Oral Health-Related Quality of Life among Complete Denture Stomatitis Patients Treated with Methylene-Blue-Mediated Photodynamic Therapy

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Abstract: Aim: The aim was to assess the effect of antimicrobial photodynamic therapy (a-PDT) on the oral health-related quality of life (OHRQoL) of denture stomatitis patients. Methods: Forty patients were randomly selected to participate. Candidal proliferation was confirmed by using a CHROMagar culture and Gram staining. The denture surface and palatal mucosa were sprayed with a methylene blue photosensitizer prior to the photobiomodulation application. Laser therapy was applied two times a week at 72 h intervals for a period of 8 weeks. The OHIP-EDENT questionnaire was used to analyze the improvement in the OHRQoL. A Wilcoxon test was used to perform the candidal colony-forming unit’s count and comparison. A t-test was applied to evaluate the OHRQoL responses. Results: The overall CFU/mL values were higher in the dentures of the patients compared to a palatal mucosa swab. For instance, the CFU count was reduced from 5.56 ± 2.15 (baseline) to 3.17 ± 2.77 CFU/mL on day 60 on the palates. Similarly, the a-PDT application on the intaglio surface of the denture showed a reduction from 38.83 ± 14.71 to 29.05 ± 15.52 CFU/mL. A significant difference (p < 0.05) was found in function improvement as well as a reduction in physical pain, psychological discomfort, physical disability, and social interaction among the participants after photobiomodulation treatment. Conclusions: The OHRQoL was significantly improved in the DS patients. The Candida albicans abundance was radically reduced after the a-PDT application.

Keywords: edentulous; Candida albicans; complete denture; low-level laser therapy; oral health impact profile; quality of life

1. Introduction

Oral disorders, whether localized or generalized, can affect speech, function, nutritional status, and appearance, which can lead to a reduction in social interactions and family life [1]. The "oral health-related quality of life (OHRQoL)" questionnaire emphasizes the aspects of people’s lives affected by oral disease. The OHRQoL not only analyzes pain and physical functioning but also evaluates life satisfaction and social and psychological functioning [2].

Conventionally, patient management in dentistry and medicine is based on the clinical signs and symptoms of a particular disease by the clinicians, with less contribution from patients [3]. As patients can convey facts regarding changes in their social life and oral functions because of painful oral conditions, patient-based outcomes can be a component of the decision-making process [4,5]. Currently, the impact of edentulism and denture prescription on quality of life is increasingly recognized as an important component of therapy and outcome measures in clinical trials [6]. In this regard, denture stomatitis (DS) is one of the most prevalent oral lesions. The swelling, erythema, and edema of the oral mucosa covering the hard and soft palate are the obvious signs and symptoms of DS and...
may not be diagnosed or treated expeditiously [7]. Denture stomatitis, an inflammation of the denture-bearing mucosa, can be caused by various factors, including poor denture hygiene, Candida albicans overgrowth, and trauma. Its classifications include simple DS, characterized by erythema, edema, and sometimes pain; Candida-associated DS, with erythema, edema, and pseudomembrane formation; angular cheilitis, an inflammation of the skin at the mouth’s corners; and linear gingival erythema, a red, edematous, and sometimes painful inflammation of the marginal gingiva. A specific classification depends on an individual’s presentation. The prevalence rate of denture stomatitis among denture wearers varies widely depending on the study population, with estimates ranging from 15% to over 60% [8]. The etiology of the disease is unclear but is closely associated with a carbohydrate-rich diet, poor oral hygiene, vitamin deficiency, and the judicious wearing of dentures. It is more prevalent in immunocompromised patients. The opportunistic organism Candida albicans is commonly associated with denture stomatitis. The organism is mostly found on denture surfaces and the oral mucosal lining, especially in the posterior tongue region [9].

Denture stomatitis commonly appears and affects the elderly population with dentures, and the inflammatory lesion negatively affects their quality of life [6,9]. The orthodox treatment for DS is antifungal drugs administered through topical and systemic routes [7]. The use of antifungal therapy comes with side effects. The long-term use of such drugs may lead to the development of microorganism strains that are resistant to the therapy and the recurrence of DS [10]. The optimal treatment has not been proposed in general; however, the application of contemporary techniques and equipment can deliver effective approaches. They may provide safe, efficient, user-friendly, and cost-effective treatment methods without the disadvantages of topical or systemic antifungal medication [11].

Anti-microbial photodynamic therapy (a-PDT) with various dyes and wavelengths is considered a contemporary method alongside low-level laser therapy. The a-PDT stimulates the “biological cell’s chromophores at appropriately low doses of visible wavelength light, which causes the generation of reactive oxygen species (singlet oxygen and superoxide’s)” [12,13].

It is a proven fact that DS is caused by the superficial proliferation of Candida species, which makes them accessible to photodynamic photons [14]. The principal advantage of using a-PDT is that it does not require the maintenance of a high level of drug dose, unlike topical and systemic antifungal drugs. A-PDT is beneficial even in the management of recurrent candidal infections. In this way, photodynamic therapy is considered safe and more effective in the management of DS [15]. The effect of photobiomodulation (PBM) is considered similar to that of fungicidal therapy in terms of efficacy. However, it is recommended to irradiate the palatal soft tissue alongside the acrylic denture base for a better outcome [16].

To describe the biological effect of a-PDT, Cardeira CD et al. [17] exposed human blood contaminated with Candida albicans to a laser with a 660–678 nm wavelength and 40 Mw power. The a-PDT with 660 nm light was more effective than that with 780 nm light as a fungicidal agent. Furthermore, this finding was substantiated by Simunovic-Soskic et al. [18], who achieved fungicidal activity at 685 nm with light with a power of 30 Mw applied to DS cases. Moreover, the study by Paz-Cristobal et al. [19] claimed that PBM applied with hypericin and dimethylene blue was found to be effective in eliminating fluconazole-resistant Candida albicans strains. The authors believe that the data available on the oral health-related quality of life (OHRQol) of DS patients treated with this modality seem to be sparse and not rationalized. Therefore, the working hypothesis was as follows: does OHRQol improve in DS patients treated with a-PDT? The purpose of the present study was to assess the effect of photobiomodulation therapy on the oral health and quality of life of denture stomatitis patients.
2. Materials and Methods

2.1. Ethical Disclosure and Informed Consent

The ethical approval was acquired from the research review committee of the Center for Specialist Dental Practice and Clinical Research (UDCRC/040/021). All participants included in the research provided informed consent and were able to leave the study without consequences. The patients were recruited from a private dental practice.

2.2. Sample Size Estimation

In the present study, the sample size was identified by employing the mean and standard deviation values for oral health-related quality of life after photodynamic therapy (18.4 ± 4.8) and distilled water application (24.45 ± 8.6) from a previous similar study. Employing a sample size calculation with a 95% confidence interval and 80% power using OpenEpi, Version 3 (mean difference method), an approximate sample size of 42 was determined.

2.3. Subject Criteria

Inclusion criteria:

- Complete denture-wearing patients: To ensure that all participants have DS. Denture stomatitis is caused by irritation of the denture-bearing mucosa, so only patients who wear dentures are at risk of developing the condition.
- Age range from 40 to 65 years: To control for age-related factors that could affect the development of DS.
- Diagnosed with denture stomatitis (DS) characterized by mucosal burning, erythema, and a loss of filiform papillae: To ensure that all participants have DS and that the severity of their DS is comparable.

Exclusion criteria:

- Systemic diseases, including diabetes, heart problems, cancer, or AIDS: These diseases can affect the immune system and make patients more susceptible to infections, including Candida albicans infections.
- Pregnancy: Pregnancy can affect the oral microbiome, which could potentially affect the development of DS.
- Routine illness history: Patients with a history of routine illnesses may have impaired immune systems, which could make them more susceptible to DS.
- Multi-pharmacy or antibiotic use in the last 2 months: Medications, especially antibiotics, can affect the oral microbiome, which could potentially affect the development of DS.

2.4. Candida Sampling and Culture

Candida spp. was confirmed by using a microbiological culture. The sampling process involved obtaining swabs from the maxillary complete denture prosthesis and mucosa, each deposited in 5 mL of 0.9% sterile saline. Following this, vortexing (vortex mixer 0 to 3400 rpm, Cole-Parmer, Vernon Hills, IL, USA) for 60 s facilitated the efficient extraction of microorganisms into the liquid medium. The resulting liquid was directly used for the microbiological culture, with a portion transferred to CHROMagar Candida (CHROMagar Candida, Belgium, France) culture plates for texture, color, and morphology evaluation. Incubation at 37 °C for 24 h allowed Candida colonies to develop. The samples were carefully transported to the laboratory at a controlled temperature of 2–8 °C (refrigerated conditions) to preserve the viability of the collected microorganisms. The subsequent steps included colony counting, morphological assessment, and Gram staining on the grown colonies, providing a comprehensive analysis of the fungal load and characteristics.
2.5. Photobiomodulation Application

For all the included patients, the surface of the denture and palatal mucosa were sprayed with a methylene blue (MB) photosensitizer (ExSyn, Mumbai, India) at a concentration of 450 µg/mL mixed in water. After 10 min of spraying, irradiation was carried out using a gallium–aluminum–arsenide (GaAlAs) diode laser. The laser was systematically moved across the entire surface of the denture to ensure comprehensive coverage. Both the anatomical structure of the palatal mucosa and the intaglio surface of the denture prosthesis were exposed to the laser. The characteristics of the applied laser, including the wavelength (660 nm (nm)), energy density (28 J/cm²), laser output (100 mW (mW)) power, and mode of transmission (continuous), were standardized. After treatment, the prosthesis was bathed in clean water and dried on absorbent paper. The PBM treatment was carried out 2 times a week with 72 h intervals for a period of 8 weeks. To optimize the therapeutic effect while minimizing potential damage to surrounding healthy tissues, the operator systematically directed the laser beam to different points on the anatomical structures during the irradiation process. Additionally, all patients were advised to scrub the dentures under running water with a soft toothbrush after meals and bedtime and soak the dentures overnight in clean water.

2.6. Oral Health-Related Quality of Life Assessment

The questionnaire used in the present study assessed the demographic data of the participants, including age, gender, education (primary (up to standard five), secondary (up to standard nine), and tertiary education), marital and socioeconomic status, oral habits, and smoking status. The oral health-related quality of life (OHRQoL) of all patients was assessed before and after PDT treatment. OHRQoL was evaluated using the OHIP-EDENT. The questionnaire was scored between 0 and 76, and the higher the score, the lower the OHRQoL. It was available in the English and Arabic languages. The main domains assessed in the questionnaire were functional limitation (FL), physical pain (P1), psychological discomfort (P2), physical disability (D1), psychological disability (D2), social disability (D3), and handicap (H). The oral health impact profile for the edentulous patients questionnaire comprised 19 items and 5 responses: never (1), hardly ever (2), occasionally (3), fairly often (4), and very often (5). The Candida counts from the palate and denture surfaces were estimated as a colony-forming unit (CFU/mL). The CFU was assessed at baseline, 15, 30, and 60 days.

2.7. Statistical Analysis

The data were tabulated and assessed using the Statistical Program for the Social Sciences (Version 26, SPSS, IBM, CA, USA). A Shapiro–Wilk test was used to assess the normal distribution of the obtained data. A Candidal CFU comparison among groups was performed with the Wilcoxon test. Demographic data and OHIP-EDENT responses were evaluated with descriptive statistics and t-tests, respectively.

3. Results
3.1. Participants Recruitment

A flow diagram presenting the participant recruitment process is shown in Figure 1. Eighty-two edentulous patients with DS were assessed for eligibility for the study. Forty patients were excluded based on the exclusion criteria. One participant not willing to participate declined the invitation. Upon follow-up, one participant did not respond. Therefore, 40 participants were included in the study (27 males (67.5%) and 13 females (32.5%)). The mean age of the participants was 54.20±15.39 years.
Figure 1. Flow diagram of the study’s methodology and patient recruitment process.

3.2. Baseline Characteristics

The baseline characteristics of the participants are shown in Table 1. The majority of the participants (15 (37.5%)0 had a middle socioeconomic status, and as far as education level is concerned, 34 (85%) participants were literate. Eleven denture stomatitis patients had cigarette smoking habits. A water pipe and electronic cigarette smoking habit were prevalent in five (12.5%) and three (7.5%), respectively. Out of the total, 19 (47.5.5%) patients were smokers, and 18 (45%) denture stomatitis patients were nonsmokers.

Table 1. Distribution of demographic factors among participants.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Variable</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marital status</td>
<td>Unmarried</td>
<td>14 (35)</td>
</tr>
<tr>
<td></td>
<td>Married</td>
<td>26 (65)</td>
</tr>
<tr>
<td></td>
<td>Illiterate</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Education</td>
<td>Primary/Middle</td>
<td>8 (20)</td>
</tr>
<tr>
<td></td>
<td>High school</td>
<td>15 (37.5)</td>
</tr>
<tr>
<td></td>
<td>College</td>
<td>11 (27.5)</td>
</tr>
<tr>
<td></td>
<td>No response</td>
<td>6 (15)</td>
</tr>
<tr>
<td>Socioeconomic status</td>
<td>Low</td>
<td>13 (32.5)</td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>15 (37.5)</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>13 (32.5)</td>
</tr>
<tr>
<td>Habits</td>
<td>Cigarette smoking</td>
<td>11 (27.5)</td>
</tr>
<tr>
<td></td>
<td>Waterpipe smoking</td>
<td>5 (12.5)</td>
</tr>
<tr>
<td></td>
<td>Electronic cigarette</td>
<td>3 (7.5)</td>
</tr>
<tr>
<td>Smoking</td>
<td>Past smoker</td>
<td>3 (7.5)</td>
</tr>
<tr>
<td></td>
<td>Smoker</td>
<td>19 (47.5)</td>
</tr>
<tr>
<td></td>
<td>Nonsmoker</td>
<td>18 (45)</td>
</tr>
</tbody>
</table>

n: frequency, %: percentage.
3.3. Periodic Comparison after Photodynamic Intervention

The overall CFU/mL values were higher in the dentures of the patients than the palates. A reduction in the mean CFU count was observed in all three instances of PBM application. The CFU count was reduced from $5.56 \pm 2.15$ CFU/mL (baseline) to $3.17 \pm 2.77$ CFU/mL by day 60. Similarly, the impact of the a-PDT application on the intaglio denture surface showed a reduction from day 0 ($38.83 \pm 14.71$ CFU/mL) to $29.05 \pm 15.52$ CFU/mL on day 60. A significant difference ($p \leq 0.05$) was found for *Candida albicans’s* abundance in the denture and palatal mucosa over the 0-to-60-day period. The effect size was $0.71$ CFU/mL on the palatal mucosa and $1.74$ CFU/mL on the dentures (Table 2).

### Table 2. Mean candidal counts in CFU/mL found on palates and dentures following PDT.

<table>
<thead>
<tr>
<th>DS Trt</th>
<th>Site</th>
<th>Follow-Up</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td>PDT</td>
<td>Palate</td>
<td>Day 0</td>
<td>3.56 ± 2.15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Day 15</td>
<td>4.34 ± 2.20 *</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Day 30</td>
<td>3.48 ± 2.48 †</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Day 60</td>
<td>3.17 ± 2.77 †</td>
</tr>
<tr>
<td></td>
<td>Denture</td>
<td>Day 0</td>
<td>38.83 ± 14.71</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Day 15</td>
<td>33.75 ± 16.13 *</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Day 30</td>
<td>25.66 ± 18.10 †</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Day 60</td>
<td>29.05 ± 15.52 *</td>
</tr>
</tbody>
</table>

* significantly different from baseline ($p < 0.05$); † significantly different from day 15 ($p < 0.05$). PDT: photodynamic therapy; DS Trt: denture stomatitis treatment; CFU: Colony-forming units.

3.4. Comparison of OHIP-EDENT Scores before and after Photobiomodulation Therapy

The comparison of the OHRQoL status pre- and post-a-PDT intervention is described in Table 3. Overall, the OHRQoL was improved in the post-treatment phase. A significant difference ($p < 0.05$) was found in function improvement as well as a reduction in physical pain, psychological discomfort, physical disability, and social interaction among the participants. Moreover, no significant post-treatment improvement ($p > 0.05$) compared to the baseline OHIP-EDENT scores was observed in the psychological disability and handicap domain scores. Nonetheless, a significant difference was found in the mean OHIP-EDENT scores ($p < 0.05$); see Figure 2.

![Figure 2](image-url)
Table 3. Pre- and post-treatment scores of OHIP-EDENT domains.

<table>
<thead>
<tr>
<th>Domains</th>
<th>Pre-Treatment Score Mean (SD)</th>
<th>Post Treatment Score Mean (SD)</th>
<th>Comparison (p-Value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functional limitation (FL)</td>
<td>12.80 ± 4.11</td>
<td>10.87 ± 3.83</td>
<td>&lt;0.05 *</td>
</tr>
<tr>
<td>Physical pain (P1)</td>
<td>12.75 ± 3.06</td>
<td>10.08 ± 3.70</td>
<td>&lt;0.05 *</td>
</tr>
<tr>
<td>Psychological discomfort (P2)</td>
<td>5.44 ± 2.0</td>
<td>4.11 ± 1.32</td>
<td>&lt;0.05 *</td>
</tr>
<tr>
<td>Physical disability (D1)</td>
<td>9.61 ± 3.05</td>
<td>8.03 ± 2.17</td>
<td>&lt;0.05 *</td>
</tr>
<tr>
<td>Psychological disability (D2)</td>
<td>4.53 ± 1.80</td>
<td>4.38 ± 2.40</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Social disability (D3)</td>
<td>4.60 ± 1.37</td>
<td>5.08 ± 1.15</td>
<td>&lt;0.05 *</td>
</tr>
<tr>
<td>Handicap (H)</td>
<td>3.36 ± 2.51</td>
<td>3.05 ± 2.41</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Total</td>
<td>53.09 ± 2.70</td>
<td>45.6 ± 2.42</td>
<td>&lt;0.05 *</td>
</tr>
</tbody>
</table>

* * p < 0.05 shows significant difference; SD: standard deviation.

4. Discussion

Quality of life (QoL) assessment has an important place in health care and has proven to be an endpoint in clinical studies conducted recently. The effects of illness on QoL can be related to the impairment, disability, and handicap models of disease [20]. QoL is considerably interlinked with oral health status. OHRQoL mainly focuses on those characteristics of human life that are affected by dental care and oral health [5]. Poor oral health produces impaired OHRQoL. The clinical manifestation of DS that develops with denture use has been shown previously to have a negative impact on OHRQoL [21]. This study assesses the effect of photobiomodulation therapy on OHRQoL in denture stomatitis patients. The outcome of the study accepts the working hypothesis.

The present study focused on the examination of OHIP-EDENT questionnaire items to evaluate both poor and improved oral health-related quality of life in patients with DS treated with PBM (with a gallium–aluminum–arsenide (GaAlAs) diode laser). The score of various domains in the OHIP-EDENT scale was better in the post-treatment phase compared to the pre-treatment period. This finding was in accordance with previous results, as shown by Paz Cristobal et al. [19], where a-PDT was applied to treat DS patients. This study could not be compared with the current study in a true sense, as a subjective assessment of OHRQoL was not performed. A quality of life analysis post-treatment has been used with removable dentures, fixed partial dentures, dental implants, and oral hygiene by various investigators [1,6,21], but data on the photobiomodulation (PBM) management of DS patients are not available.

The OHIP-EDENT scale items were divided into seven theoretical domains, namely functional limitation, pain, psychological discomfort, physical disability, psychological disability, social disability, and handicap [22]. In this study, oral health-related quality of life was better in patients treated with PBM. The functional limitation score of 10.87 ± 3.83 was promising, obtained after PBM application, and its difference from the pretreatment scores was significant. Similarly, the physical pain, psychological discomfort, physical disability, and social disability scores were better post-PBM in both the denture and tissue applications, which explained why function, physical symptoms, and psychosocial symptoms significantly improved in the second round of PBM application by day 30 and onwards. This was well supported by the reduction in the CFU count on the denture surface. The CFU count was reduced by a factor of 10 from the baseline to day 60. The psychological disability and handicap scores of the patients were not improved after PBM application, and the mean scores were found to be similar. This finding was similar to studies conducted by Mumco et al. [23] and Al-Omiri et al. [24], where patients with stomatitis were managed with steroids and immunosuppressive drugs. They found improvements in the quality of life of patients suffering from Behcet’s disease and recurrent aphthous stomatitis. However, the lack of data on OHRQoL assessment in stomatitis patients with PBM application does
not allow for a fair comparison with our study. Further researches on QoL assessment and PBM application are necessary to substantiate the outcome of this study.

In this study, PBM was applied at 15, 30, and 60 days on palatal tissue and intaglio denture surfaces with a wavelength of 660 nm, an energy density of 28 J/cm$^2$, and a laser output of 100 W to combat DS. The modality adopted in the present study has been used by several investigators in the past. Maver-Biscanin et al. [25] analyzed the effectiveness of two different wavelengths of PBM (685 and 830 nm). The two wavelengths were compared with a placebo treatment and miconazole. The outcome revealed that the colony count of *Candida albicans* in the culture medium was reduced significantly with both wavelengths of the laser. The justification for evaluating various wavelengths was based on a study by Nussbaum et al. [26], in which PBM with wavelengths of 630, 660, 810, and 905 was analyzed on different microbial species. The results showed that the bacterial species examined showed variability in terms of sensitivity to PBM irradiation, and this variation was dependent on the course of time and radiation energy applied. Studies evaluating oral health-related quality of life post-PBM are limited, and there is a need to clarify the impact of this protocol on satisfaction and quality of life. Additionally, Nussbaum et al. reported that low-level laser therapy applied at a 660 nm wavelength provided an inhibition of bacterial growth when compared with an 810 nm wavelength application of lasers. However, Maver-Biscanin et al. proposed that a higher wavelength of PBM provides a better effect against DS caused by fungi compared to bacteria. They used laser therapy at 685 and 830 nm against *Candida albicans*. The high wavelength requirement might have been due to the biological characteristic of *Candida albicans*, which is different from bacterial species. The fungal cell wall has a thick layer of beta-glucan and chitin that provides a permeability barrier against laser rays [25].

Seyedmousavi et al. [27] emphasize the energy level of the laser, and they applied PDT on *Candida albicans* with 685 and 830 nm wavelengths at different energy levels (3, 5, 10, and 20 J). In this study, the energy density level was kept at 28 J/cm$^2$. Their outcome was similar to our study and the study by Maver-Biscanin et al. [25]. The optimum PBM efficacy was obtained in their study with an energy level of 10 J. The study described that the antifungal activity of PBM was linked with fluctuations in the intracellular fluid levels within an organism, which cause disruption to the cell membranes. It was suggested that the application of PBM at various wavelengths was absorbed by a special pigment (chromophores) in fungi, which causes stress and growth inhibition. They also concluded that irradiation exposure of the denture base and soft tissue with 10 J of energy should be directly applied without the use of a methylene blue photosensitizer at a concentration of 450 µg/mL [25].

Contrary to these studies, some researchers have stated that *candida albicans* cells are resistant to radiation wavelengths and are not affected by PBM [25,28]. To serve this purpose, target microorganisms should be sensitized first by the application of dyes. The reactive oxygen components produced accelerated the perforation of the cell membrane, fastening the translocation of photosensitizer molecules into the cell and causing photodamage to the internal cell organelles [25]. It is also reported that the dyes might be lethal to the microorganisms even in the absence of irradiation [29]. However, clinical and laboratory trials have described different results. For instance, Merigo et al. [30] investigated the effect of PBM at various wavelengths in a clinical study with and without “erythrosine, curcumin, and toluidine blue” dyes at 405, 532, and 650 wavelengths on fungi. They reported that PBM with erythrosine and curcumin with blue laser light alters the molecules intracellularly, which decreases the antifungal activity of low-level laser therapy. However, Aziz et al. [31] claimed that laser irradiation at 808 nm with indocyanine green dye potentially reduces the growth of *Candida albicans*. These findings are in accordance with the current study, where the fungicidal activity of PBM is substantiated by the prior application of a methylene blue photosensitizer at a concentration of 450 µg/mL for 10 min. Mima et al. [32] analyzed the clinical outcome and mycological effectiveness of PBM and nystatin in denture stomatitis patients. The study revealed no difference in the antifungal activity of...
both Nyatatin and PBM. Maciel et al. [28], with a similar methodology to our study, applied PBM with methylene blue and miconazole to dentures and soft tissues to manage DS. The methods of Maciel et al. [28] were different from those of Mima et al. [32]. The former study used methylene blue dye in the first appointment, whereas the other sessions were solely conducted with only PBM. However, Mima et al. [32] applied PBM with a photosensitizer agent three times a week for 15 days, with six sessions overall. Maciel et al. [28] reported a 40% decrease in *Candida albicans* from a palatal mucosal smear with PBM, while, on the other hand, the clinical signs and symptoms were improved by 80% in the miconazole group. Additionally, in the miconazole group, the recurrence was lower at 12.5% compared to the PBM group at 25%.

The findings of this study revealed that the application of PMB drastically improves stomatitis in denture wearers. Furthermore, PBM therapy also improves the OHRQoL in such patients. However, the outcome needs further clarity, for which additional investigations with trials are needed to compare the clinical efficacy of PBM with the *Candida albicans* reduction count. We assume that since PBM affects the cell membrane of microorganisms, the modification of the membrane in response to environmental stimuli may alter it and reduce the sensitivity of fungi to the laser treatment. Furthermore, as proven, the fungi keep an extracellular biofilm as a mechanical barrier to chemical agents, which may substantiate the microorganisms defense against any antifungal agents.

This study, with a strong methodology and a focus on patient perception, outlines the importance of PBM in DS treatment, but despite its strengths, we met some limitations. The study outcome was based on a laboratory analysis of the CFU counts of *Candida albicans* only, which does not provide a clinical correlation or focus on the risks or side effects of PBM, which may appear in the long run. Furthermore, the PBM could not be compared with other chemical or antifungal agents to produce an unbiased outcome. The use of PBM could produce radiation. The nonionizing radiation could be a direct physical hazard to dermal cells and the retina. The chemical agent used for photosensitization may cause skin hazards through subcutaneous absorption; it can also pose risks from ingestion and inhalation exposures [11]. Further investigation is warranted to explore the safe use of PBM with the recommendation of a protection protocol for staff to overcome occupational hazards. Another possible limitation of this study is related to the use of the OHRQoL tool to assess patient perception. Such studies are based on subjective responses that can be influenced by the psychological and behavioral attitudes of a patient. Further clinical studies supported by a patient opinion evaluation (OHRQoL) with a homogenous group distribution, a larger sample size, and strict inclusion criteria comparing PBM with conventional antifungal therapies are recommended.

5. Conclusions

Oral health-related quality of life was significantly improved in denture stomatitis patients after a-PDT-assisted management. a-PDT has a significant role in the treatment of denture stomatitis patients. The modality seemed to be successful in reducing the CFU/mL count of *Candida albicans* in both palatal tissues and denture surfaces. Additional clinical trials focusing on an antifungal comparison of a-PDT with other therapeutic agents and an evaluation of clinical indicators are suggested.


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**Institutional Review Board Statement:** Ethical approval was acquired from the research review committee of the Center for Specialist Dental Practice and Clinical Research (UDCRC/040/021).

**Informed Consent Statement:** All included patients consented to their inclusion in the project/study. The participants were able to leave the project without any consequences.
Data Availability Statement: The data for the study can be acquired through a request to the corresponding author.

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Abbreviations

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<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tr>
<td>a-PDT</td>
<td>Antimicrobial photodynamic therapy</td>
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<td>DS</td>
<td>Denture stomatitis</td>
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<td>OHRQoL</td>
<td>Oral health-related quality of life</td>
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<td>OHIP-EDENT</td>
<td>Oral health impact profile for edentulous patients</td>
</tr>
<tr>
<td>PBM</td>
<td>Photobiomodulation</td>
</tr>
<tr>
<td>MB</td>
<td>Methylene blue</td>
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