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Original Article

Effects of semiconductor laser combined with compound chlorhexidine- and dexamethasone membrane therapy on periodontal health and gingival crevicular fluid inflammation in patients with chronic periodontal disease

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Abstract: Objective: To explore the effects of a semiconductor laser combined with compound chlorhexidine and dexamethasone membrane in the treatment of chronic periodontal disease, and its effects on periodontal health and gingival crevicular fluid inflammatory factors. Methods: The clinical data of 100 patients with chronic periodontal disease were retrospectively analyzed. According to different treatment methods, they were divided into a conventional treatment group (n=46, receiving conventional periodontal basic treatment) and a combined treatment group (n=54, receiving conventional treatment plus semiconductor laser and compound chlorhexidine-dexamethasone membrane). Periodontal health-related indicators, gingival crevicular fluid inflammatory factor levels, and Oral Health Impact Profile-14 (OHIP-14) scores were compared before and after treatment. The clinical efficacy and occurrence of adverse reactions were evaluated. Results: After treatment, the plaque index, probing depth, sulcus bleeding index, attachment loss, interleukin-6, high-sensitivity C-reactive protein and tumor necrosis factor-αlevels were lower than before treatment, and the OHIP-14 scores were improved (all $P<0.05$), with significantly more improvement in the combined treatment group (all $P<0.05$). The conventional treatment group had higher overall effective rate, shorter symptom improvement time (gingival swelling and pain, bad breath, loose teeth) and lower incidence of adverse reactions (all $P<0.05$). Conclusion: Semiconductor laser combined with compound chlorhexidine and dexamethasone membrane has definite clinical effects for chronic periodontal disease. It can effectively improve periodontal health, reduce the levels of inflammation in gingival crevicular fluid, improve patients' quality of life, and is highly safe.

Keywords: Chronic periodontal disease, semiconductor laser, compound chlorhexidine and dexamethasone membrane, gingival crevicular fluid, inflammatory factors

Introduction

Chronic periodontal disease is a common clinical oral condition, that includes chronic periodontitis and gingivitis. Its pathological characteristics are mainly inflammatory destruction of periodontal supporting tissues such as gums, cementum, and alveolar bone. Without timely intervention and treatment, as the disease progresses, it can lead to alveolar bone resorption, periodontal pocket formation, tooth mobility, and even tooth loss. This not only affects the patient's chewing function and facial appearance, but also stands as the primary cause of tooth loss in adults [1]. Currently, basic treatments such as supragingival scaling and subgingival scaling and root planing are mostly used clinically for chronic periodontal diseases, with the purpose of completely removing plaque and calculus and eliminating inflammation [2]. However, clinical practice shows that for some complex cases, especially those with deep periodontal pockets, anatomic areas that are difficult to reach with instruments, or patients with excessive host response, simple mechanical treatment may have problems such as incom-

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plete debridement, poor inflammation control, and easy recurrence, thereby limiting its effectiveness [3, 4]. Consequently, identifying effective auxiliary treatment options has always been an important direction for clinical research in periodontics.

As a local sustained-release preparation, the compound chlorhexidine-dexamethasone membrane, can maintain a high drug concentration in the periodontal pocket. Dexamethasone has anti-inflammatory and anti-edema effects, while chlorhexidine possesses a broad-spectrum antibacterial effect. The two synergize to enhance the antibacterial effect and inhibit excessive inflammatory response [5]. As a physical auxiliary method, semiconductor laser therapy has shown good application prospects in the clinical treatment of various oral diseases in recent years [6, 7]. This therapy can act on inflammatory lesions through biological stimulation, optical effects, and mechanical effects, promoting the absorption of local inflammation, and promote blood circulation [8]. The combined use of semiconductor laser and compound chlorhexidine and dexamethasone membrane may exert synergistic effects. However, there are currently few clinical reports on the combined treatment of chronic periodontal diseases. In view of this, this study conducted a retrospective analysis to evaluate the clinical effect of semiconductor laser combined with compound chlorhexidine and dexamethasone membrane in assisting periodontal basic treatment of chronic periodontal disease, and to explore its effect on periodontal health and inflammatory factors in gingival crevicular fluid (GCF).

Materials and methods

General information

The clinical data of 100 patients with chronic periodontal disease who were treated in Tongxiang Hospital of Traditional Chinese Medicine from January 2023 to January 2025 were retrospectively analyzed.

Inclusion criteria: (1) meeting the diagnostic criteria for chronic periodontal disease [9]; (2) complete clinical data; (3) disease duration >3 months; (4) age between 18-60 years old.

Exclusion criteria: (1) combined with other oral diseases; (2) pregnancy or lactation; (3) combined with malignant tumors and severe organ dysfunction; (4) allergic reactions; (5) receiving antibiotics or laser treatment within 3 months before enrollment.

The sample size of this single-center retrospective study was determined based on the number of patients who met the inclusion and exclusion criteria. No sample size estimation was performed in advance. In addition, patients and treatment providers were not blinded. However, during the evaluation process of outcome indicators, periodontal-related clinical indicators and scale scores were completed by the same group of medical staff who had been uniformly trained and did not participate in the treatment process to minimize detection bias.

In this study, the change in probing depth (PD) was used as the primary outcome measure. Referring to the method for comparing means of two independent samples, a two-tailed test level of $\alpha=0.05$ and a test power of $1-\beta=0.80$ were set. Based on the estimation of the difference in PD changes and standard deviations between the two groups, the required sample size for each group was approximately 30-40 cases. Actually, 46 patients were enrolled in the conventional treatment group and 54 in the combined treatment group, with a total sample size of 100, which met the requirements for statistical analysis.

According to different treatment methods, patients were divided into a conventional treatment group (n=46, receiving conventional periodontal basic treatment) and a combined treatment group (n=54, receiving conventional treatment plus semiconductor laser and compound chlorhexidine-dexamethasone membrane).

This study was reviewed and approved by the Medical Ethics Committee of Tongxiang Hospital of Traditional Chinese Medicine, and the study design complied with the principles of the Helsinki Declaration. Since this was a retrospective analysis using only existing clinical data, and all data were anonymized before analysis, the Ethics Committee waived the requirement of informed consent.

Methods

All patients received conventional periodontal basic treatment. Subgingival calculus and den-

tal plaque were removed using a scaler, followed by irrigation of residual pathogens, granulation tissue, and other substances around the periodontal pocket with normal saline. The combined treatment group received additional semiconductor laser therapy and compound chlorhexidine dexamethasone membrane on the basis of routine periodontal treatment, with specific procedures as follows. First, semiconductor laser therapy was performed using a semiconductor laser therapeutic apparatus with a wavelength of 810 nm, an output power of 1.5 W, a pulse mode, and a frequency of 10 Hz. The laser was delivered into the periodontal pocket through an optical fiber with a diameter of 300 μm, and scanned slowly in a Z-shaped pattern along the inner wall of the periodontal pocket. The treatment time was adjusted according to the periodontal pocket depth: for pockets with a depth ≥6 mm, each tooth was irradiated for 45 seconds; for pockets with a depth <6 mm, each tooth was irradiated for 30 seconds. Due to individual differences in periodontal pocket morphology and actual irradiation area during clinical treatment, it was difficult to accurately and uniformly calculate the laser energy density. Therefore, this study mainly reports key indices such as laser wavelength, output power, working mode, irradiation time, and optical fiber diameter. After laser irradiation, the periodontal pocket was alternately irrigated with normal saline and 3% hydrogen peroxide. Following irrigation, treatment with compound chlorhexidine dexamethasone membrane (Guizhou Shenqi Pharmaceutical Co., Ltd., approval number: H20053044) was administered. The film was inserted from the bottom of the periodontal pocket to the gingival margin using a periodontal probe, with an administration frequency of once a week for a total treatment duration of 4 weeks.

Observation indicators

This study mainly observed the short-term changes in patients' periodontal health status, inflammatory factor levels, and clinical symptoms within 4 weeks after treatment to evaluate the short-term efficacy of the combined treatment regimen.

Periodontal health-related indicators: Before treatment and 4 weeks after treatment, a trained team of medical staff assessed the Plaque Index (PLI), Probing Depth (PD), Sulcus Bleeding Index (SBI), and Attachment Loss (AL) in both groups. The PLI is scored on a 0-3 scale: 0 points indicates no plaque in the gingival margin area, and 3 points indicates a large amount of soft deposits in the gingival sulcus, gingival margin area, or interproximal surfaces; higher scores indicate poorer plaque control. PD was obtained by continuously measuring the sulcus depth between the tooth and gingiva three times and calculating the mean value; the probing depth of healthy gingiva is usually 1-3 mm, and higher values indicate more severe periodontitis. The SBI is scored on a 0-5 scale: 0 points indicate no bleeding on probing (healthy gingiva), and 5 points indicate spontaneous bleeding; higher scores indicate more severe bleeding. AL is the most critical indicator for diagnosing periodontitis and judging its severity: AL of 1-2 mm is mild attachment loss, 3-4 mm is moderate attachment loss, and ≥5 mm is severe attachment loss.

Inflammatory factors in GCF: Before treatment and 4 weeks after treatment, after removing gingival plaque and debris, Whatman filter paper was inserted into the bottom of the labial gingival sulcus, left in place for 30 seconds, then removed and placed into an Eppendorf tube containing 0.2 mL PBS buffer. The tube was centrifuged at 1×10^5 rpm for 10 minutes, and the supernatant was collected and stored for subsequent detection. Enzyme-linked immunosorbent assay (ELISA) was used to determine interleukin-6 (IL-6), high-sensitivity C-reactive protein (hs-CRP), and tumor necrosis factor-α (TNF-α) in the GCF of patients with chronic periodontal disease in both groups. Kits were provided by Bohui Biotechnology (Guangzhou) Co., Ltd., and the operation was performed strictly in accordance with the kit instructions.

Oral health-related quality of life: Patients in both groups were evaluated before treatment and 4 weeks after treatment by the same trained medical staff using the Oral Health Impact Profile-14 (OHIP-14) [10]. This scale includes 7 dimensions (e.g., physical pain, social disability) with 0-8 points per dimension, and a total score ranging from 0 to 56 points. Oral health-related quality of life exhibits a negative correlation with the scores of each dimension and the total score of OHIP-14.

Table 1. Comparison of baseline data between the two groups [($\bar{x}$ ±s)/n (%)]

Data	Control group (n=46)	Study group (n=54)	χ^2/t	*P*
Gender				
Male	28 (60.87)	30 (55.56)	0.288	0.592
Female	18 (39.13)	24 (44.44)		
Age (years)	42.32±4.34	42.86±4.62	0.599	0.551
Disease type			0.122	0.726
Chronic periodontitis	30 (65.22)	37 (68.52)		
Chronic gingivitis	16 (34.78)	17 (31.48)		
Course of the disease (months)	13.85±3.05	14.25±3.38	0.617	0.539
Body mass Index (kg/m^2)	22.77±2.10	22.51±2.03	0.628	0.531
Degree of tooth loosening			0.343	0.558
I	24 (52.17)	25 (46.30)		
II	22 (47.83)	29 (53.70)		

Clinical efficacy: Four weeks after treatment, efficacy was evaluated with reference to the Chinese Guidelines for the Prevention and Treatment of Periodontal Diseases [11]. Markedly effective: PD <2 mm; symptoms such as tooth mobility, gingival bleeding, and swelling or pain completely or basically disappeared, and masticatory function was completely or basically restored.

Effective: PD between 2-3 mm; symptoms such as tooth mobility, gingival bleeding, and swelling or pain were significantly relieved, and masticatory function was significantly improved.

Ineffective: Failure to meet the criteria for markedly effective or effective.

Total effective rate = (markedly effective rate + effective rate).

Symptom improvement time: The improvement times of symptoms such as gingival swelling and pain, halitosis, and tooth mobility were compared between the two groups.

Adverse reactions: During treatment, all adverse reactions were recorded, including secondary infection, gingival bleeding, skin rash, and pharyngeal burning sensation.

Statistical analysis

SPSS 25.0 software was used for statistical analysis. Quantitative data (e.g., periodontal health-related indicators, inflammatory factors in GCF) were expressed as mean ± standard deviation ($\bar{x}$ ± s) and analyzed using the t-test. Qualitative data (e.g., treatment efficacy) were expressed as number of cases (percentage) and analyzed using the chi-square (χ^2) test. A *P* value <0.05 was considered significant.

Results

Comparison of baseline data

There were no significant differences between the two groups in terms of baseline characteristics, including sex, age, disease type, body mass index (BMI), and degree of tooth mobility (all P>0.05), indicating good comparability between groups (**Table 1**).

Comparison of periodontal health indicators

Before treatment, there were no significant differences in periodontal health indicators (PLI, PD, SBI, or AL) between the two groups (all P>0.05). After four weeks of treatment, all indicators improved significantly in both groups, with the combined treatment group showing greater improvement than the conventional treatment group (all P<0.05) (**Figure 1**).

Comparison of inflammatory factors in GCF

Before treatment, there were no significant differences inflammatory factor indicators (IL-6, hs-CRP, and TNF-α) in GCF between the two groups (all P>0.05). After 4 weeks of treatment, the inflammatory factor indicators in both groups were significantly reduced, and the above-mentioned indicators in the combined treatment group were more significantly reduced (all P<0.05) (**Table 2**).

Comparison of oral health-related quality of life

Before treatment, there were no significant differences in OHIP-14 scores between the two groups (all P>0.05). After four weeks of treatment, both groups showed significant reductions in OHIP-14 scores across all dimensions and in total score, with the combined treatment group demonstrating a more pronounced improvement (all P<0.05) (**Table 3**).

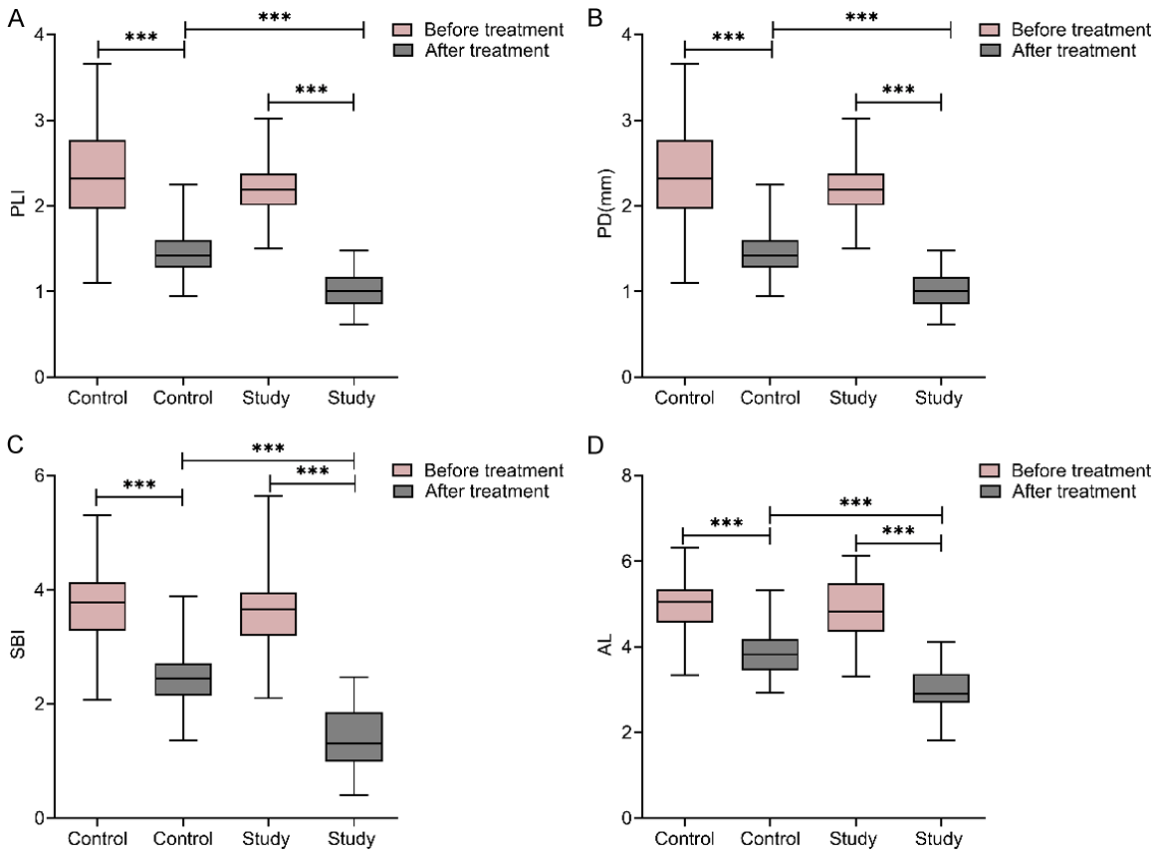

Figure 1. Comparison of periodontal health-related indicators between the two groups before treatment and 4 weeks after treatment. A. PLI; B. PD; C. SBI; D. AL. ***P<0.001. Plaque Index (PLI), Probing Depth (PD), Sulcus Bleeding Index (SBI), Attachment Loss (AL).

Table 2. Comparison of inflammatory factor indicators in gingival crevicular fluid before treatment and 4 weeks after treatment between the two groups ($\bar{x}\pm s$)

Indicator	Control group (n=46)	Study group (n=54)	*t*	*P*
IL-6 (pg/ml)				
Before treatment	83.54±8.65	84.12±7.21	0.366	0.715
After four weeks of treatment	46.25±5.24*	28.14±4.32*	18.944	<0.001
hs-CRP (mg/L)				
Before treatment	13.54±2.58	13.92±2.31	0.777	0.439
After four weeks of treatment	9.25±2.02*	7.37±1.75*	4.987	<0.001
TNF-α (ng/L)				
Before treatment	9.37±1.52	9.22±1.37	0.519	0.605
After four weeks of treatment	5.32±1.12*	3.02±0.87*	11.548	<0.001

Note: Compared with before treatment in this group, *P<0.05.

Comparison of clinical efficacy

The total effective rate was 80.43% (37/46) in the conventional treatment group and 96.30% (52/54) in the combined treatment group. The combined treatment group had a significantly higher total effective rate than the conventional treatment group (P<0.05), indicating that the combined therapy produced a superior clinical effect (**Table 4**; **Figure 2**).

Table 3. Comparison of OHIP-14 scores before treatment and 4 weeks after treatment between the two groups ($\bar{x}$±s, score)

Indicator	Control group (n=46)	Study group (n=54)	*t*	*P*
Functional limitations				
Before treatment	6.02±1.24	6.08±1.19	0.247	0.806
After four weeks of treatment	3.42±1.37*	2.29±1.02*	10.391	<0.001
Psychological discomfort				
Before treatment	5.98±1.44	5.82±1.51	0.539	0.591
After four weeks of treatment	3.21±0.87*	2.05±0.74*	7.206	<0.001
Physiological pain				
Before treatment	6.34±1.05	6.45±0.92	0.558	0.578
After four weeks of treatment	2.85±0.96*	1.92±0.75*	5.435	<0.001
Social disorder				
Before treatment	5.52±1.59	5.34±1.64	0.555	0.580
After four weeks of treatment	2.51±0.87*	1.59±0.55*	6.413	<0.001
Physiological disorder				
Before treatment	5.66±1.28	5.74±1.17	0.326	0.745
After four weeks of treatment	2.95±1.01*	2.05±0.77*	5.050	<0.001
Psychological disorder				
Before treatment	5.32±1.33	5.17±1.19	0.595	0.553
After four weeks of treatment	3.02±0.88*	2.31±0.62*	4.714	<0.001
Disability				
Before treatment	5.23±1.45	5.11±1.38	0.423	0.673
After four weeks of treatment	2.35±0.81*	1.42±0.59*	6.625	<0.001
Total score				
Before treatment	41.85±4.84	41.21±5.12	0.639	0.524
After four weeks of treatment	23.52±4.21*	14.87±3.84*	10.740	<0.001

Note: Compared to before treatment in this group, *P<0.05.

Table 4. Comparison of clinical efficacy between the two groups [n (%)]

Clinical efficacy	Control group (n=46)	Study group (n=54)	χ^2	*P*
Markedly effective	22 (47.83)	32 (59.26)		
Effective	15 (32.61)	20 (37.04)		
Ineffective	9 (19.57)	2 (3.70)		
Total effective rate	37 (80.43)	52 (96.30)	6.384	0.012

Comparison of symptom improvement time

The time for symptom improvement was significantly shorter in the combined treatment group compared to that of the conventional treatment group for all assessed symptoms (all P<0.05) (**Table 5**).

Comparison of adverse reactions

The incidence rate of adverse reactions in the conventional treatment group was 19.57% (9/46), and that in the combined treatment group was 3.70% (2/54). The combined treatment group had a significantly lower incidence of adverse reactions than the conventional treatment group (P< 0.05) (**Table 6**).

Discussion

The pathogenesis of chronic periodontal disease is complex and is mainly related to factors such as dental plaque, host immune response, genetics, and poor oral hygiene. In the past, mechanical methods such as supragingival scaling, subgingival scaling, and root planing were often used to treat this type of disease. However, due to the variable morphology of periodontal pockets and the complex root shape, mechanical treatment is often difficult to completely remove dental plaque and calculus, and the treatment effect is poor [12]. Therefore, it is important to find other treatment options.

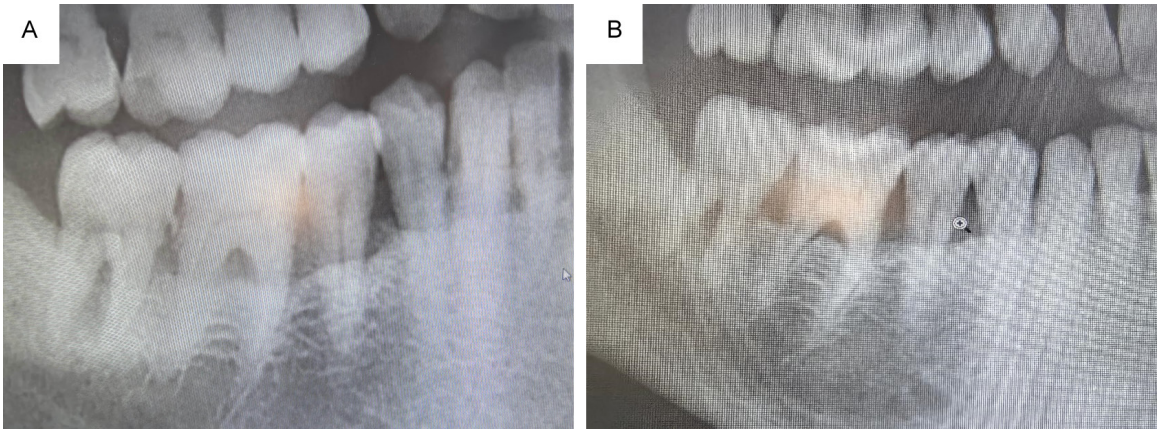

Figure 2. Comparison of periodontal imaging before and after treatment in the combined group. A. Before treatment, periodontal bone resorption and periapical radiolucent lesions were observed. B. After treatment, periodontal bone density was increased and the inflammatory resorptive lesions were significantly reduced, suggesting favorable repair of periodontal tissues.

Table 5. Comparison of symptom improvement time between the two groups ($\overline{x}$±s, d)

Symptom	Control group (n=46)	Study group (n=54)	*t*	*P*
Swollen and painful gums	4.65±1.02	2.89±0.78	9.766	<0.001
Bad breath	8.05±2.02	4.34±1.78	9.763	<0.001
Loose teeth	10.87±3.21	8.52±2.13	4.370	<0.001

Table 6. Comparison of adverse reactions between the two groups [n (%)]

Type	Control group (n=46)	Study group (n=54)	X^2	*P*
Secondary infection	5 (10.87)	0 (0.00)		
Bleeding gums	4 (8.70)	0 (0.00)		
Rash	0 (0.00)	1 (1.85)		
A burning sensation in the throat	0 (0.00)	1 (1.85)		
Total	9 (19.57)	2 (3.70)	6.384	0.012

This study used a combination of laser therapy and topical medication to treat patients with chronic periodontal disease. The results demonstrated that the combined treatment group had superior clinical efficacy compared with the conventional treatment group, and the improvement time of gum swelling and pain, bad breath, and loose teeth were significantly shorter than those of the conventional treatment group. It is suggested that the clinical effect of semiconductor laser combined with compound chlorhexidine and dexamethasone membrane in the treatment of chronic periodontal disease is accurate and can significantly improve clinical symptoms. The underlying mechanism may be attributed to chlorhexidine, a cationic surfactant with broad-spectrum antimicrobial activity that helps remove dental plaque [13]. Dexamethasone is a glucocorticoid drug that has anti-inflammatory and anti-allergic effects. It can reduce tissue edema and exudation, thereby promoting periodontal pocket closure and gingival health, reducing the damage of inflammation to periodontal ligament and alveolar bone, and creating good conditions for tissue regeneration [14]. As an emerging treatment method, semiconductor laser treatment technology is widely used in the clinical treatment of a variety of oral diseases and has received high praise [15]. It exerts antibacterial and repair-promoting effects through thermal effects and photobiomodulation. Irradiating the tooth can effectively destroy the cell structure of bacteria in the root canal, thereby removing microorganisms and their metabolites. At the same time, it can denature and solidify proteins, thereby removing periodontal pathogenic bacteria and granulation tissue, promoting the growth of collagen tissue, and conducive to the reattachment of periodontal soft tissue [16,

17]. Abdullah et al. found in a randomized controlled trial that semiconductor laser is effective in treating chronic periodontitis and can effectively adjust periodontal health indicators and reduce bacterial load [18].

In terms of periodontal health, this study revealed that after four weeks of treatment, both groups showed significant improvements in periodontal health indicators (PLI, PD, SBI, and AL) as well as OHIP-14 dimension scores and total scores, with the combined treatment group exhibiting more pronounced improvements. It is basically consistent with the research results of Feng and others. It shows that this combined treatment plan can effectively improve the periodontal health of chronic periodontal disease and promote the improvement of life quality [19]. Furthermore, this study found that the incidence of adverse reactions in the combined treatment group (3.70%) was lower than that in the conventional treatment group (19.57%) ($P<0.05$), indicating that the safety of this combined treatment regimen is good. This may be because the semiconductor laser-assisted debridement may reduce the risk of secondary infection, while the anti-inflammatory effect of the compound chlorhexidine and dexamethasone membrane helps reduce the occurrence of adverse reactions such as gingival bleeding [20].

Clinical findings indicate that inflammatory response plays an important role in the occurrence and development of chronic periodontal disease. When the body is stimulated by pathogenic bacterial infection, immune cells such as macrophages and fibroblasts in the gingival tissue will secrete a large number of inflammatory factors such as IL-6, hs-CRP, and TNF-α. These inflammatory factors intensify the inflammatory response by activating collagenase and vascular endothelial cells, destroy periodontal tissue, and then induce periodontitis and gingivitis [21]. The results of this study showed that after four weeks of treatment, the inflammatory factor indicators such as IL-6, hs-CRP, and TNF-α were significantly reduced in both groups, and the above-mentioned inflammatory factor indicators were reduced more significantly in the combined treatment group. It shows that semiconductor laser combined with compound chlorhexidine and dexamethasone membrane can effectively inhibit the inflammatory response, reduce inflammatory damage, and promote recovery. The underlying mechanisms may include the broad-spectrum antimicrobial effect of chlorhexidine, which inhibits infection at its source, and the immunomodulatory action of dexamethasone, which mitigates inflammatory damage. The two work together to synergistically suppress the inflammatory cascade reaction. Semiconductor laser therapy can remove pathogenic bacteria from the gingival epithelium through thermal denaturation, while avoiding damage to connective tissue and microvessels, thus inhibiting inflammatory responses and reducing tissue destruction [22]. Moreover, semiconductor laser therapy can enhance local microcirculation through biological stimulation, improve tissue oxygen supply, inhibit the activity of periodontal pathogenic bacteria, and inhibit the release of inflammatory mediators, which can help relieve inflammation in the periodontal pocket and promote the reconstruction of microecological balance.

However, this study has several limitations as a single-center retrospective study. First, despite efforts to balance baseline characteristics, the non-randomized selection of treatment regimens may have led to indication bias. Additionally, some potential confounding factors (e.g., smoking status, diabetes mellitus, periodontal phenotype, concomitant medications, and operator experience) were not included in multivariate adjustment, and the impact of residual confounding cannot be completely ruled out. Second, the relatively limited sample size and slight imbalance in the number of cases between the two groups may have compromised statistical power. Third, blinding was not implemented for patients or treatment providers, possibly introducing performance bias and detection bias. Although standardized evaluation procedures were adopted and assessments were conducted by relatively independent personnel to mitigate this, further validation is needed. Fourth, the 4-week evaluation period reflected only short-term efficacy, failing to assess the combined regimen's impact on the long-term stability and recurrence risk of chronic periodontal disease.

Future studies should conduct prospective, large-sample, multi-center randomized controlled trials with balanced groupings, blinding

design, and extended follow-up durations (e.g., 3, 6, or 12 months) to further verify the reliability of the present findings.

In conclusion, semiconductor laser combined with compound chlorhexidine and dexamethasone membrane has definite clinical effects for chronic periodontal disease. It can effectively improve periodontal health, reduce the levels of inflammation in gingival crevicular fluid, improve patients' quality of life, and is highly safe.

Disclosure of conflict of interest

None.

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