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In vitro use of a low-level laser therapy device inhibits growth of *Malassezia pachydermatis*

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Objective
To determine the in vitro activity of the low-level laser (light) therapy (LLLT) device (Phovia; Vetoquinol) on *Malassezia pachydermatis*.

Methods
Clinical isolates of *M pachydermatis* (n = 30) and a commercially available anamorph of *M pachydermatis* (ATCC strain 14522) were used in this study. Both groups of organisms were plated on potato agar plates and exposed to the LLLT device for 2, 4, 6, and 8 minutes with a 30-second break after every 2 minutes of exposure. The plates were then incubated at 37 °C for 48 hours. Each experiment was run in duplicate. The experiment for the internal control was repeated independently 6 times. Nonirradiated plates served as the viability control (positive control). The number of CFUs between each treatment and the control was analyzed using a repeated-measures ANOVA or a Friedman test followed by a post hoc analysis.

Results
Compared to the control, there was a statistically significant decline in CFUs after a minimum of 4 minutes of exposure to the LLLT device in both groups compared to unexposed controls.

Conclusions
This preliminary in vitro study demonstrated that the LLLT device tested can inhibit the growth of *M pachydermatis*.

Clinical Relevance
This in vitro study offers a novel proof-of-concept approach to treating *Malassezia* infections in veterinary medicine. Low-level laser (light) therapy has the potential to shorten treatment durations and reduce side effects, making it a promising alternative to standard antifungal therapy, particularly in the context of antifungal resistance.

Keywords: in vitro, dogs, *Malassezia pachydermatis*, low-level light therapy, Phovia

Lipophilic yeasts of the genus *Malassezia* inhabit the skin of humans and animals. The genus *Malassezia* includes 18 species in humans and animals, some of which can cause pathogenic skin disease.[1] *Malassezia globosa* and *Malassezia restricta* are prevalent on the skin of both healthy and diseased humans and dogs,[2,3] whereas *Malassezia pachydermatis*, a commensal yeast, is frequently implicated in dermatitis and otitis in dogs and cats.[3,4] Although a commensal organism, *M pachydermatis* can trigger disease when the microbiota and host immunity are altered.[5]

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Malassezia pachydermatis can cause severe itching in dogs[6] and is a prevalent secondary infection in dogs with allergies. Due to the frequent recurrence in dogs and need for multiple rounds of antifungal therapy, these cases can become increasingly difficult to manage. Traditionally, both topical and oral forms of antifungal therapy are utilized, although they may take several weeks to show efficacy. One randomized controlled trial concluded that 3% chlorhexidine shampoo demonstrated clinical effectiveness comparable to that of 2% miconazole/chlorhexidine shampoo in treating *Malassezia* dermatitis.[7] The use of systemic therapy, including ketoconazole and itraconazole, is widespread.[5,8] However, systemic therapy may require weeks to be effective,[9] and prolonged use of systemic antifungals can lead to elevated liver enzymes, gastrointestinal signs, and potential drug interactions.[10,11]

In recent years, treating *Malassezia* dermatitis has grown increasingly difficult due to the yeast's emerging resistance as evidenced by in vitro research[12–15] and clinically through a documented case.[16] Another challenge in treating this infection is the lack of existing Clinical and Laboratory Standards Institute (CLSI) guidelines for determining *Malassezia* spp susceptibility to oral antifungal medications.[17]

An alternative topical form of antimicrobial therapy is a form of light technology, specifically low-level laser (light) therapy (LLLT). Low-level laser (light) therapy has gained attention for its efficacy in treating various skin conditions, including bacterial and fungal infections.[18] Though its mechanism remains incompletely understood, it is hypothesized that when mitochondrial chromophores, such as cytochrome c oxidase, absorb light, a cascade of reactions occurs. Light exposure prompts the dissociation of nitric oxide from cytochrome c oxidase, which boosts enzyme activity, electron transport, mitochondrial respiration, and ATP production.[19,20] A key process is the electron transfer to molecular oxygen, which results in the generation of reactive oxygen species (ROS) that exert a cytotoxic effect locally.[18,19] Low-level laser (light) therapy is also capable of enhancing tissue healing by stimulating fibroblast and collagen activity, specifically by upregulating HS27 fibroblasts, collagen-1-α-1, and VEGF.[19]

Human studies[21] have demonstrated that LLLT can inhibit fungal growth. However, research on the application of LLLT for yeast in veterinary medicine remains limited. The veterinary device Phovia (Vetoquinol) introduces an innovative LLLT modality that is effective as a standalone or complementary antimicrobial treatment for canine conditions such as superficial bacterial folliculitis, deep pyoderma, and interdigital furunculosis. It achieves efficacy after a standard 2-minute phototherapy session.[22–24] In clinical settings, a photoconverting hydrogel is administered to the affected skin to broaden the wavelength of the LLLT device from its single blue light peak wavelength (approx 446 nm) to a range spanning 500 to 700 nm during the standard 2-minute phototherapy session.[25] This application of hydrogel alters the spectrum of wavelengths and augments tissue healing.

Since light within the range of 380 ± 2 and 392.5 ± 1 nm wavelengths has been demonstrated to inhibit the growth of *Malassezia* species,[26] a photoconverting gel to increase light wavelength may not be necessary to inhibit *Malassezia* spp growth. Due to the rise of resistant *Malassezia* strains, the demand for innovative antifungal treatments, and the potential advantages of LLLT for *Malassezia* spp, this in vitro investigation aimed to evaluate the impact of the LLLT device, excluding the photoconverting hydrogel, on laboratory and clinical isolates of *M pachydermatis* in dogs.

Methods

Malassezia pachydermatis *clinical isolates*

Thirty clinical isolates of *Malassezia* spp were obtained from dogs diagnosed with otitis externa associated with *Malassezia* infection. The isolates were identified based on characteristic colony morphology, including their white-to-cream color and smooth, ellipsoidal shape, which are typical features of *Malassezia* spp grown on solid agar media.[1] Their identification as *M pachydermatis* was confirmed via matrix-assisted laser desorption ionization–time of flight analysis. *Malassezia pachydermatis* ATCC 14522 isolate was utilized as an internal control to validate the experimental procedure, providing a baseline against which the effects on the clinical isolate group could be compared.

Minimum fungicidal concentration assay

The minimum fungicidal concentration assay was modified and adapted from the CLSI guidelines from 2017[17] to account for the clumping behavior of *M pachydermatis* during inoculum preparation. To address the issue of clumping, the inoculum suspension was vortexed thoroughly and, if necessary, diluted further to disperse the clumps and ensure a uniform distribution of yeast cells for accurate testing. The methodology used to prepare the *Malassezia* sp was referenced using CLSI guidelines and clinical guidelines.[17,27] The microorganisms maintained at −80 °C were seeded onto Potato Dextrose Agar (PDA; Thermo Scientific Remel) plates and incubated at 37 °C for 72 hours. Next, colonies were collected with a sterile loop (Thermo Scientific) and plated onto fresh PDA plates for an additional 48 hours at 37 °C. After 48 hours of incubation, colonies were suspended in sterile water to achieve a 0.5 MacFarland standard using a nephelometer (Thomas Scientific). The yeast suspension was serially diluted using sterile water to achieve a final concentration of 10^4 CFU/mL, and 100 µL of the suspension was plated onto PDA 90-mm petri dishes. This was necessary to achieve a countable number of colonies for the experiment (30 to 300 CFU/plate).

Phototherapy using the LLLT device

Phototherapy was carried out using an LLLT device (Phovia; Vetoquinol) consisting of 12 bulbs that deliver noncoherent blue light (440 to 460 nm) at a single peak wavelength (approx 446 nm). The center bulbs emit 130 mW/cm^2, and the peripheral bulbs emit 55 mW/cm^2. The power density ranges from 55 to 129 mW/cm^2 at a 5-cm distance.

The PDA plates were categorized into 5 groups: group 1 served as the positive control, consisting of nonirradiated plates used to evaluate the viability of *Malassezia* colony growth. Group 2 included plates exposed to 2 minutes of irradiation, group 3 to 4 minutes of irradiation, group 4 to 6 minutes of irradiation, and group 5 to 8 minutes of irradiation.

Groups 3 through 5 underwent a 30-second pause (resting time) from light after each automatic 2-minute interval of phototherapy by the LLLT device. After irradiation, the plates were incubated at 37 °C for 48 hours. After 48 hours of incubation, yeast colonies were counted manually using a colony counter (Weber Scientific), and the total number of CFUs per plate was recorded. Each experiment was performed in duplicate. The mean CFU count

for each experiment was calculated and statistically compared to the positive control group.

The same procedure described above was performed for both the clinical isolates and internal control to ensure consistency and comparability of the results. The only difference was that the experiment for the internal control group was independently repeated 6 times to confirm the reliability and reproducibility of the findings under standardized conditions.

Statistical analysis

A commercially available statistical analysis software (Prism, version 10; GraphPad Software Inc) was used for all analyses. The number of CFUs per milliliter was first tested for normality using the Shapiro-Wilk test ($\alpha = 0.05$). The number of CFUs before and after exposure was analyzed statistically using the Friedman multiple comparison test followed by the Dunn multiple comparison test as a post hoc analysis for the clinical isolates. Analysis of variance followed by the Dunnett multiple comparison test as a post hoc analysis was used to compare the number of CFUs before and after exposure for the internal control. Each variable for each treatment group was compared to the positive control group (before exposure). An effect size was also calculated and reported as a Cohen *d* value; a small effect will have a *d* between 0 and 0.2, a medium effect will have a *d* between 0.2 and 0.5, and a large effect will have a $d > 0.5$. Differences between the percentage of reduction in CFUs per milliliter of the clinical isolates and the internal control were analyzed using area-under-the-curve analysis and the unpaired Student *t* test. Statistical significance was set at $P < .05$.

Results

Clinical isolates

Colony-forming units per milliliter of *M pachydermatis* were compared to the control. The CFUs-per-milliliter value quantified the concentration of viable yeast cells in a liquid suspension based on the number of colonies that formed after plating a sample. After a minimum of 4 minutes of LLLT exposure, there was a statistically significant ($P < .0001$; $d = 0.39$) decline in CFUs per milliliter of *M pachydermatis* compared to the internal control. This effect persisted at 6 ($P < .0001$; $d = 0.91$) and 8 ($P < .0001$; $d = 1.21$) minutes. Although not statistically significant ($P = .07$; $d = 0.23$), after 2 minutes of phototherapy there was a 15.9% (median, 14.8%) decrease in growth compared to the positive control **(Figure 1)**. In contrast, decreases of 29.7% (median, 28%), 53.4% (median, 54.9%), and 68.8% (median, 68.5%) in CFUs per milliliter were observed after 4, 6, and 8 minutes of exposure, respectively.

Internal control group

As for the internal control group, there was a statistically significant decline in CFUs per milliliter of *M pachydermatis* organism after 4 minutes of LLLT exposure ($P = .018$; $d = 1.9$) compared to the control. This effect continued to hold significance after 6 ($P = .021$; $d = 2$) and 8 minutes ($P = .018$; $d = 2.3$; **Figure 2**).

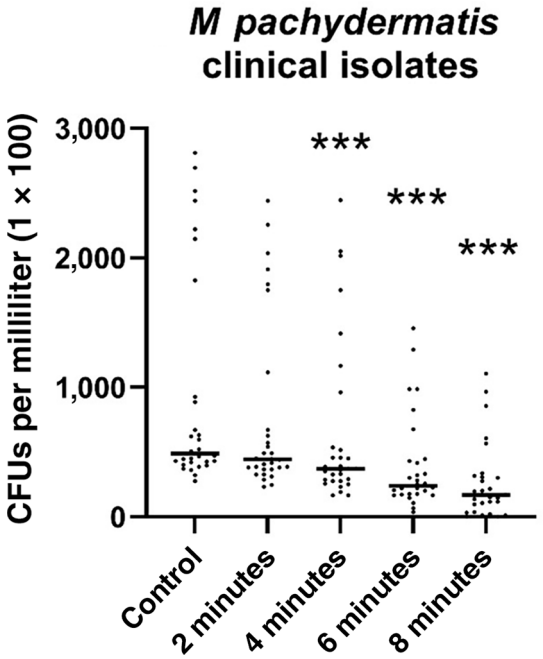

Figure 1—The effect of low-level laser (light) therapy (LLLT) on clinical isolates (n = 30) of *Malassezia pachydermatis*. Compared to the control, there was a statistically significant decline in CFUs per milliliter after a minimum of 4 minutes of irradiation. Data are presented as median value (bar) and individual data points. ***$P < .0001$.

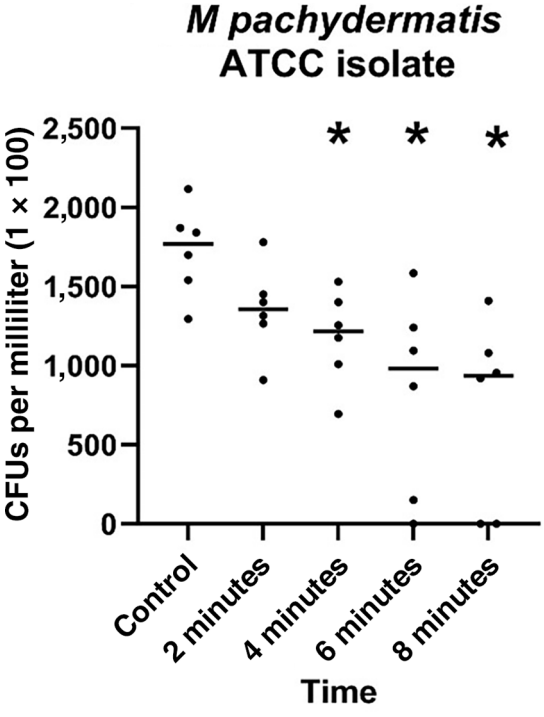

Figure 2—The effect of LLLT on the ATCC strain 14522 (internal control) of *M pachydermatis*. Compared to the control, there was a statistically significant decline in CFUs per milliliter of *M pachydermatis* after 4 minutes of irradiation. Data are presented as median value (bar) and individual data points. *$P < .05$.

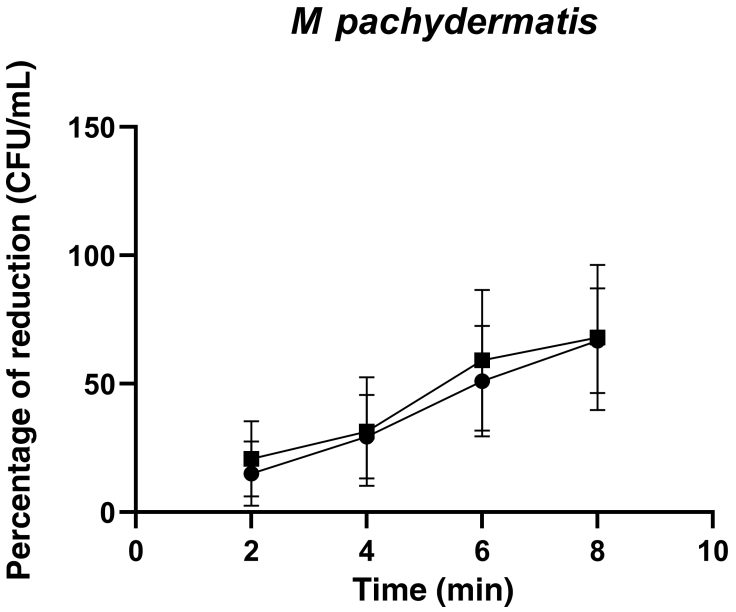

Figure 3—The effect of LLLT on the clinical isolates (n = 30) of *M pachydermatis* compared to ATCC strain 14522 (internal control); there was not a statistically significant difference in the behavior of isolates before and after irradiation with the Phovia lamp. Data are presented as average values and SEs of the mean (bars).

A reduction in CFUs per milliliter equal to 31.7% (median, 27.4%), 55% (median, 42.4%), and 59.2% (median, 50.4%) was seen after 4, 6, and 8 minutes of exposure, respectively.

Comparison between clinical isolates and the internal control group

When the area under the curve of the percentage of reduction in CFUs per milliliter of clinical isolates was compared to the area under the curve of the internal control group, there was a lack of significant difference. These results were confirmed using the unpaired Student *t* test for each time point ($P > .05$; **Figure 3**).

Discussion

The results of this study show that the LLLT device had a time-dependent effect on the growth of both the clinical and internal control group. Specifically, the internal control group and clinical isolates showed a significant decrease in CFUs per milliliter after at least 4 minutes of irradiation. There was not a significant difference between the effect of the LLLT device on the percentage of reduction of CFUs per milliliter for either clinical or laboratory isolates ($P > .05$; Figure 3). A complete fungicidal activity (100% reduction in CFUs per milliliter) was not achieved under the tested conditions for either the internal control group or clinical isolates.

While LLLT has been studied for bacterial skin conditions, research on its effects on *M pachydermatis* remains limited. To the authors' knowledge, only 1 veterinary study[2] has investigated this, using a combination of red (630 nm) and blue light (405 nm), a photosensitizer, and δ-aminolaevulinic acid, on 4 canine clinical isolates of *M pachydermatis*. The results of this study indicated that the photodynamic system reduced the CFUs per milliliter of *M pachydermatis* in vitro and found that blue light was "superior to red light under all conditions." Similarly, our results showed inhibition of *M pachydermatis* at the 440-to-460-nm blue light wavelength even without a photosensitizer. Additionally, an in vitro human study[3] utilizing LLLT in the 405-to-430-nm range demonstrated inhibition of *Candida* spp with single and dual 2-minute LLLT exposures comparable to our 4-minute timepoint without the use of a photosensitizer.

Veterinary studies exploring the use of LLLT for bacterial infections show promising results. Marchegiani et al[22] demonstrated that dogs with superficial bacterial folliculitis treated solely with the LLLT device, either weekly or twice weekly, achieved quicker clinical resolution compared to those treated with systemic antibiotics alone. In a study on multidrug-resistant canine pyoderma, twice weekly LLLT treatments led to reduced lesion scores and resolution of multidrug-resistant infection without adjunct therapy.[22] Notably, these studies demonstrated beneficial effects on clinical signs of bacterial infections within the standard 2-minute treatment. Considering the proven benefits of LLLT for bacterial infection in clinical settings, the response in *Malassezia* patients treated with LLLT may surpass our preliminary in vitro findings, underscoring the need for both in vivo and clinical trials to confirm its efficacy.

Resistant strains of *Malassezia* spp have been on the rise, and treatment is becoming more challenging.[4] In human literature, LLLT has been effective when combined with fluconazole against resistant *Candida* strains.[28] Whether LLLT is clinically effective against resistant strains of *Malassezia* spp in companion animals has not been investigated and warrants further exploration. The mechanism of action of LLLT is, to a large extent, not well understood. Microorganisms naturally produce porphyrins, which are potent photosensitizers found in the electron transport system of mitochondria. A commonly accepted theory posits that when porphyrins absorb

light, they generate ROS. These ROS can induce irreversible oxidative damage to cellular structures, such as the cell wall, cytoplasm, proteins, and lipids, ultimately leading to microbial cell death.[29] Low-level laser (light) therapy also has the capacity to promote tissue healing. When utilized within the red-light spectrum (600 to 650 nm), LLLT decreases tissue inflammation by stimulating the activation of collagen, fibroblasts, fibroblast growth factor, and PDGF, thereby enhancing tissue healing.[19]

Some additional considerations are important. First, the findings of this in vitro study are confined to the application of the LLLT device within a laboratory environment. The photosensitizer gel was omitted as extending the wavelength spectrum of light to augment tissue effects was deemed unnecessary for several reasons. Previously shown data support LLLT antifungal activity in the 400-nm range without the use of a photosensitizer[30] and even in pulsed doses of light therapy between 100 to 280 nm without a photosensitizer.[31] The present study also excluded the use of a photosensitizer gel, meaning that clinical healing aspects cannot be assessed based on the results of this study. From a clinical standpoint, we regard this study as proof of concept. To replicate the outcomes observed in this in vitro study, the LLLT device would require multiple 2-minute sessions, a cumulative effect that has not been examined on actual skin as this duration of treatment exceeds the current recommendations of 4 total minutes of exposure per session. Extended administration of the lamp in a widespread infection could pose potential risks to the skin, highlighting the importance of further studies to explore this safety aspect. Conceivably, when the lamp is used in vivo with the gel, it is possible that shorter treatment times than what we have found in our in vitro study may be sufficient to kill *Malassezia* organisms. Future studies should address both the effects of longer treatment duration on live patients as well as the impact of the gel on the viability of *Malassezia* spp in live animals.

In summary, this study focused on the in vitro discovery of the antifungal effect of the LLLT device on *M pachydermatis* clinical and standardized isolates. The findings suggest that the application of blue light emitted by the LLLT device has a time-dependent impact on *M pachydermatis* growth in vitro. Further in vivo research is warranted to validate the potential of LLLT in treating *Malassezia* dermatitis in clinical patients.

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