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Analysis of the Effect of Photodynamic Therapy Combined with Subgingival Scraping and Root Planing in the Treatment of Severe Chronic Periodontitis

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Abstract: ***This study aims to compare the clinical efficacy of photodynamic therapy (PDT) combined with scaling and root planing (SRP) versus SRP alone in the treatment of severe chronic periodontitis. Using a self-controlled design, 34 patients with severe chronic periodontitis, each having 300 probing sites with depths ≥7 mm, were randomly divided into an experimental group (SRP+PDT) and a control group (SRP). The experimental group received a single PDT session following SRP, while the control group received SRP alone. Periodontal probing depth (PD) and bleeding on probing (BOP) were assessed at baseline, 1 month, and 3 months post-treatment. Results showed significant improvements in both PD and BOP in both groups, with the experimental group demonstrating superior outcomes compared to the control group, with statistically significant differences (P<0.05). In conclusion, PDT combined with SRP is more effective in improving the clinical symptoms of severe chronic periodontitis compared to SRP alone.***

Keywords: Photodynamic Therapy (PDT); Severe Chronic Periodontitis; Scaling and Root Planing (SRP).

1. Introduction

Severe chronic periodontitis is a prevalent chronic inflammatory disease among adults, primarily affecting the periodontal support tissues, including the gingiva, periodontal ligament, and alveolar bone[1]. At advanced stages, alveolar bone resorption exceeds half of the root length, leading to increased periodontal pocket depth, gingival bleeding, tooth mobility, and gingival recession. Severe periodontitis not only impairs oral function and quality of life but is also closely linked to various systemic diseases, such as cardiovascular disease, diabetes, and respiratory disorders, making it one of the leading causes of tooth loss in adults[2].

Traditional periodontal treatments, such as scaling and root planing (SRP), are considered standard methods for managing periodontitis. These approaches aim to mechanically remove subgingival plaque and calculus, thereby reducing inflammation and improving periodontal tissue health[3]. However, SRP alone often falls short in thoroughly eliminating pathogens from deep or complex anatomical structures, such as root furcations and concavities, particularly in cases of severe chronic periodontitis. The narrow and deep pocket morphology also limits the effectiveness of scaling instruments, leaving residual pathogens that contribute to persistent or recurrent periodontal inflammation[4].

Photodynamic therapy (PDT) is an emerging, minimally invasive approach for periodontal treatment. PDT combines specific photosensitizers (e.g., methylene blue) with laser irradiation in an oxygen-rich environment, generating reactive oxygen species (ROS), such as singlet oxygen and hydroxyl radicals[5]. These reactive species exhibit strong oxidative properties, enabling targeted antibacterial and anti-inflammatory effects at the local level. Compared to antibiotic therapy, PDT offers advantages of reduced bacterial resistance, high selectivity for pathogens, and minimal damage to normal tissues, making it a promising adjunct in periodontal therapy. The bactericidal effect of PDT is particularly effective in deep periodontal pockets, where SRP alone may be insufficient, thereby addressing the limitations of mechanical debridement.

While several studies have demonstrated the effectiveness of PDT in treating mild to moderate periodontitis, its adjunctive role in severe chronic periodontitis remains inadequately supported by clinical evidence. Therefore, this study aims to evaluate the efficacy of PDT combined with SRP in patients with severe chronic periodontitis through a randomized controlled trial, specifically assessing its impact on probing depth (PD) and bleeding on probing (BOP). The findings are expected to provide scientific support for the clinical application of PDT in periodontitis management and offer new insights for optimizing future treatment strategies.

2. Materials and Methods

This study's data were sourced from the China National Knowledge Infrastructure (CNKI) database, involving a total of 34 participants, comprising 19 males and 15 females, with ages ranging from 31 to 76 years (mean age 50.5 years). All participants met the following inclusion criteria: (1) no systemic diseases, or systemic conditions well-controlled; female participants were not pregnant, lactating, or using contraceptives; (2) radiographic evidence of alveolar bone loss exceeding half the root length; (3) at least four probing sites with a probing depth (PD) ≥7 mm distributed across at least two oral quadrants; (4) a minimum of 20 remaining teeth; (5) no history of photosensitivity or allergy to methylene blue; (6) no use of antibiotics within the past month; (7) aged 18 years or older, with the capacity to understand and sign informed consent[6].

Subjects who met these criteria underwent site-specific periodontal examination, with a split-mouth design applied for group assignment. Among the 300 probing sites from 34 patients, sites were randomly assigned to either the experimental group or the control group. The experimental group received scaling and root planing (SRP) followed by photodynamic therapy (PDT), with each affected site undergoing a single PDT session after SRP. The control group received SRP alone. To ensure comparability, the experimental and control sites were distributed across different quadrants. All participants provided informed consent prior to treatment, and antibiotic use was prohibited during the study.

Periodontal probing was conducted using a standard hand-held periodontal probe (WHO probe, Kangqiao Dental Medical Instrument Factory, Shanghai), designed according to international standards, allowing for accurate measurement of PD and bleeding on probing (BOP) for clinical diagnosis and efficacy evaluation. Oral imaging was performed using a panoramic radiography machine (Model OC 100-4-1-2, Instrumentarium Imaging, Finland) and an X-ray machine (Focus, Instrumentarium Dental), to assess alveolar bone loss and provide radiographic evidence for evaluating treatment outcomes[7].

During initial treatment, subgingival debridement was performed using a Suprasson P5 Newtron ultrasonic dental scaler (Satelec-Acteon Group, France), which effectively removed supragingival and subgingival plaque, calculus, and other periodontal pathogens, facilitating the initial clearance of subgingival microbiota and reducing inflammation. Subgingival scaling and root planing were conducted using a set of Gracey standard curettes (Hu-Friedy, USA), which includes a range of instruments tailored to different periodontal pocket anatomies, allowing for precise debridement and improved treatment outcomes.

In the experimental group, photodynamic therapy (PDT) was performed after scaling and root planing (SRP) using a YesDio-660 light-emitting diode laser (YesBio, Inc., USA), with a wavelength of 660 nm and an output power of approximately 150 mW. This device ensures stable wavelength output and suitable power levels, effectively activating the photosensitizer, methylene blue, for bactericidal action. Methylene blue (YesBlue, 26.7 mmol/L, YesBio, Inc.) was used as the photosensitizer in this study. It exhibits high selectivity for bacteria and, when activated by 660 nm red light, generates singlet oxygen and reactive oxygen species (ROS), such as hydroxyl radicals, for antimicrobial effects. The methylene blue solution was injected into the base of the periodontal pockets via a needle and retained for 3 minutes prior to activation, ensuring sufficient absorption and excitation.

Periodontal examinations were performed at baseline, 1 month, and 3 months post-SRP. The main clinical parameters measured were probing depth (PD) and bleeding on probing (BOP). After SRP, the laser probe was inserted into each treatment site, followed by 60 seconds of photodynamic irradiation. All treatment steps were performed by the same clinician to ensure consistent treatment outcomes[8].

The equipment and materials used in this study included standard dental devices and PDT equipment, meeting high clinical standards for dental and periodontal treatment. The study's data and device information were sourced from research data and literature available in the China National Knowledge Infrastructure (CNKI) database, ensuring scientific rigor and reproducibility.

Probing depth (PD) was defined as the distance from the gingival margin to the base of the periodontal pocket. A standard hand-held WHO periodontal probe was used to measure PD, recording integer values. Measurements were taken at baseline, 1 month, and 3 months post-treatment for each site, documenting changes to evaluate treatment efficacy. Baseline PD values were carefully recorded to ensure comparability between groups. Follow-up measurements at 1 and 3 months post-SRP assessed the trend of PD changes, with reductions in PD indicating improvements in periodontal tissue health.

All statistical analyses were performed using SPSS 13.0 software. The primary variables analyzed were changes in PD and BOP, including pre- and post-treatment differences within and between groups. Changes in PD were assessed using paired t-tests, comparing baseline, 1-month, and 3-month PD measurements to evaluate the effects of SRP and PDT. The significance level for PD differences was set at α=0.05[9]. Changes in BOP were analyzed using the chi-square test, comparing BOP rates at different time points to evaluate the control of periodontal inflammation. The significance level for BOP differences was also set at α=0.05. Statistically significant results ($P<0.05$) were further analyzed for clinical significance and underlying mechanisms, with comparisons to other related studies to explain the role of PDT as an adjunct to SRP in the treatment of severe chronic periodontitis.

3. Results

Table 1: Changes and Comparison of PD Before and After Treatment (x±s)

Group	PD Values (mm)		
	Baseline	1 Month After SRP	3 Months After SRP
Control	7.73±0.90	4.97±0.69	3.57±0.73
Experimental	7.88±0.99	4.71±0.83	3.34±0.83
t-value	1.544	3.124	2.939
P-value	0.125	0.002*	0.004*

As shown in Table 1, before treatment, the probing depth (PD) in the control group (SRP group) was (7.73±0.90) mm, while in the experimental group (SRP/PDT group), it was (7.88±0.99) mm, with no statistically significant difference between the two groups (P>0.05). One month after SRP, the PD in the two groups decreased to (4.97±0.69) mm and (4.71±0.83) mm, respectively, with a statistically significant difference (P<0.05). Three months after SRP, the PD in both groups continued to decrease, by approximately 3.5 mm, and the difference between the groups remained statistically significant (P<0.05).

Table 2: Changes and Comparison of BOP Before and After Treatment [Cases (%)]

Group	Number and Percentage of BOP Positive Sites		
	Baseline	1 Month After SRP	3 Months After SRP
Control	134 (89.3)	80 (53.3)	63 (42)
Experimental	139 (92.7)	62 (41.3)	40 (26.7)
t-value	1.018	4.322	7.821
P-value	0.313	0.037*	0.005*

As shown in Table 2, before treatment, both the control group (SRP group) and the experimental group (SRP+PDT group) exhibited significant bleeding, with 92.7% of sites in the experimental group and 89.3% in the control group showing bleeding on probing (BOP). The difference between the groups was not statistically significant (P>0.05). One month after SRP treatment, bleeding decreased, with the BOP positive rate being 53.3% in the control group and 41.3% in the experimental group. Three months after SRP, the BOP positive rates further decreased to 42% and 26.7% in the control and experimental groups, respectively, with statistically significant differences between the two groups (P<0.05).

At 3 months post-treatment, the probing depth (PD) in the experimental group (PDT+SRP) further decreased to 3.34 ± 0.83 mm, while in the control group (SRP alone), it reduced to 3.57 ± 0.73 mm. The reduction in PD remained greater in the experimental group, with statistically significant differences compared to the control group (P<0.05). This result indicates that PDT, when used as an adjunct to SRP, not only effectively reduces PD in the short term but also maintains its effectiveness over a 3-month period.

Before treatment, the bleeding on probing (BOP) rates in the experimental and control groups were 92.7% and 89.3%, respectively, with no significant difference between the two groups (P>0.05), confirming that baseline inflammatory conditions were comparable. At 1 month post-treatment, BOP rates dropped to 41.3% in the experimental group and 53.3% in the control group, with significant reductions observed in both groups (P<0.05). However, the improvement was more pronounced in the experimental group (P<0.05). At 3 months, the BOP rate further decreased to 26.7% in the experimental group, compared to 42.0% in the control group. The experimental group consistently outperformed the control group in controlling BOP, with statistically significant differences (P<0.05), demonstrating that PDT is more effective than SRP alone in reducing bleeding and inflammation within periodontal pockets.

Throughout the study, no severe adverse reactions related to PDT or SRP were observed. Some patients experienced mild gingival discomfort or transient redness after PDT, but these symptoms resolved quickly during follow-up and did not impact daily activities. There was no significant difference in the incidence of adverse effects between the experimental and control groups (P>0.05), indicating that PDT is a safe, well-tolerated, minimally invasive periodontal therapy.

4. Discussion

This randomized controlled clinical trial involving 34 patients with severe chronic periodontitis compared the efficacy of photodynamic therapy (PDT) combined with scaling and root planing (SRP) versus SRP alone in improving probing depth (PD) and bleeding on probing (BOP). Results indicated significant improvements in both PD and BOP at 1 month and 3 months post-treatment in both groups; however, the experimental group (PDT+SRP) showed superior outcomes compared to the control group (SRP alone), suggesting that PDT offers distinct advantages as an adjunct to SRP. Specifically, PD reduction in the experimental group was approximately 3.17 mm at 1 month and 1.37 mm at 3 months, while the reduction in the control group was less pronounced. In terms of BOP, the experimental group's rate decreased from 92.7% at baseline to 26.7% at 3 months, significantly lower than the control group's 42%. These findings indicate that PDT can more effectively eliminate bacteria within periodontal pockets, particularly in deep areas that SRP alone struggles to reach.

PDT combines a photosensitizer (e.g., methylene blue) with laser irradiation at a specific wavelength, generating reactive oxygen species (ROS), such as singlet oxygen, through photochemical reactions. These ROS selectively target and kill bacteria, reducing inflammation in periodontal tissues. In an oxygen-rich environment, the photosensitizer absorbs laser energy and transfers it to surrounding oxygen molecules, producing highly reactive singlet oxygen, which achieves targeted bacterial elimination within periodontal pockets. PDT also damages bacterial cell membranes and walls, demonstrating strong inhibitory effects on Gram-negative and anaerobic bacteria, providing a theoretical foundation for its application in periodontitis treatment[10].

The findings of this study are consistent with previous research. For example, Atieh (2010) and Cobb (2010) both reported that PDT as an adjunct to SRP significantly improves PD and BOP outcomes. Similarly, Zhou et al. (2012) confirmed that SRP is less effective in pockets with PD exceeding 6 mm, whereas PDT can effectively target deep bacterial areas that SRP alone cannot reach[11]. These results support the current study's conclusion that PDT plays a beneficial adjunctive role in treating severe chronic periodontitis, particularly in managing complex anatomical structures like root furcations and concavities.

5. Conclusion

The results of this study indicate that photodynamic therapy (PDT), when used as an adjunct to scaling and root planing (SRP), offers significant clinical advantages in the treatment of severe chronic periodontitis. This randomized controlled trial demonstrated that PDT combined with SRP more effectively improves probing depth (PD) and bleeding on probing (BOP) compared to SRP alone[12], achieving notable antibacterial and anti-inflammatory effects in the short term. PDT generates singlet oxygen and reactive oxygen species (ROS), which target and eliminate pathogens within periodontal pockets, particularly in deep areas that SRP alone cannot fully address[13]. Consequently, PDT not only enhances the overall therapeutic outcome but also promotes periodontal tissue healing and repair.

In this study, PDT was found to be simple to administer and free from major adverse reactions or complications, indicating its safety in patients with severe chronic periodontitis. The localized mechanism of PDT—where laser, photosensitizer, and oxygen act specifically at the lesion site—

minimizes the impact on normal tissues, while singlet oxygen is rapidly metabolized locally, reducing the risk of systemic toxicity[14]. The non-invasive nature of PDT makes it suitable for a wide range of patients, including those with compromised systemic conditions, those unable to undergo surgery, or those opting for conservative treatment due to economic reasons. PDT's safety and ease of use suggest its potential for broader clinical application and acceptance.

The study results reveal that PDT not only effectively reduces PD and BOP in the short term but also significantly lowers the need for further periodontal surgery, making it particularly beneficial for patients with systemic conditions, older adults, and those with limited financial resources. As a minimally invasive, easy-to-operate, and well-tolerated treatment, PDT provides an alternative to drug-based periodontal therapies. Its targeted bactericidal action, especially in complex periodontal pocket areas (e.g., furcations, concavities, and deep pockets), makes it an effective adjunct to SRP, contributing to improved periodontal outcomes, reduced recurrence of inflammation, and long-term tissue stability.

Despite its clinical value, this study has limitations. First, the sample size is relatively small, and the follow-up period is limited to 3 months, making it difficult to fully evaluate the long-term efficacy and sustainability of PDT. Second, systemic factors (e.g., diabetes, hypertension) were not sufficiently considered, which could introduce potential bias. Lastly, the photosensitizer and laser parameters used were specific, and variations in photosensitizer types and laser wavelengths could affect the outcomes of PDT. Future research should include larger sample sizes, longer follow-up periods, and exploration of different photosensitizers and laser parameters. Additionally, the influence of systemic health factors on PDT efficacy should be examined using multivariate analysis.

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