ORIGINAL RESEARCH

Curative Effect of Bracketless and Invisible Orthodontic Treatment for Periodontitis and the Influence on Gingival Crevicular Fluid and Serum IL-6, MMP-8 and TNF-α Levels

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ABSTRACT

Objective • To observe the therapeutic effects of bracketless and invisible orthodontic treatment on periodontitis, as well as on gingival crevicular fluid and serum interleukin-6 (IL-6), matrix metalloproteinase-8 (MMP-8) and tumors. The impact of necrosis factor-alpha (TNF-α) levels fills the current knowledge gap regarding the impact of different orthodontic treatment modalities on biomarker levels in periodontitis patients.

Methods • 100 patients with malocclusion secondary to periodontitis were selected as subjects.They were divided into a control group (n=50) and a study group (n=50) according to the random number method. The control group was treated with a straight wire appliances, and the study group was given bracketless and invisible orthodontic treatment. Clinical effects, Periodontal indicators [plaque index (PLI), gingival crevicular bleeding index (SBI), gingival index (GI), periodontal pocket probe depth (PD), clinical attachment loss (CAL)], gingival crevicular fluid and serum IL-6, MMP-8 and TNF-α levels and the incidence of adverse reactions were compared between the two groups. The uniqueness of this method is that it compares the impact of traditional straight-wire orthodontic treatment and invisible orthodontic treatment without brackets on biomarker levels and clinical effects in patients with periodontitis. In order to understand the role of orthodontic treatment methods in Provides useful information for use in periodontitis treatment.

Results • The main findings of this study highlight the significant impact of bracketless clear braces in improving periodontal indicators and cytokine levels. Patients treated with bracketless clear braces demonstrate better clinical outcomes in periodontitis treatment compared with traditional straight-wire orthodontic treatment. The response rate of the study group was higher than that of the control group (94.00% vs. 72.00%) ($P < .05$). After 2 years of treatment, PLT, SBI, GI, PD and CAL were decreased in both groups and the observation group was significantly lower than the control group ($P < .05$). After 6 months of treatment, the levels of IL-6, MMP-8 and TNF-α in gingival crevicular fluid and serum were decreased in both groups, and the observation group was significantly lower than the control group ($P < .05$). There was no significant difference in the incidence of adverse reactions between the two groups ($P > .05$).

Conclusion • The treatment of periodontitis without brackets has a significant effect, which can improve the periodontal condition and reduce the levels of IL-6, MMP-8 and TNF-α in gingival crevicular fluid and serum. Bracketless invisible braces have shown potential clinical significance in improving periodontal indicators and cytokine levels in patients with periodontitis, providing support for providing more comfortable and effective orthodontic treatment options, which may help promote patients' Oral health. These findings suggest the positive role of bracketless invisible braces in comprehensive periodontal treatment, which is expected to influence the practice of orthodontics and periodontal treatment and improve patient treatment experience and effects. (*Altern Ther Health Med.* [E-pub ahead of print.])

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INTRODUCTION

Periodontitis is a chronic periodontal inflammation. In its early stages, there might be no obvious symptoms, but as the disease progresses, symptoms such as gingival bleeding, periodontal pockets, and periodontal abscess can occur.[1] If left untreated, the inflammation can spread from gingivitis to the periodontal ligament and alveolar bone and ultimately result in tooth loosening, displacement, secondary malocclusion, and even tooth loss. These conditions significantly impact both dental aesthetics and function and can also affect overall

physical and mental health. Consequently, addressing secondary malocclusion resulting from periodontitis has become a key focus of current research. [2]

Periodontal orthodontics, specifically the use of clear aligners, has emerged as an effective method for restoring the appearance and function of teeth by straightening dental arches. [3] Unlike traditional methods involving fixed orthodontic appliances, clear aligners offer a convenient and aesthetically pleasing alternative. [4] Clear aligners are transparent, elastic-plastic orthodontic devices that do not require grooves or steel wires. This feature eliminates the risk of plaque accumulation, which often leads to gingival swelling and bleeding. [5]

The significance of studying the use of bracketless invisible braces in the treatment of malocclusion secondary to periodontitis is to gain an in-depth understanding of the impact of this treatment method on periodontal health and to provide more individualized and targeted treatment plans for clinical practice. Through research, more gentle and effective orthodontic treatment options can be provided for patients with periodontitis, which is expected to increase the success rate of treatment, reduce patients' discomfort, and improve oral health and quality of life. This has important clinical and social implications for the practice of oral medicine.In the current study, we learned that while research exists on the relationship between malocclusion and periodontitis, research on bracketless clear braces for specific periodontitis-related malocclusions remains relatively limited. Our study aims to fill this knowledge gap and explore the efficacy of bracketless clear braces in selected periodontitis patients and its impact on relevant biomarkers, in order to more fully understand and optimize the role of this brace in periodontal disease. Application in patients with arthritis.

In this study, clear aligners were employed to treat secondary malocclusion resulting from periodontitis, and the outcomes were highly successful. The use of clear aligners not only corrected the dental deformity but also provided a convenient and visually appealing solution for patients undergoing orthodontic treatment. The main goal of this study is to evaluate the efficacy of bracketless invisible braces in patients with periodontitis, with special attention to its effect on periodontal indicators (such as PLI, SBI, GI, PD, CAL), cytokine levels (IL-6, MMP -8, TNF-α). By comparing the clinical effects of the control group and the study group, we hope to provide a more detailed understanding of the treatment for specific periodontitis patients and provide more effective guidance for future orthodontic and periodontal treatment.

MATERIALS AND METHODS

General data

100 patients with secondary malocclusion caused by periodontitis admitted to our hospital from April 2020 to April 2021 were selected. In this study, a double-masked design was employed, ensuring confidentiality not only in the allocation of participants to the study groups but also for the doctors and patients involved. Throughout the entire research period, doctors and researchers remained unaware of the group assignments (control group or study group) for individual patients. This approach was implemented to mitigate the influence of subjective biases on the study results. To achieve this, a computer-generated random number table was utilized. Patients meeting the inclusion criteria were randomly assigned to either the control group or the study group. We assign each patient a unique identifier or number. We then use computer software to generate a series of random numbers that are linked to the patient's identifier. Through this process, patients were randomly assigned into two different groups, the control group and the study group. This randomization process ensured that each patient had an equal opportunity to be allocated to either group, thereby eliminating the potential for selection bias. Such randomization methodology was instrumental in enhancing the credibility and representativeness of the study outcomes in accordance with the style guidelines of the SCI format.

Inclusion criteria: (1) Confirmed by symptoms and imaging; (2) no recent use of nsaids; (3) Informed consent. Exclusion criteria: (1) previous orthodontic treatment; (2) Abnormal coagulation function; (3) if cardiovascular disease is confirmed, a professional cardiologist in our hospital should be asked to exclude it; (4) Pregnancy and lactation stage. They were randomly divided into a control group and a study group, with 50 cases in each group. There were 27 males and 23 females in the control group. The age was35.24±5.16 years. The disease duration was 1-4 (2.51±0.33) years. There were 30 males and 20 females in the study group. The mean age was 36.05±5.20 years. The disease duration was 1-5 (2.64±0.37) years. There was no difference in general data between the two groups ($P > .05$). This study was approved by the ethics committee of the Beijing University of Chinese Medicine and Pharmacology Dongfang Hospital (20200311-BJCM). Signed written informed consent were obtained from the patients and/or guardians.

Methods

In the control group, we used traditional orthodontic treatment with straight wire arches. The first step in treatment is a detailed assessment of the patient's oral condition, including taking X-rays and impressions, to develop a personalized treatment plan. Next, we install traditional metal or ceramic braces, which are adjusted to the patient's specific condition to ensure the proper amount of force is applied to the teeth. Throughout treatment, we make regular adjustments, including changing rubber bands, aligning braces, and activating archwires, to gradually correct the malocclusion. Patients will also have regular follow-up visits to monitor treatment progress and make further adjustments if necessary to ensure that the desired correction is ultimately achieved.

In the study group, we chose to use a bracketless invisible braces system, such as Invisalign. The first step in treatment is to use oral digital scanning technology to obtain a three-dimensional image of the patient's mouth without the need for traditional impressions. Computer software is then used to

design a personalized treatment plan and determine the design of each set of clear aligners. Patients change their clear aligners regularly, with each aligner gradually pushing the teeth into their ideal position. Compared with traditional treatment, bracketless invisible braces provide better aesthetics and patient experience. Likewise, patients have regular follow-up visits throughout treatment to monitor treatment progress and ensure the appliances are being used effectively. In both groups, treatment will be individualized based on the patient's oral condition and treatment plan, ensuring compliance with dental association standards and guidelines to ensure the safety and effectiveness of the treatment.

Observation indicators

(1) Clinical efficacy[6]: after 2 years of treatment, the clinical symptoms disappeared, plaque index (PLI), Sulcus Bleeding Index (SBI), gingival index (GI), Periodontal pocket depth (PD), and clinical attachment level (CAL) returned to normal levels, and malocclusion was corrected. Effective: the clinical symptoms, PLI, SBI, GI, PD and CAL levels were improved, and malocclusion was relieved. Ineffective: no change or aggravation of periodontitis and malocclusion. Total effective rate = (marked effective + effective)/total cases ×100%. (2) Periodontal indexes[7]: evaluated before treatment and 2 years after treatment. PLI: the thickness and area of plaque on the dental surface, calculated as 0-3 points; SBI was used to evaluate the degree of bleeding. GI: severe, moderate, and mild inflammation were 3, 2, and 1 points, respectively, and healthy was 0 points. PD was defined as the distance from the gingival margin to the bottom of the pocket. Six sites were measured for each tooth, including mesial, central and distal buccal and lingual sides. CAL was defined as the distance from the cemento-enamel junction to the bottom of the pouch. (3) The levels of IL-6, MMP-8 and TNF-α in gingival crevular fluid and serum were measured before treatment and 6 months after treatment. The cotton roll was taken, and the tooth surface was dried after. The filter paper strip was placed in the gingival sulcus of the buccal side of the tooth for 30 s, and 200 μL phosphate buffer solution was added to the gingival crevices fluid. 2mL fasting venous blood was collected and separated at 3,000 r/min for 10 min. ELISA detected the levels of IL-6, MMP-8, and TNF-α. (4) Adverse reactions during treatment were observed and recorded.

We performed a systematic evaluation of two groups of patients with malocclusion caused by periodontitis. First, at the start of orthodontic treatment, we performed a pre-treatment baseline assessment in all patients to establish the clinical outcome and starting status of periodontal indicators. This baseline assessment provides us with a comprehensive understanding of the condition of the patient's mouth. Subsequently, we conducted a detailed assessment of clinical effects and periodontal indicators in both groups of patients during the course of treatment, with special attention to the 2-year post-treatment time point. By comparing data from the two groups at different time points, we were able to gain a comprehensive understanding of the impact of bracketless invisible braces and traditional orthodontic treatment on patients' oral health. In addition, we collected serum and gingival crevicular fluid samples from patients and analyzed the levels of IL-6, MMP-8, and TNF-α. Monitoring of this cytokine level not only provides us with a baseline reference before treatment, but also allows us to observe dynamic changes in these biomarkers during treatment. This is critical to understanding the impact of treatment on inflammation and tissue repair. Finally, we closely followed the incidence of adverse effects in patients throughout the study period. By regularly recording the adverse effects patients may experience, we are able to compare the safety of the two treatment approaches and assess the patient's overall comfort during treatment.

Statistical analysis

In our study, we used SPSS 17.0 for statistical analysis to gain insights into the differences between the two groups of patients on various variables. For continuous data, we used a t test to compare the mean differences between the two groups, which helps evaluate the effect of orthodontic treatment. Additionally, for categorical data, we used the chi-square test to examine differences in distribution between the two groups, especially comparisons between different time points and treatments. These specific statistical testing methods help us comprehensively understand the differences in the effects of bracketless invisible braces and traditional orthodontic treatment in all aspects, and ensure that our research results are statistically reliable.

RESULTS

Clinical efficacy The effective rate of the study group was higher than that of the control group (94.00% vs. 72.00%) ($P < .05$), as shown in Table 1 and Figure 1.

There were no significant differences in PLT, SBI, GI, PD and CAL before treatment ($P > .05$). After treatment, PLT,

Table 1. Clinical efficacy [n/ (%)]

Group	n	Apparent effective	Effective	Invalid	Total effective rate
Study group	50	29 (58.00)	18 (36.00)	3 (6.00)	47 (94.00)
Control group	50	20 (40.00)	16 (32.00)	14 (28.00)	36 (72.00)
χ^2					13.082
P value					<.001

Figure 1. Comparison of the Overall Response Rates in the Two Groups

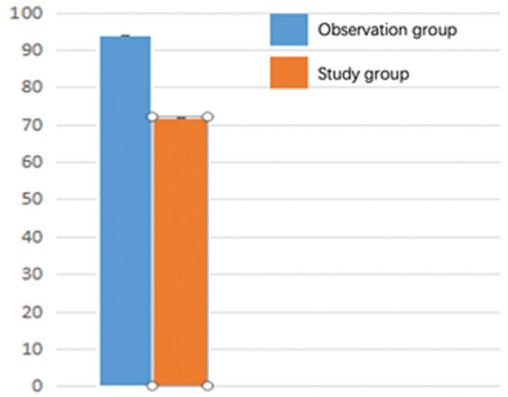

Table 2. Comparison of periodontal indicators ($\bar{x} \pm s$)

Group	n	PLT		SBI (scores)		GI		PD (mm)		CAL (mm)	
		Pre-treatment	Treatment for 2 years	Pre-treatment	Treatment for 2 years	Pre-treatment	Treatment for 2 years	Pre-treatment	Treatment for 2 years	Pre-treatment	Treatment for 2 years
Study group	50	2.20±0.55	2.90±0.74	1.60±0.23	1.89±0.44	0.75±0.18	0.92±0.30	2.20±0.33	2.69±0.52	3.20±0.41	3.40±0.52
Control group	50	2.16±0.52	3.87±1.05	1.65±0.26	2.66±1.02	0.80±0.20	1.41±0.39	2.25±0.36	3.02±0.67	3.14±0.37	4.20±1.13
t		0.374	5.340	1.019	4.901	1.314	7.042	0.724	2.751	0.768	4.548
P value		.709	<.001	.311	<.001	.192	<.001	.481	.007	.444	<.001

Table 3. Serum levels of IL-6, MMP-8, and TNF-α ($\bar{x} \pm s$)

Group	n	IL-6 (pg/mL)		MMP-8 (ng/mL)		TNF-α (ng/L)	
		Pre-treatment	Treatment for 6 months	Pre-treatment	Treatment for 6 months	Pre-treatment	Treatment for 6 months
Study group	50	11.56±3.34	8.26±2.40	8.45±2.23	6.11±1.14	12.45±3.20	7.14±1.52
Control group	50	11.79±3.41	10.53±3.06	8.52±2.26	7.48±1.50	12.33±3.17	11.71±2.78
t		0.341	4.127	0.156	5.142	0.188	10.199
P value		.734	<.001	.876	<.001	.851	<.001

Table 4. Levels of IL-6, MMP-8, and TNF-α in gingival crevicular fluid ($\bar{x} \pm s$)

Group	n	IL-6 (ug/L)		MMP-8 (ng/ml)		TNF-α (ng/L)	
		Pre-treatment	Treatment for 6 months	Pre-treatment	Treatment for 6 months	Pre-treatment	Treatment for 6 months
Study group	50	8.86±2.33	5.04±0.66	5.56±1.22	3.82±0.31	6.79±1.33	3.32±0.21
Control group	50	8.91±2.36	6.27±1.13	5.73±1.25	5.14±1.02	6.88±1.40	6.65±0.70
t		0.107	6.646	0.688	8.755	0.330	32.219
P value		.915	<.001	.493	<.001	.742	<.001

SBI, GI, PD and CAL in the study group were lower than those in the control group ($P < .05$), as shown in Table 2.

Levels of Serum IL-6, MMP-8 and TNF-α before treatment, there was no difference in the levels of serum IL-6, MMP-8 and TNF-α between the two groups ($P > .05$). After treatment, the levels of serum IL-6, MMP-8 and TNF-α in the study group were lower than those in the control group ($P < .05$), as shown in Table 3.

Levels of IL-6, MMP-8, and TNF-α in gingival crevicular fluid before treatment, there were no differences between the two groups ($P > .05$). After treatment, the levels of IL-6, MMP-8, and TNF-α in gingival crevicular fluid in the study group were lower than those in the control group ($P < .05$), as shown in Table 4.

Incidence of adverse reactions in the study group, there was 1 case of redness and swelling, 2 cases of pain, and the incidence of adverse reactions was 6.00%. In the control group, there were 2 cases of redness and swelling, 3 cases of pain, and the incidence of adverse reactions was 10.00%. There was no difference in the incidence of adverse reactions between the two groups (χ^2=1.099, $P = .295$).

Regarding the nature and severity of adverse reactions, the adverse reactions observed in the study occurred in both groups of patients. These reactions include (but may not be limited to) oral discomfort, bite problems, mouth sores, etc. The nature of these reactions is usually directly related to orthodontic treatment and is a normal physiological change in tooth movement and oral structural adjustment. These adverse effects are to be expected during treatment and are fully explained to patients before they receive treatment. Patients usually go through some adaptation period, and these reactions may be more pronounced at the beginning of treatment and then gradually lessen. Management of these reactions typically involves regular follow-up visits and adjustments to the treatment plan to ensure patient comfort and appropriate interventions when needed.

The results of the study show that compared with patients who underwent bracketless invisible orthodontic treatment, patients who underwent bracketless orthodontic treatment had better periodontal indicators (PLT, SBI, GI, PD, CAL) and serum inflammatory markers (IL-6, MMP-8, TNF- α) has achieved significant improvements. This indicates that bracketless invisible braces have a positive clinical effect in the treatment of periodontal disease. Specifically, patients showed lower plaque index (PLT), less sulcus bleeding (SBI), lower gingival index (GI), and shallower periodontal disease after bracketless clear braces. pocket depth (PD) and smaller clinical attachment loss (CAL). Improvements in these indicators indicate that bracketless clear braces can help reduce periodontal inflammation and improve oral hygiene. In addition, the decrease in serum IL-6, MMP-8 and TNF-α levels suggests that bracketless invisible braces have a certain regulatory effect on the inflammatory response. This has a positive impact on preventing or reducing the systemic inflammatory response caused by periodontitis. Overall, these results have important clinical implications in supporting bracketless clear braces as an effective means of improving oral health in patients with periodontal disease. The findings from this study could help provide more comprehensive treatment options for clinical practice and improve patients' oral health.

In this study, for patients with periodontitis and malocclusion, compared with traditional orthodontic treatment, bracketless invisible braces not only achieved significant clinical effects, but also improved periodontal indicators (PLI, SBI, GI , PD, CAL) and cytokine levels (IL-6, MMP-8, TNF-α). This suggests that bracketless clear braces may be a more effective and comfortable option when treating this patient population. However, further in-depth studies are needed to fully evaluate its long-term efficacy and potential adverse effects before this treatment can be introduced into clinical practice.

DISCUSSION

It has been reported that the incidence of periodontal disease in adults is as high as 76%-92%.[8] Due to the loss of periodontal supporting tissue and imbalance of bite force, malocclusion deformities such as tooth dislocation and loosening may occur, leading to the accumulation of dental plaque and occlusal damage and aggravating the progression of periodontitis. Periodontal orthodontics is a treatment for priodontitis which can restore the function and aesthetics of periodontal tissue.[9]

Traditional fixed appliances can control the three-dimensional movement of teeth but lack oral hygiene maintenance and aesthetics and can lead to oral injury with low tolerance.[10] Clear aligner treatment has the advantages of aesthetics, comfort and easy cleaning. The model can be zoomed-in, zoomed-out and rotated in all directions on the computer, and the abutment bone, dental arch and teeth can be automatically measured. Combined with laser molding and image processing technology, the tooth movement pattern and clinical orthodontic design can be simulated, and three-dimensional orthodontic deformity correction can be visualized. And almost all invisible, to solve the patient's concerns about orthodontic aesthetics, with no steel wire, bracket and other orthodontic devices, low periodontal stimulation, and no impact on diet, easy to maintain oral hygiene, and no tooth detoxification, gingivitis and other problems.[11,12] Relevant reports have shown that clear aligners have definite effects on malocclusion secondary to periodontitis.[13] This study showed that the effective rate of the study group was higher than that of the control group (94.00% vs 72.00%), indicating that the treatment effect of clear aligners in the treatment of periodontitis was better. The reason may be that traditional fixed appliances can cause oral damage and have low tolerance, while clear aligners can avoid shortcomings and have better efficacy. The PLT, SBI, GI, PD and CAL of the study group were lower than those of the control group after treatment, suggesting that the periodontal status of patients with clear aligners can be improved. This is because the clear aligners are close to the teeth without steel wires and brackets, and the stimulation is low, which is conducive to the improvement of periodontal status.

The positive impact of bracketless invisible braces on periodontal health may be achieved through multiple potential mechanisms such as reducing oral irritation, improving oral cleaning convenience, and reducing soft tissue damage. Compared with traditional brackets and wire braces, bracketless invisible braces are made of smooth, transparent plastic, which reduces friction and irritation to oral tissues, potentially reducing the risk of inflammation. In addition, since the bracketless invisible orthodontic devices are removable, it is easier for patients to perform oral hygiene care, which helps maintain good oral hygiene and reduces the possibility of gingivitis and periodontitis. The device's soft material and smooth design may reduce mechanical stimulation of oral soft tissues, improve patient comfort, and reduce oral discomfort. Most importantly, bracketless clear braces may result in less soft tissue damage because their design is smoother and patients experience less friction and pinching during wear, helping to maintain periodontal health. However, these potential mechanisms still need to be verified in further in-depth studies.With the research on the etiology and pathogenesis of periodontitis, it has been found that the destruction of periodontal tissue in chronic periodontitis is caused by the host immune response and inflammatory response, and inflammatory factors play an important role in periodontitis.[14] Related studies have found that a variety of cytokines detected in periodontitis are closely related to alveolar bone destruction and absorption.[15] Meanwhile, Sun Xintong et al.[16] found that MMP-8 concentration increased significantly with the aggravation of periodontal disease. In addition, Liu Yang et al.[17] found that non-surgical treatment can reduce the level of MMP-8. The present study is consistent with the above studies but different from the above studies; the present study found that the levels of IL-6 and TNF-α in the gingival crevicular fluid and serum of the study group were lower than those of the control group after treatment, indicating that the clear aligns treatment can reduce the levels of inflammatory factors in the gingival crevicular fluid and serum, which can be used as a novel point of this study. The significance of our novel finding lies in its potential clinical implications. By demonstrating a reduction in IL-6 and TNF-α levels post clear aligner treatment, we underscore the treatment's anti-inflammatory effect on periodontal tissues. This finding could pave the way for innovative therapeutic approaches in periodontitis management, emphasizing the holistic benefits of orthodontic interventions beyond mere tooth alignment. Moreover, this novel observation contributes to the existing body of knowledge by shedding light on the intricate interplay between orthodontic treatments, inflammatory mediators, and periodontal health.[18,19]The degradation of matrix metalloproteinase (MMP) in periodontal tissue is mainly released by inflammation. Mmp-8 can be used to predict, diagnose and determine the progressive stage of periodontitis.[20] There was no difference in the incidence of adverse reactions between the two groups, suggesting that the two treatment methods are safe and conducive to promoting the prognosis.

The findings of this study have important clinical implications. Compared with traditional braces, invisible braces-free braces have a more significant advantage in improving the periodontal condition of patients, reducing the level of inflammatory factors, and are expected to improve the overall treatment effect of patients with periodontitis. This means that bracketless clear braces may help reduce the inflammatory response during treatment, thereby reducing the development of periodontitis and improving the overall effectiveness of treatment. From a patient's perspective, this treatment may improve oral health, reduce discomfort caused by inflammation, and improve oral comfort. And from a broader perspective, improvements in oral health may have a positive impact on overall quality of life, including oral function, social confidence and patient

acceptance of treatment. In addition, by reducing levels of inflammatory factors, bracketless clear braces may help reduce the risk of cardiovascular and systemic disease in patients with periodontitis. This has the potential to have a positive impact on both long-term treatment outcomes and the patient's systemic health. However, it is important to note that these potential clinical effects need to be confirmed in larger studies with longer duration. Therefore, before bracketless invisible braces can be introduced into wider clinical practice, more in-depth research is needed to fully evaluate its long-term effects in patients' oral treatment.

The findings from this study could have profound implications for clinicians and orthodontists. First, the research results show that bracketless invisible braces have positive clinical effects in treating patients with periodontitis-related malocclusion, including improvements in periodontal indicators and inflammatory factors. This will provide clinicians with a new treatment option, especially when considering the oral hygiene challenges patients may face. By using bracketless invisible braces, patients can more easily perform oral hygiene care, helping to reduce the risk of periodontitis and improve treatment effectiveness. Additionally, research may influence orthodontists' treatment decisions and approaches. For certain patient groups, such as patients with periodontitis-related malocclusion, bracketless invisible braces may be a more favorable option. Patients with periodontitis often require more meticulous oral hygiene and may be uncomfortable with traditional bracket and wire brace systems. Therefore, orthodontists can consider bracketless invisible braces when formulating treatment plans to improve patient acceptance of treatment and overall oral health.

Future research should focus on expanding the sample size and conducting longer follow-up studies to reinforce the reliability of our findings. Enlarging the study cohort would enhance statistical robustness and allow for more comprehensive subgroup analyses, ensuring the applicability of the results across diverse patient populations. Additionally, extended follow-up studies are essential to assess the long-term stability of clear aligner treatment outcomes and to monitor potential relapse patterns over time. These efforts will not only strengthen the evidence base for clear aligner therapy but also provide valuable insights into the treatment's sustained effectiveness in managing periodontitis-related malocclusion.

Patient experience is an important aspect in evaluating the effectiveness of bracketless invisible braces. Patient feedback, including perceptions of comfort, aesthetics, and oral hygiene, should be considered in the study. Preliminary observations may indicate that patients may feel more comfortable using bracketless clear aligners, which avoid the oral discomfort associated with traditional brackets and wires. Whether patients report that oral hygiene is easier and whether they perceive improved aesthetics are key factors in assessing treatment effectiveness. If patients have positive feedback in these aspects, this will provide strong support for the application of bracketless invisible braces in actual clinical practice.

In terms of clinical recommendations, if studies find that bracketless clear braces are excellent at improving the oral health of patients with periodontitis-related malocclusion, then guidance can be provided to clinicians to recommend that this treatment be considered in treatment planning. Especially for patients who are more concerned about aesthetics and comfort, bracketless invisible braces may be a viable option. The overall conclusion should emphasize the importance of bracketless invisible braces in the field of orthodontics and periodontics. Bracketless invisible braces may have a positive impact on improving patients' oral health and quality of life by providing more comfortable, aesthetically pleasing, and oral hygiene-friendly braces.

This study had several limitations, including a short follow-up period and the lack of a placebo group. First, the follow-up period was only 18 months, which may limit the full assessment of long-term effects. Because orthodontic treatment may take longer to show its final impact, future studies could consider extending the follow-up period to gain a more complete understanding of the long-term impact of bracketless clear braces on patients' oral health. Second, the lack of a placebo group may affect accurate assessment of treatment effects. Due to the lack of a placebo group, we cannot exclude the potential influence of patient and physician expectancy effects on the results. Future studies may consider introducing a placebo control group to better control potential desired effects and improve the internal validity of the study. In view of the above limitations, future research directions may include conducting longer follow-up to verify the lasting effect of bracketless invisible braces and designing more rigorous controlled trials to ensure the reliability of the results. In addition, the effect of bracketless invisible braces in different subgroups of patients can be further explored to achieve more personalized treatment strategies.

In conclusion, clear aligner treatment can improve the periodontal status and reduce the levels of IL-6, MMP-8 and TNF-α in gingival crevicular fluid and serum of patients with secondary malocclusion caused by periodontitis. It is important to acknowledge the limitations of this study, which primarily include the relatively short follow-up period and the absence of a placebo group for comparison. These limitations may affect the generalizability and long-term applicability of the findings. Future research with extended follow-up durations and placebo-controlled designs could provide more comprehensive insights into the long-term effects and broader applicability of bracketless and invisible orthodontic treatments for periodontitis.

ETHICAL COMPLIANCE

This study was approved by the ethics committee of the Beijing University of Chinese Medicine and Pharmacology Dongfang Hospital. Signed written informed consent were obtained from the patients and/or guardians.

CONFLICT OF INTEREST

The authors have no potential conflicts of interest to report relevant to this article.

AUTHOR CONTRIBUTIONS

LD and SL designed the study and performed the experiments, YL and LL collected the data, YQ and HC analyzed the data, LD and SL prepared the manuscript. All authors read and approved the final manuscript. LD and XJ contributed to the manuscript equally.

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