR, VL, and IR fall under the category of optical radiation, ranging from 10 nm to 1 mm, commonly referred to as «light»[1]. Light is characterized by its wavelength, energy, frequency, and amplitude, with the VL spectrum (400-700 nm) representing the portion of EMR detectable by the human eye[1].

A key property of light is its ability to interact with biological tissues. When light is absorbed by chromophores within tissues, it triggers biochemical changes that modulate biological processes, leading to observable clinical effects. This phenomenon is naturally observed in processes such as photosynthesis and the conversion of sunlight into vitamin D[2]. In medicine, this principle is applied through photobiomodulation (PBM), a photochemical process in which light from a laser or other sources interacts with cells, inducing beneficial biological responses[2].

The therapeutic use of light has ancient origins, having been practiced in civilizations such as Rome, Greece, China, and India[3]. However, the modern concept of photobiomodulation therapy (PBMT) originated with the pioneering work of Dr. Endre Mester in 1967. While initially assessing the oncological safety of low-level laser irradiation in the red and near-infrared spectrum using a murine model, his team found no evidence of skin dysplasia. Instead, they unexpectedly observed increased hair growth and accelerated wound healing. These findings led to further research on the biological effects of low-power lasers, and by 1974, the "biostimulation effect" was introduced into clinical practice[4,5].

Before delving into the specifics of light therapy in veterinary dermatology, it is important to clarify the terminology. Over time, this therapy has been referred to by various names, including «cold laser,» «low-level laser therapy» (LLLT), «low-level light therapy,» «laser ther-

PBMT is a non-invasive therapy using light to stimulate biological responses, gaining traction in veterinary dermatology for managing various skin disorders beyond wound healing.

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Table 1 - Key Terms and Parameters in Photobiomodulation Therapy. This table defines the most common terms and parameters used in PBMT[10,15].

Term	Abbreviation (SI)	Definition
Chromophore		A molecule that absorbs photons at certain wavelengths (photo acceptor). For example, melanin, hemoglobin, porphyrins, cytochrome C oxidase.
Wavelength	Measured in nanometers (nm)	The distance between two successive points in a wave that is characterized by the same phase of oscillation. Different wavelengths of visible light are perceived by the eye as different colors. The wavelength of a laser determines its absorption properties and depth of penetration.
Joule	J	Unit of energy or work. The total number of joules delivered per session is equal to the total energy emitted per session.
Dose/Fluence	J/cm^2	A measure of the amount of energy delivered to the surface of the target tissue.
Power	W	The rate at which energy is emitted. An expression of energy over time vs the total amount delivered. Expressed in watts (1 W 1 J/s).
Irradiance/power density	W/cm^2	Density of radiation/power on a given surface.
Continues wave	CW	Emission of radiant energy in a constant intensity at a specific power.
Frequency	Measured in hertz (Hz)	The number of light waves passing a fixed point in a specific time interval (the number of cycles per second).
Spot size		The radius of the laser beam. The width of the laser beam at the surface of the tissue being treated.

apy,» «photobiostimulation,» and «photobiomodulation». To standardize nomenclature, a consensus meeting recommended adopting the term «photobiomodulation» or «photobiomodulation therapy» to describe treatments that employ non-ionizing light sources such as lasers, LEDs, and broadband light in the visible and infrared spectrum[3,6].

For clarity and consistency, the terms Photobiomodulation (PBM) and Photobiomodulation Therapy (PBMT) will be used interchangeably throughout this text.

In veterinary dermatology, light therapy has gained increasing attention as a non-invasive therapeutic tool for managing various skin conditions, including wound healing, bacterial infections, and inflammatory disorders[3,7,8]. This review will explore its mechanisms of action, clinical applications, and future directions in veterinary dermatology.

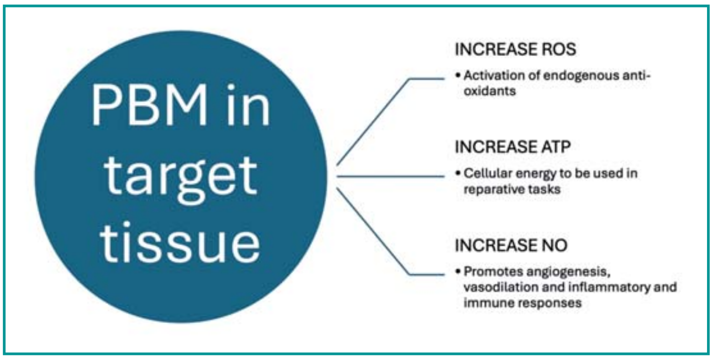

Figure 1 - Main factors underlying the beneficial effects of PBM. ROS: Reactive Oxygen Species; ATP: Adenosine Triphosphate; NO: Nitric Oxide.

Mechanism of Action

Photobiomodulation therapy promotes cellular repair through multiple mechanisms, primarily involving cytochrome C oxidase in the mitochondrial respiratory chain. This enzyme functions as a photoreceptor, absorbing light in the 500-1100 nm range, leading to the dissociation of nitric oxide (NO) and enhanced oxygen binding. As a result, cytochrome C oxidase activity is optimized, which increases ATP production and boosts cellular metabolism. Additionally, the release of NO contributes to vasodilation, angiogenesis, and immune modulation. The controlled production of reactive oxygen species (ROS) activates antioxidant defenses and supports cellular signaling, growth, and differentiation. These combined effects help alleviate pain, reduce inflammation, promote vasodilation, and enhance tissue healing[3,7,8] (Figure 1).

The therapeutic effects of PBMT are influenced by several physical and clinical irradiation parameters, such as energy density, wavelength, power density, emission mode, and irradiation time.[2,3,5]. To further understand photobiomodulation, it is important to familiarize ourselves with common terms and definitions of key parameters (Table 1).

Wavelength and Tissue Penetration

Wavelength is a critical factor in light absorption and tissue penetration. Ultraviolet light (100-400 nm) is primarily absorbed by melanin, proteins, and nucleic acids, limiting its penetration. Visible light (400-760 nm) interacts mainly with melanin, hemoglobin, and myoglobin, making it effective for superficial tissues. Near-infrared light (760-1200 nm) penetrates deeper as it is absorbed by various chromophores, whereas wavelengths above 1400 nm are predominantly absorbed by water, restricting their depth of action[9,10].

Light penetration into tissues depends not only on wavelength but also on biological and physical factors such as reflection, scattering, and absorption[1]. Studies using cadavers and laboratory animals, alongside extrapolations from tissue research, have helped estimate light delivery at different depths. Surface dosages between 2 and 20 J/cm² are generally considered appropriate for photobiomodulation[2]. However, factors such as species, body size, coat and skin color, hair density, and anatomical location can influence light penetration[11-13].

In companion animals, pigmentation and hair density significantly affect light transmission. Equine studies have shown that unshaved skin reduces laser penetration, while darker pigmentation further limits it. Shaving enhances transmission by reducing scatter and minimizing absorption by melanin[12,14]. Similarly, human studies indicate that laser penetration is markedly reduced in the first millimeter of skin. Additionally, differences between *in vivo*, *ex vivo*, and *in vitro* studies, as well as interspecies variations, must be considered when determining appropriate dosing strategies[12] (Figure 2 a, b).

Light penetration varies with wavelength; near-infrared reaches deeper tissues, while factors like species, pigmentation, and hair density require tailored phototherapy protocols.

Figure 2a

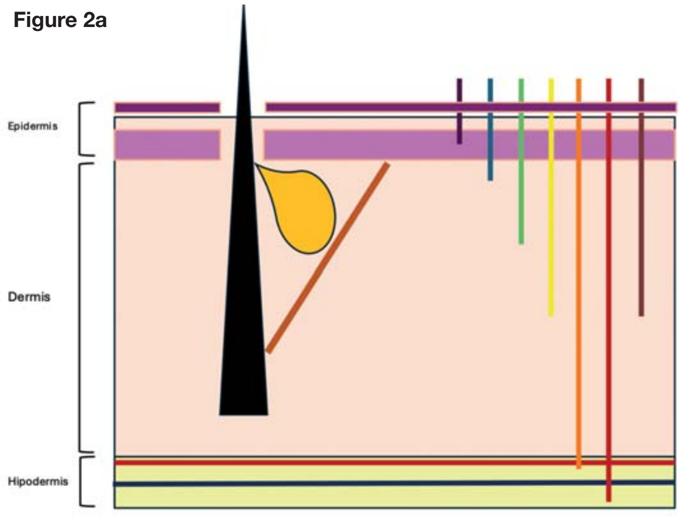

Figure 2b

Wavelength (nm)	Color Range
150–380	UV
390–470	Violet to Deep Blue
475–545	Blue–Green
545–600	Yellow to Orange
600–650	Red
650–950	Deep Red – NIR
950–1200	NIR

Figure 2a,b - Approximation of Wavelength Penetration.
This figure illustrates the relationship between various wavelengths and their depth of penetration into biological tissues, highlighting how different wavelengths influence tissue absorption and therapeutic efficacy.

Most Commonly Used Devices in Light Therapy

Light therapy, or phototherapy, includes several modalities, such as Photobiomodulation (PBM), Fluorescent Biomodulation (FBM), and Photodynamic Therapy (PDT). Among these, PBM, formerly known as Low-Level Laser Therapy (LLLT), utilizes both coherent light sources (lasers) and noncoherent sources such as light-emitting diodes (LEDs), arc/flash lamps, halogen lamps, and fluorescent lights, typically within the 600-900/1200 nm wavelength range[1,15].

Photobiomodulation (PBM)

PBM is defined as a nonthermal light therapy that utilizes non-ionizing light sources, including lasers, LEDs, and broadband light, within the visible and infrared spectrum. By interacting with endogenous chromophores, PBM triggers photophysical and photochemical reactions at different biological scales, leading to therapeutic benefits such as pain relief, reduced inflammation, immune modulation, and enhanced wound healing and tissue regeneration[6].

Due to its ability to stimulate biological responses without causing thermal damage, PBM has been extensively studied in dermatological applications. Both *in vitro* and *in vivo*

Figure 3 - Example of a Class IV Multi-Wavelength Laser from ASA Laser Veterinary® (ASA S.r.l., Italia).
This figure showcases a high-power therapeutic laser that operates at multiple wavelengths, designed to enhance tissue penetration and optimize photobiomodulation effects.

PBM uses visible to infrared light for pain relief, inflammation reduction, and healing, with efficacy influenced by wavelength, intensity, exposure time, and distance.

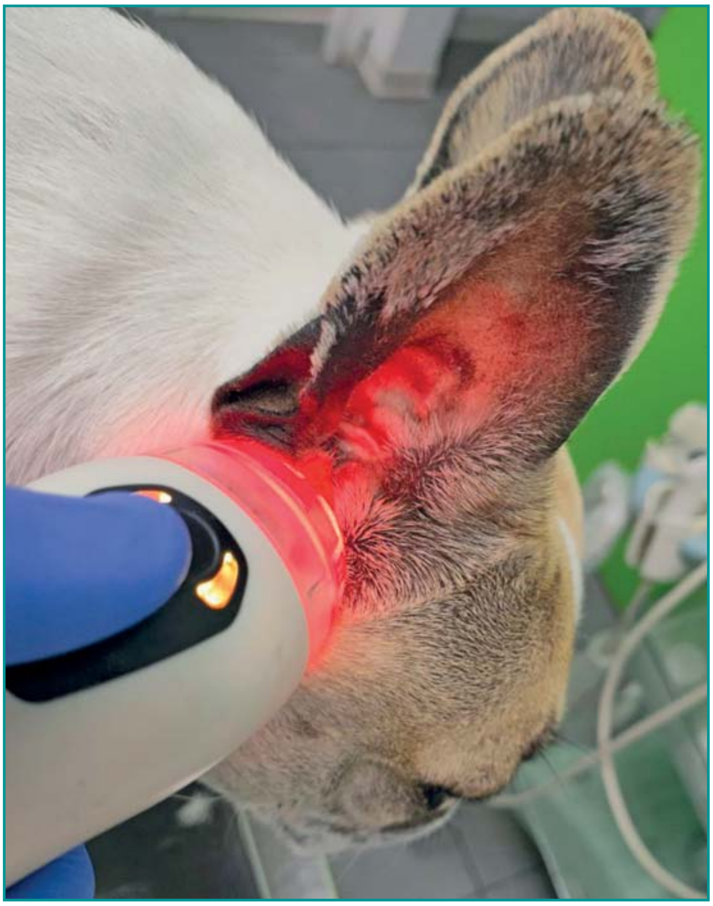

Figure 4 - Application of PBMT with a Class IV Laser in a Canine Patient with external otitis. Photo courtesy of Luca Luciani.
Application of PBMT with a Class IV laser in a canine patient with otitis. The treatment aims to reduce inflammation, and alleviate dermatological symptoms, highlighting the non-invasive and targeted nature of PBMT.

research support its effectiveness in treating skin disorders and modulating bacterial loads in wound healing[3,10,16,17].
PBM treatments are typically delivered through lasers or LED arrays. The treatment area is measured in mm² or cm², while the distance between the light source and the target tissue ranging from direct contact to 1-20 cm, affects power density, with greater distances leading to reduced intensity. Additionally, PBM devices can operate in continuous or pulsed modes, influencing therapeutic outcomes[18].
In clinical practice, a wide range of light-emitting sources and treatment protocols are used, with variations in wavelength, irradiated area, intensity, and exposure time. While most commonly reported doses are below 50 J/cm², numerous studies have described a broader spectrum of parameters[15] (Figure 3, 4).
While PBM has gained substantial attention for its therapeutic effects, another light-based therapy that has shown promise in dermatology is FBM. Unlike PBM, FBM uses a photoconverting gel combined with blue LED light to induce therapeutic fluorescence, which can provide unique benefits, especially in treating inflammatory skin conditions[19].

Fluorescent Biomodulation

FBM involves the application of a photoconverting gel containing chromophores directly to the lesion, followed by exposure to a blue LED lamp. This process generates fluorescence, which interacts with the target tissues to induce therapeutic effects[19,20].
The commercial device system typically involves illuminating a photoconverter gel layer (approximately 2 mm thick) applied to the lesions for 2 minutes, using a non-coherent blue LED light (440-460 nm peak wavelength, 55-129 mW/cm² power density) held at about 5 cm from the target tissue[19,21] (Figure 5).
Although the exact mechanism of action is not fully understood, *in vitro* models and clinical trials have demonstrated a reduced inflammatory profile in various skin disorders and increased collagen deposition during wound healing. Notably, Ferroni and colleagues observed beneficial effects on mitochondrial homeostasis in inflamed cells, suggesting that FBM's therapeutic action may be linked to the regulation of mitochondrial function[22] (Figure 6).
Moving from FBM's fluorescence-driven mechanism of action, we now turn to Photodynamic Therapy (PDT), which involves a photosensitizing agent and light exposure to trigger oxygen-dependent reactions that have both cytotoxic and immunomodulatory effects.

Photodynamic Therapy

PDT involves applying a photosensitizing agent, such as aminolevulinic acid (a precursor to porphyrins), to

FBM combines a chromophore gel and blue LED light to produce fluorescence, promoting collagen production, reducing inflammation, and supporting mitochondrial health in tissue repair.

pathological tissues. Upon exposure to visible light, a light-activated reaction occurs, generating ROS that produce cytotoxic and immunomodulatory effects[20]. PDT has been studied for its potential in wound healing, where it has demonstrated positive outcomes in animal models, such as rats[24]. It is also well-demonstrated that PDT, when combined with blue light and a photosensitizing agent, exerts an antibacterial effect *in vitro*, specifically against bacteria such as *Staphylococcus pseudintermedius*[25].
When using light therapy modalities such as PBM, FBM, and PDT, safety precautions are critical to prevent potential harm. Both animals and humans should wear appropriate protective eyewear, such as goggles, to protect the eyes from intense light, as exposure to certain wavelengths can cause ocular damage. Additionally, it is important to adhere to recommended power densities, exposure times, and treatment distances to minimize the risk of harm from light exposure[3].
Regarding the comparison of efficacy between PBM, FBM, and PDT, it is challenging due to the variations in mechanisms of action and the diversity of treatment protocols employed for similar skin conditions.

USE OF LIGHT THERAPY IN VETERINARY MEDICINE

In veterinary medicine, PBM has been explored for a wide range of applications, including pain management, musculoskeletal disorders, neurology, dental, and dermatology[3,10,15,26].
One of the most extensively studied and promising areas of PBM application is wound healing[3].
In clinical practice, light therapy is increasingly being adopted in veterinary dermatology, utilizing various light sources and treatment protocols. As the use of light-based therapies grows, it is essential to assess their effectiveness in treating a broad spectrum of skin conditions in animals.

PBM, FBM, and PDT differ in mechanisms and applications; comparing their effectiveness is difficult due to varied protocols, emphasizing the importance of safety and individualized use.

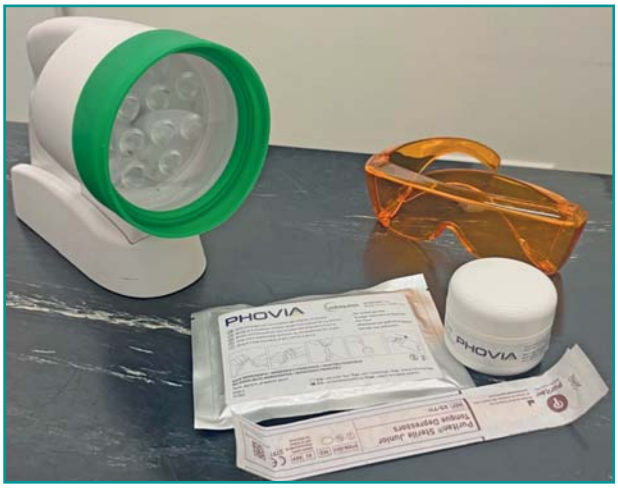

Figure 5 - Phovia® device (Vetoquinol, France).
This figure illustrates the Phovia® Fluorescent Biomodulation device (Vetoquinol, France), designed for therapeutic use in skin treatments.

Indications of light therapy in veterinary dermatology

Wound Healing

Several *in vitro* and *in vivo* studies have examined the effects of PBMT and FBM on wound healing across various species, including dogs, horses, and exotic animals[4,27,28]. These studies demonstrate the potential of

Figure 6 - Phovia® device (Vetoquinol, France).
This image shows the Phovia® Fluorescent Biomodulation device in action. It includes a blue LED light source positioned over a layer of photoconverting gel on a feline skin lesion. Photo courtesy of Alexandra Dehesa.

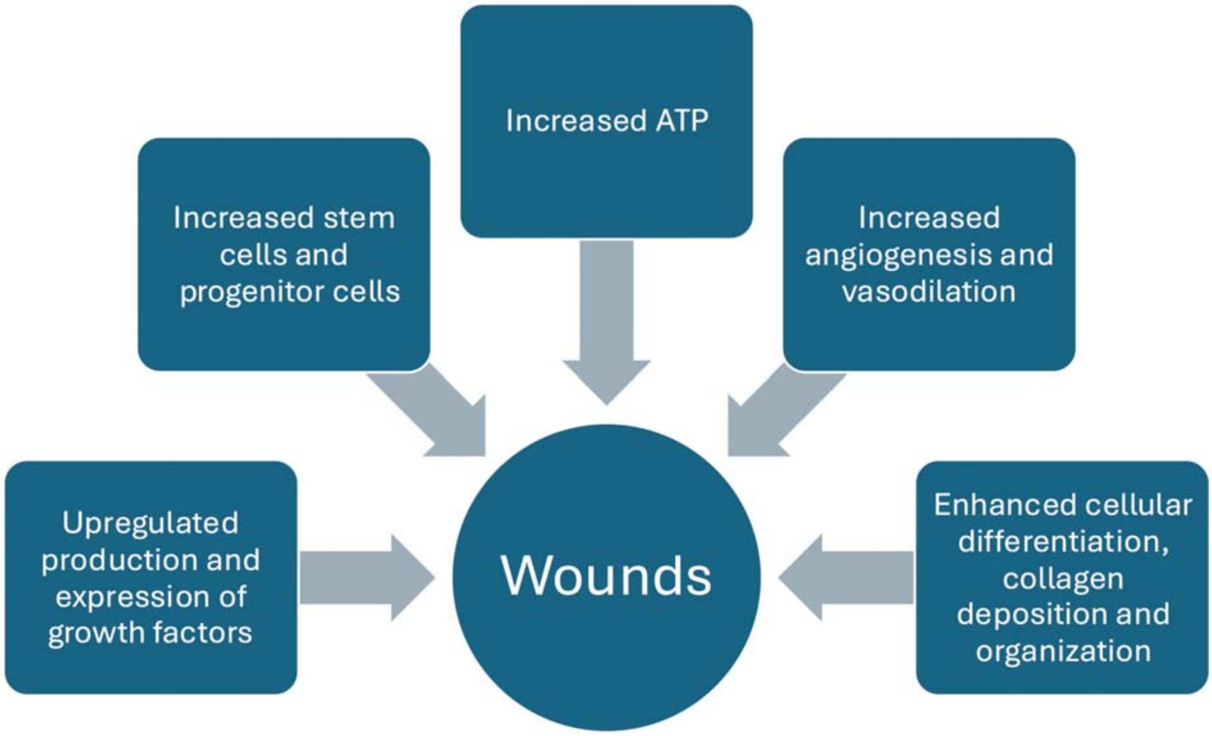

Figure 7 - Summary of PBM's *in vitro* biological effects on skin wounds.

light-based therapies to promote tissue regeneration and reduce inflammation during the wound healing process (Figure 7).

FBM has shown promising results. For instance, a study in mouse models demonstrated its ability to regulate collagen remodeling in skin grafts[23]. Two studies specifically assessed FBM's impact on surgical wounds. One study from Selvaggio et al. applied FBM to half of a surgical wound, with saline used on the other half. Histological and immunohistochemical analysis revealed reduced inflammation in the FBM-treated areas, though no macroscopic differences were noted[29]. Another study on female dogs undergoing mastectomy showed macroscopic improvements in FBM-treated areas, with bacterial swabs revealing no bacterial presence[30]. A case report further supports FBM's potential in managing traumatic wounds[31].

PBM for wound healing has been widely studied in veterinary medicine, although results have been mixed. While several studies have explored the topic, well-controlled, blinded studies are limited. Most research shows a low to moderate risk of bias, though some studies have a higher degree of uncertainty[20].

In dogs, some well-controlled studies found no effect of laser treatment on surgically created or open wounds[32,33]. However, one study reported faster healing and improved scarring with PBM[34]. Additionally, Hoisang et al. demonstrated significant acceleration of chronic wound healing, with a notable reduction in wound area[35].

Beyond wound healing, studies on laser penetration show that direct skin contact significantly improves light absorption compared to non-contact applications. Clipping hair and lighter skin tones also enhance laser penetration, though most energy remains confined to superficial tissues[12,36].

Studies on horses have produced varied results. While some research found no significant effect on wound healing, other studies noted clear benefits, such as improved regeneration of pharyngeal tissue and granulation tissue in the limbs compared to traditional treatments like bandages and liniments[37-39]. Laser intensity is a crucial variable, with one study cautioning that excessive doses could be harmful to tissues[40]. As in dogs, studies on laser penetration in horses confirm that most of the energy is absorbed by superficial tissues, with absorption increasing when the skin is clipped and cleaned. Interestingly, while one study suggested that lighter-colored

Although promising, light therapy's inconsistent results underline the need for more research to establish effective, species-specific treatment guidelines in veterinary medicine.

Figure 8 - Application of PBM to an ulcerative lesion in a peregrine falcon.

horses may experience better penetration, another found no direct connection between skin pigmentation and laser effectiveness[14,41].

Studies on exotic animals, such as rabbits, iguanas, and toads, have also explored the effects of PBM. In toads and iguanas, there were no observable macroscopic or histopathological improvements when PBM was combined with sulfadiazine cream[42,43]. However, in rabbits, histopathological improvement was reported when PBM was applied daily for 7 days in a published research[44] (Figure 8).

These findings underscore the complexity of using light therapy in veterinary dermatology. While positive outcomes have been observed, results remain inconsistent, highlighting the need for further research to refine treatment protocols and develop clearer clinical guidelines.

Bacterial skin diseases

Several studies have been published in recent years exploring the use of different light therapy protocols and devices for the management of bacterial diseases and their effects on bacterial cells[25,45,46]. Both *in vivo* and *in vitro* studies have investigated the impact of PBM on bacterial cells and bacterial skin diseases in animals[17,45].

For instance, FBM has been supported by various evidence-based publications demonstrating improvements in different skin conditions *in vivo* settings. Several studies have reported promising results in canine patients with deep and superficial pyoderma, including multidrug-resistant pyoderma[21,47,48]. In some of these studies, FBM was used as the sole intervention, leading to improvements in lesion scores and reductions in bacterial presence observed in cytology[47,49]. However, the absence of control groups in some of these studies makes interpretation of the results challenging. Other studies have also evaluated the use of fluorescent light energy (FLE) as an adjunct therapy alongside antibiotic treatment. In cases of interdigital pyoderma and forunculosis, patients receiving both antibiotics and FBM exhibited faster lesion resolution compared to those treated with antibiotics alone[50,51]. Additionally, a randomized controlled trial compared patients receiving antibiotics alone with those receiving antibiotics plus PBM under different protocols, demonstrating a reduced time to resolution of bacterial folliculitis[48]. Furthermore, a study on uncomplicated bacterial otitis externa evaluated three different patient groups treated with either topical antibiotics or different FBM protocols. All groups showed improvements in bacterial colony-forming units (CFU) and clinical scores[52]. FBM has also been explored as an adjunct therapy in a few case reports, including ocular dermatitis and a particularly interesting case of deep pyoderma in a patient with calcinosis cutis[53,54]. Recently, an *in vitro* study investigated the direct effect of FLE on bacterial cells and found no significant impact[46]. This finding raises the possibility that the improvements observed in bacterial skin diseases may be due to PBM's influence on inflammatory pathways rather than a direct antibacterial effect. Further research is needed to confirm this hypothesis.

Photobiomodulation has been widely studied for its effects on bacterial cells, particularly in *in vitro* models[45]. A substantial body of literature, with a high level of evidence, has demonstrated its potential to inhibit bacterial growth in various skin diseases complicated by bacterial infections, such as infected ulcers. For instance, an *in vitro* study by de Sousa et al. showed that PBM effectively inhibited the growth of *Pseudomonas aeruginosa*, *Escherichia coli*, and *Staphylococcus aureus*, bacteria commonly associated with infected ulcers[45].

While the *in vitro* evidence is robust, *in vivo* studies are more limited. However, some noteworthy examples exist. PBM has been shown to reduce *Staphylococcus aureus* colonization and accelerate wound healing in diabetic rat models[55]. More recently, a placebo-controlled clinical trial in veterinary medicine evaluated the effects of PBM on bacterial load in traumatic wounds in dogs. The study reported a statistically significant reduction in colony-forming unit counts in PBM treated groups compared to the placebo group[17].

FBM effectively treats canine pyoderma, including resistant cases, while PBM aids bacterial control in wounds, supporting reduced antibiotic use in veterinary care.

Microbiome

Interestingly, the impact of PBM on the microbiome has gained attention in recent years, with studies exploring its potential to modulate microbial composition. In human medicine, PBM has been shown to influence the microbiome in various diseases, including Parkinson's disease[56].

In veterinary medicine, two notable studies have examined microbiome changes in canine atopic dermatitis with light therapy. One study utilized ultraviolet light with an excimer light and demonstrated a shift in the microbiome composition of atopic dogs after 2 months of treatment[57]. The second study, which used PBMT, did not achieve a significant overall change in the microbiome of atopic dogs. However, some alterations in bacterial composition were observed in certain patients[5].

These findings, along with human research, highlight the potential of PBM to influence dysbiosis in specific diseases, warranting further investigation.

Figure 9 - Application of PBMT in a canine patient with pododermatitis.

Alopecia

Another indication for which light therapy has been used in veterinary dermatology is alopecia in canine patients. An early study by Olivieri and colleagues investigated the effects of PBM in seven dogs with non-inflammatory alopecia, applying treatment to one area while leaving another untreated. At the end of the two-month study, significant improvement was observed in six out of the seven patients[58].

One particularly intriguing condition, for which the pathomechanism remains unclear and no definitive treatment exists, is Alopecia X. In 2024, a protocol study was published outlining an ongoing investigation into Alopecia X in three different groups of Spitz dogs treated with melatonin, PBM, or a combination of both[59]. The results of this study may provide valuable insights, especially considering that PBM has shown success in certain types of alopecia in humans[60].

Miscellaneous dermatological disorders

Other dermatological disorders that have been investigated or documented in the literature as being treated with PBMT and FBM include canine atopic dermatitis (CAD), perianal fistula in German Shepherd dogs, acral lick dermatitis, aural hematoma, edema, snake bites, and pododermatitis[61-67] (Figure 9).

In a study on CAD, PBM was applied for one month to the interdigital area of dogs with CAD and pedal pruritus. However, no significant difference was observed between the treatment group and the placebo group[63].

A pilot study on canine sterile nodular pododermatitis, conducted in 2016, reported a significant improvement in lesion scores in PBM treated patients compared to the control group[62].

In four German Shepherds with perianal fistulas, multiple sessions of FBM as a standalone therapy were conducted, resulting in clinical improvement in all patients.

PBM and FBM show varying success in treating diverse conditions such as CAD, fistulas, dermatitis, edema, and snake bites, with some cases showing notable clinical improvement.

Only one dog required more than seven sessions[64].
Acral lick dermatitis is a frustrating condition that often requires multimodal therapy. A study comparing a PBM-treated group with a control group aimed to determine whether PBM could be a useful tool for managing this disorder. While no significant improvement in lesion scores was observed between groups, interestingly, the treated group showed increased hair regrowth[65].
PBM has also been shown to reduce edema, as demonstrated in an experimental model using rodents[66]. Additionally, research exploring the effects of PBM on lesions resulting from snake bites found positive outcomes in both local and systemic responses. Among the different protocols tested, a combination of infrared and near-red light proved to be the most effective[67].

DISCUSSION

Phototherapy, or light therapy, is increasingly being utilized in veterinary medicine, particularly in veterinary dermatology. The most commonly used forms in dermatology are Photobiomodulation Therapy and Fluorescent Biomodulation Therapy.
The mechanisms of action for these therapies are not yet fully understood, and they differ significantly. PBM, previously known as low-level laser therapy, operates through endogenous chromophores such as cytochrome C oxidase in the mitochondria, producing its biological effects at the cellular level[3]. In contrast, FBM employs a blue light lamp in combination with an exogenous chromophore contained in a gel or matrix, generating fluorescent light that interacts with tissues to exert its therapeutic effects[19].
These technologies have been applied in various dermatological conditions, including wound healing, bacterial infections, skin microbiome modulation, pododermatitis, and others[5,47,68]. The available literature consists largely of randomized controlled studies and case reports, leading to variability in the level of evidence presented across different studies.
Regarding FBM, one of its advantages is that the physical parameters remain consistent across all veterinary studies since it is a single commercial product with a standardized treatment protocol (440-460 nm peak wavelength, 55-129 mW/cm² power density). However, variations arise in the number of sessions and individualized treatment decisions based on specific cases and observed outcomes[51,64]. A drawback of FBM is that existing studies are limited to canine patients, with no *in vitro* studies conducted in veterinary medicine except for a single previously mentioned exception. This limitation results in a reliance on case reports and a scarcity of high-quality, randomized controlled trials where FBM is used as a sole or adjunctive therapy, making it difficult to draw definitive conclusions[20].
PBM, on the other hand, has a more extensive body of literature available compared to other light therapies, encompassing *in vitro* and *in vivo* studies. Its applications extend beyond veterinary dermatology to fields such as orthopedics, neurology, rehabilitation, pain management, and odontostomatology[3,10,15]. In veterinary dermatology, most studies focus on wound healing across various

Figure 10 - Example of different programs for dermatological conditions using a Class IV laser device.

Phototherapy, particularly PBM and FBM, is safe and promising but requires further research to develop standardized, effective protocols across species and skin conditions.

species, including equines, reptiles, rabbits, and others[28,68]. However, the results are mixed, some studies demonstrate significant improvement, while others show no difference between treated and control groups. One of the major challenges in PBM research is the heterogeneity of treatment parameters and protocols across studies. This variability prevents direct comparisons between studies and hampers the establishment of standardized protocols and optimal dosing guidelines.

Despite these challenges, there is sufficient evidence to conclude that light therapy is a safe and potentially beneficial treatment for various dermatological conditions. PBM has proven effective in treating contaminated wounds[17], while FBM has shown positive results in deep pyoderma as a sole therapy[47], highlighting its role in antibiotic stewardship. Additionally, research on the quality of life of patients receiving FBM therapy suggests that both patients and their owners experience an improvement in well-being following treatment[69].

However, despite these promising outcomes, there remains a need for standardized treatment protocols. Variations in light parameters such as wavelength, energy density, and treatment duration can significantly influence therapeutic outcomes. Further research is essential to establish optimal phototherapy protocols for different conditions and species to ensure consistent and effective results. Multicenter studies with standardized methodologies could help improve the comparability of results and strengthen the evidence base.

Phototherapy, including PBM and FBM, offers a non-invasive and potentially effective treatment for various veterinary dermatological conditions, though mechanisms and outcomes vary.

Comparisons with human medicine could also provide valuable insights. In human dermatology, light therapy has been widely studied for conditions such as psoriasis, acne, and chronic wounds[70]. Understanding how these findings translate to veterinary applications could help refine protocols and expand potential indications.

Additionally, although light therapy is considered safe, potential adverse effects or limitations should be acknowledged. While minimal, these could include inconsistent responses across different species, potential tissue overheating in PBM, or variations in effectiveness due to differences in skin type and disease severity[19,40].

In conclusion, light therapy in its various forms presents a promising, adjunctive, and safe treatment modality in veterinary dermatology. However, further research is needed to develop standardized protocols, assess cost-effectiveness, and expand well-designed studies across different species, dermatological conditions, and variations in coat and skin pigmentation. This will be essential to fully harness its therapeutic potential and ensure consistent, reliable outcomes.

FUTURE DIRECTIONS AND RECOMMENDATIONS FOR LIGHT THERAPY IN VETERINARY DERMATOLOGY

Based on the current body of evidence and the continued advancement of light therapies such as PBM, FBM, and PDT in veterinary dermatology, the following recom-

Figure 11 - Summary of guidelines for writing a high-quality article on PBM in veterinary medicine[71].

Principle	Recommendation
Use Standardized Terminology	Avoid outdated or inconsistent terminology such as low-level laser therapy (LLLT) or other variations for photobiomodulation therapy (PBM/PBMT).
Incorporate Clear and Informative Data	Summarize key data, including treatment parameters (wavelength, fluence, energy density), clinical applications, and outcomes.
Define a Clear Clinical Question	Every article should set a well-defined clinical question and use existing evidence to answer it. Light therapy results must align with established knowledge in molecular and cellular biology to ensure scientific coherence.
Stay Updated on Mechanisms of Action	Articles should reflect the most recent research on light therapy mechanisms of action at the molecular, cellular, and physiological levels. A thorough understanding of these mechanisms strengthens the credibility and scientific foundation of the article.
Prioritize High-Quality Research	Focus on publishing well-designed studies, including randomized controlled trials and systematic reviews, to ensure robust and reliable conclusions. The long-term goal should be to enhance the credibility of light therapy as a scientifically validated therapeutic modality.

mendations and guidelines are proposed for future studies and clinical applications[71].

1. Evidence of Safety and Ease of Use
PBM, FBM, and PDT have demonstrated non-invasive administration with rarely reported side effects during the study periods. These therapies are easy to apply in non-sedated patients, making them highly practical options for veterinary dermatology.

2. Need for Further Research
Ongoing research is crucial to fully understand the scope and potential of light therapy in veterinary dermatology. Expanding the research base will help clarify its clinical applications and optimize therapeutic protocols for better outcomes.

3. Recommended Study Designs
Large-scale, randomized, double-blind, and controlled *in vivo* studies are essential to validate the effectiveness of light therapy in veterinary dermatology. Such studies will provide more reliable evidence and ensure that results are applicable in everyday clinical settings.

4. Study Design and Comparability
Future research should focus on clearly defining inclusion criteria, randomization procedures, and blinding methods. This will improve the consistency and reliability of study results and allow for better comparability across different trials.

5. Research on Antibiotic Reduction
Investigating the potential of light therapy to reduce reliance on antibiotics is a key focus area. Some studies, such as those by Marchegiani et al. or Lange et al., suggest that light therapy may shorten the duration of systemic antibiotic use[47,49,50]. This is especially important given the global concern over antimicrobial resistance.

6. Standardized Treatment Protocols
Standardized protocols for therapeutic light therapy parameters are urgently needed, as current guidelines are insufficient. Future studies should address key factors such as: spot size, wavelength, energy density, power density, pulse structure, total energy, total power, and delivery mode.
Considerations of species, pigmentation, and coat type, as these factors can influence treatment effectiveness. Controlling dosimetric parameters within a narrow range is critical to achieving consistent, positive therapeutic outcomes.

7. Prioritize High-Quality Research
Future studies should prioritize rigorous, well-designed research, particularly randomized controlled trials and systematic reviews. This approach will contribute to building a strong scientific evidence base, enhancing the credibility of light therapy as validated therapy in veterinary dermatology.

8. Use Standardized Terminology
Consistent and current terminology is essential when referring to light-based therapies. Preferred terms include photobiomodulation, photobiomodulation therapy, and fluorescence biomodulation. Outdated terms like low-level laser therapy should be avoided. These should also be clearly distinguished from photodynamic therapy, which involves light-activated photosensitizers for therapeutic purposes.

9. Stay Updated on Mechanisms of Action
As our understanding of PBM's mechanisms of action continues to evolve, it is essential to reflect the latest research on its molecular, cellular, and physiological effects. This will strengthen the scientific foundation of light therapy and ensure that articles remain grounded in the most current knowledge (Figure 11).

Terapia luminosa in dermatologia veterinaria

Riassunto
Questa revisione esamina l'applicazione della terapia luminosa, inclusi la fotobiomodulazione (PBM), la biomodulazione fluorescente (FBM) e la terapia fotodinamica (PDT), nella dermatologia veterinaria. Esplora i meccanismi d'azione, i parametri chiave di trattamento e le applicazioni cliniche, concentrandosi su come l'assorbimento della luce influenzi la guarigione dei tessuti e altri processi biologici. Vengono evidenziate le indicazioni dermatologiche supportate da studi esistenti e casi clinici, come la guarigione delle ferite, le infezioni batteriche cutanee e altre condizioni. Infine, questa revisione delinea le direzioni per future ricerche, enfatizzando la necessità di studi clinici randomizzati su larga scala e protocolli di trattamento standardizzati per stabilire l'efficacia a lungo termine della terapia luminosa in medicina veterinaria.

PUNTI CHIAVE

Mechanisms and Modalities

PBM and FBM are non-invasive light therapies with distinct mechanisms. PBM stimulates endogenous chromophores, while FBM uses fluorescent light from an exogenous gel to activate tissue repair and modulate inflammation.

Applications in Veterinary Dermatology

Both therapies have shown promise in treating wounds, infections, and inflammatory skin conditions, including deep pyoderma, pododermatitis, and perianal fistulas, although evidence quality and treatment consistency vary.

Protocols and Parameters

PBM protocols vary widely in wavelength, intensity, and application methods, making standardization difficult. In contrast, FBM uses a fixed blue LED protocol, but session number and outcomes still depend on individual cases.

Evidence and Limitations

PBM is supported by broader research across species and conditions but lacks uniformity. FBM offers consistency but limited veterinary studies, especially in non-canine species, restricting the strength of clinical recommendations.

Antibiotic Stewardship and Infection Control

PBM and FBM have demonstrated effectiveness in managing bacterial infections, including multidrug-resistant cases, supporting their use as adjunct or alternative therapies to reduce antibiotic reliance in veterinary dermatology.

Future Directions and Safety

Despite being safe and well-tolerated, more standardized, species-specific, and multicenter research is needed to establish optimal dosing protocols, assess cost-effectiveness, and broaden the clinical applicability of veterinary light therapy.

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