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Review Article

Invisible orthodontic appliance therapy is beneficial to the alleviation of periodontitis and maintenance of oral health in periodontitis patients

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Abstract: To explore the effects of invisible orthodontic appliance therapy on orthodontic patients with periodontitis. A total of 66 patients treated in our hospital from January 2015 to January 2019 were enrolled; of which 36 patients were treated with invisible orthodontic appliances as a research group, and the rest were treated through straight wire appliances as a control group. The following indexes of the two groups were evaluated: Efficacy, periodontal functional indexes including debris index, plaque index and gingival bleeding index, and incidence of adverse reactions. An enzyme-linked immunosorbent assay (ELISA) was carried out to quantify serum inflammation-related factors (high sensitivity C-reactive protein (hs-CRP), tumor necrosis factor-α (TNF-α), and interleukin-6 (IL-6)) and oral health-related biological indicators (soluble intercellular adhesion molecule-1 (sICAM-1), alkaline phosphatase (ALP), and p21-activated kinase 5 (PAK5)) in the patients before and after treatment. The visual analog scale (VAS) and Oral Health Impact Profile (OHIP)-14 were applied to evaluate the pain degree and life quality of the patients, respectively. There was no significant difference in the incidence of adverse reactions between the two groups, and the research group showed better total effective rate and periodontal functional index recovery than the control group. In addition, after treatment, both groups showed significantly decreased hs-CRP, IL-6, TNF-α, sICAM-1, ALP, and PAK5 levels and had lower VAS scores, and the levels of those indexes and VAS score of the research group were all lower than those of the control group. Furthermore, after treatment, both groups had a lower OHIP-14 score, and the research group had a lower OHIP-14 score than the control group. Invisible orthodontic appliance therapy is not only beneficial to the alleviation of periodontitis and maintenance of oral health of periodontitis patients, but also helpful to the recovery of periodontal function, pain alleviation, and improvement of life quality, so it is worthy of promotion.

Keywords: Invisible orthodontic appliance therapy, periodontitis orthodontic treatment, periodontitis, oral health

Introduction

Periodontitis is an inflammation of the supporting tissues of the teeth, giving rise to alveolar bone resorption and attachment loss of periodontal soft tissues [1]. According some studies, pathological tooth migration often brings about serious functional and aesthetic problems in adult periodontal patients, and leads to various complications, such as tooth gap and tooth tilting due to interference of anterior teeth and occlusion [2]. However, periodontal therapy alone is unable to solve the pathological and traumatic occlusal problems of patients, and periodontitis is usually treated with combined orthodontics therapy in clinical practice [3, 4]. For patients with poor oral hygiene, orthodontic force will be increased to make teeth move, resulting in severe periodontitis [5]. Therefore, this study focused on improving the efficacy of periodontitis patients and promoting the rehabilitation of patients' teeth.

Orthodontic treatment is usually adopted to treat diseases caused by bacterial inflammation of teeth and periodontal tissues (PTs) [6]. Increasing patients require orthodontic treatment due to other various reasons [7], but many patients suffer from pain and discomfort of appliances and mechanical load during orth-

odontic treatment, and about 90% of orthodontic patients feel pain during treatment [8]. Moreover, long-term orthodontic treatment will increase the risk of gingivitis, extraction of wisdom teeth, and dental caries [9]. Orthodontic treatment leads to complications and pain, so the demand for invisible orthodontic appliance therapy is constantly increasing. Invisible orthodontic appliances are appliances without brackets and steel wires, and can be worn and taken off at any time without affecting the aesthetics [10]. The thickness of an invisible orthodontic appliance is smaller than that of the first and second lateral walls, which can prevent tooth discomfort and tooth pain caused by biting or chewing food [11]. One study has reported that the invisible orthodontic appliances are increasingly used, and are simpler and more accurate than traditional orthodontic appliances [12].

At present, there are few studies on the treatment of orthodontic patients with periodontitis by invisible orthodontic appliance therapy. Therefore, this study explored the application value of invisible orthodontic appliance therapy in periodontitis patients by applying it in treatment of patients, with the goal of providing a reference basis for therapy of periodontitis patients.

Materials and methods

General materials

A total of 66 periodontitis patients treated in our hospital from January 2015 to January 2019 were enrolled and assigned to a research group (n=36) and a control group (n=30). The control group consisted of 21 males and 15 females aged between 19 and 39 years old, with an average age of 26.28±3.14 years. The control group consisted of 16 males and 14 females aged between 18 and 37 years old, with a mean age of 25.87±3.11 years.

Inclusion and exclusion criteria

The inclusion criteria of the study: Patients diagnosed with periodontitis according to oral X-ray [13], patients without mouth breathing, patients with tooth tilt between 15° and 30°, patients ≥ 18 years old, patients with complete general clinical data, and those who had received periodontal treatment in the last three months. This study was carried out with permission from the Ethics Committee of the Second Affiliated Hospital of Fujian Medical University and was in accordance with Helsinki Declaration; and all the study participants and their family members signed informed consent forms after understanding the study. The exclusion criteria of the study: Patients requiring extraction orthodontic treatment, patients with other oral diseases, patients with poor treatment compliance, patients who withdrew from the treatment halfway, patients with coagulation dysfunction, and those lost to follow up.

Treatment methods

Patients in the two groups were all given routine oral treatment, and oral health education, orthodontics, periodontal treatment; and data detection for the two groups were all carried out by the same periodontal doctor and orthodontist to ensure that all data in the treatment process of the two groups were comparable. Patients in the control group were treated with straight wire appliances based on routine treatment: The brackets were bonded as needed for the patients according to the conventional diagnosis and treatment, and the patients were instructed to have follow-up treatment once a month. Patients in the research group were treated by invisible orthodontic appliances: First, a panoramic oral film and a lateral positioning film were taken for each patient, and then digital photos of the mouth inside and outside of the patient were taken. Subsequently, a silicone rubber impression was adopted for the patient after completion of the orthodontic appliances, and the patients were instructed to wear the silicone rubber impression for not less than 20 hours a day and keep good oral hygiene at all times. Additionally, the patients were told to change the impression once every two weeks, and to have a reexamination once every 4-6 weeks.

Outcome measures

(1) Periodontal functional indexes: Periodontal examination was carried out on the 6 upper anterior teeth of each patient in the two groups by the same doctor before and after treatment to detect their debris index, plaque index, and gingival bleeding index.

(2) Detection of oral health-related biological indicators and inflammatory factors: Fasting venous blood (5 mL) was sampled from each

patient 1 day before treatment and at one week after treatment, followed by 1500 r/min centrifugation for 10 min, and saved in a freezer at -70°C for later analysis. An enzyme-linked immuno-sorbent assay (ELISA) was carried out to quantify serum soluble intercellular adhesion molecule-1 (sICAM-1), alkaline phosphatase (ALP), and p21-activated kinase 5 (PAK5), interleukin-6 (IL-6), C-reactive protein (CRP), and tumor necrosis factor-α (TNF-α) in strict accordance with instructions of the Human sICAM-1 Kit (RAF102R, Future Biotechnology Co., Ltd., Beijing, China), Human ALP Kit (Ab224335, Kemin Biotechnology Co., Ltd., Shanghai, China), Human PAK5 Kit (bs-0655R-1, Hengfei Biotechnology Co., Ltd, Shanghai, China), Human CRP Kit (K001607P, Hengfei Biotechnology Co., Ltd, Shanghai, China), Human IL-6 Kit (E-EL-H0102c, Elabscience Biotechnology Co., Ltd., Wuhan, China), and Human TNF-α (E-EL-H0109c, Elabscience Biotechnology Co., Ltd., Wuhan, China), respectively [14].

(3) Pain scoring: The visual analog scale (VAS), with a full score of 10 points, was applied to score and record the pain degree of the two groups before treatment and at one week after treatment, and a higher score indicates more severe pain.

(4) Total effective rate: Treatment with the following outcomes was determined to be markedly effective: After treatment, the patient did not suffer from gingivitis nor hemorrhage, and his/her periodontitis was completely controlled. In addition, the contact between upper and lower jaw was restored to normal, and malocclusion was completely corrected, and the dental occlusion completely restored to normal. Treatment with the following outcomes was determined to be effective: After treatment, the periodontal tissue function of the patients was improved, and the inflammatory reaction was relieved. Treatment with the following outcome was determined to be ineffective: After treatment, all the indexes were not improved.

(5) Adverse reactions: Adverse reactions of the two groups were evaluated.

(6) Life quality: The Oral Health Impact Profile (OHIP)-14 was applied to score the patients in the two groups. OHIP-14 score ranged from 0 and 56 points for 14 items, and a higher score indicates poorer oral health.

Statistically analyses

In this study, the data were analyzed statistically using SPSS 22.0 (EASYBIO Technology Co., Ltd., Beijing, China). Enumeration data were expressed as the number of cases/percentage (n/%), and compared between groups using the chi-square test. Data with theoretical frequency in chi-square test of less than 5 were processed using the continuity correction chi square test. Measurement data were expressed as the mean ± standard error of mean (mean ± SEM), and compared between groups using the independent-sample t test, and within group comparison was done using the paired t test. $P < 0.05$ implies a significant difference.

Results

General materials

There was no significant difference between the two groups in clinical baseline data such as sex, age, body mass index, place of residence, nationality, educational background, smoking history, drinking history, tooth brushing time, diet, clinical symptoms, chewing habits, and odontoprisis (all $P > 0.05$) **Table 1**.

Comparison of periodontal functional indicators between the two groups

Before treatment, there was no significant difference between the two groups in periodontal functional indexes (debris index, plaque index, and gingival bleeding index) (all $P > 0.05$). While after treatment, the periodontal functional indexes of both groups were improved, and the research group showed lower debris index, plaque index, and gingival bleeding index than the control group (all $P < 0.05$) **Table 2**.

Comparison of oral health-related biological indexes between the two groups

Before treatment, there was no significant difference between the two groups in the levels of oral health-related biological indicators: PAK5, sICAM-1, and ALP (all $P > 0.05$). While after treatment, the research group showed significantly lower levels of PAK5, sICAM-1 and ALP than the control group (all $P < 0.05$) **Table 3**.

VAS score of the two groups during treatment

The VAS score of the research group before and after treatment was (4.04±0.21) points and

Table 1. General data of the research group and the control group [n (%)] (x ± sd)

Item	The research group (n=36)	The control group (n=30)	t/χ^2 value	*P*-value
Sex			0.166	0.684
Male	21 (58.33)	16 (53.33)		
Female	15 (41.67)	14 (46.67)		
Age (Y)	26.28±3.14	25.87±3.11	0.531	0.597
Body mass index (kg/m^2)	27.7±3.9	26.9±4.2	0.801	0.425
Place of residence			1.306	0.253
Urban area	19 (52.78)	20 (66.67)		
Rural area	17 (47.22)	10 (33.33)		
Nationality			0.132	0.716
Han nationality	20 (55.56)	18 (60.00)		
Minority nationality	16 (44.44)	12 (40.00)		
Education background			0.695	0.404
≥ senior high school	24 (66.67)	17 (56.67)		
< senior high school	12 (33.33)	13 (43.33)		
Smoking history			0.596	0.440
Yes	26 (72.22)	19 (63.33)		
No	10 (27.78)	11 (36.67)		
Drinking history			0.084	0.772
Yes	24 (66.67)	21 (70.00)		
No	12 (33.33)	9 (30.00)		
Brushing time			0.430	0.512
≥ 2 minutes	11 (30.56)	7 (23.33)		
< 2 minutes	25 (69.44)	23 (76.67)		
Diet			0.409	0.522
Light	16 (44.44)	11 (36.67)		
Spicy	20 (55.56)	19 (63.33)		
Clinical symptoms			0.127	0.988
Hemorrhage	9 (25.00)	7 (23.33)		
Gingival inflammation	11 (30.56)	9 (30.00)		
Tooth mobility	6 (16.67)	6 (20.00)		
Chewing difficulty	10 (27.78)	8 (26.67)		
Chewing habit			2.475	0.115
Yes	27 (75.00)	17 (56.67)		
No	9 (25.00)	13 (43.33)		
Odontoprisis			0.820	0.365
Yes	22 (61.11)	15 (50.00)		
No	14 (38.89)	15 (50.00)		

(1.76±0.11) points, respectively, and the VAS score of the control group before and after treatment was (4.12±0.17) points and (2.76±0.14) points, respectively. So before treatment, there was no significant difference between the two groups in VAS score (P > 0.05), while after treatment, both groups had a significantly lower VAS score (P < 0.05), and the research group had a significantly lower VAS score than the control group (P < 0.05) **Figure 1**.

Comparison of inflammatory factor levels between the two groups

Before treatment, there was no significant difference between the two groups in the levels of inflammatory factors: hs-CRP, IL-6, and TNF-α (all P > 0.05). while after treatment, both of them showed significantly decreased hs-CRP, IL-6, and TNF-α levels (all P < 0.05), and the research group showed significantly lower levels of them than the control group (all *P* < 0.05) **Table 4**.

Effective rate of the two groups after treatment

The research group showed a total effective rate of 91.67%, with 24 patients markedly effectively treated (66.67%), 9 patients effectively treated (25.00%), and 3 patients ineffectively treated (8.33%). While the control group showed a total effective rate of 73.33%, with 12 patients markedly effectively treated (40.00%), 10 patients effectively treated (33.33%), and 8 patients ineffectively treated (26.67%). So the total effective rate of the research group was significantly higher than that of the control group (P < 0.05) **Table 5**.

Adverse reactions in the two groups during treatment

Adverse reactions such as oral inflammation, tissue edema, and pain occurred in both groups, but there was no significant difference between the two groups in the total incidence of adverse reactions (P > 0.05) **Table 6**.

Table 2. Comparison of periodontal functional indexes between the two groups (x ± sd)

Group	n	Debris index (%)		Plaque index (points)		Gingival bleeding index (points)	
		Before treatment	After treatment	Before treatment	After treatment	Before treatment	After treatment
The research group	36	1.24±0.31	0.12±0.07*	2.15±0.12	2.89±0.15*	0.25±0.07	0.34±0.08*
The control group	30	1.22±0.33	0.61±0.09*,#	2.17±0.11	3.81±0.18*,#	0.27±0.05	0.40±0.11*,#
t	-	0.253	24.870	0.700	22.650	1.310	2.561
P-value	-	0.801	< 0.001	0.486	< 0.001	0.195	0.012

Note: *indicates P < 0.05 vs. the situation before treatment. #indicates P < 0.05 vs. the control group after treatment.

Table 3. Comparison of oral health-related biological indexes between the two groups (x ± sd)

Group	n	PAK5 (μg/L)		sICAM-1 (ng/mL)		ALP (U/L)	
		Before treatment	After treatment	Before treatment	After treatment	Before treatment	After treatment
The research group	36	3.16±0.41	4.61±0.51*	135.09±15.21	162.89±15.21*	342.81±15.28	372.19±20.02*
The control group	30	3.22±0.40	5.32±0.54*,#	138.11±15.27	187.19±15.27*,#	345.36±15.09	408.57±20.56*,#
t	-	0.778	5.483	0.801	6.469	0.514	7.225
P-value	-	0.439	< 0.001	0.425	< 0.001	0.608	< 0.001

Note: *indicates P < 0.05 vs. the situation before treatment. #indicates P < 0.05 vs. the control group after treatment.

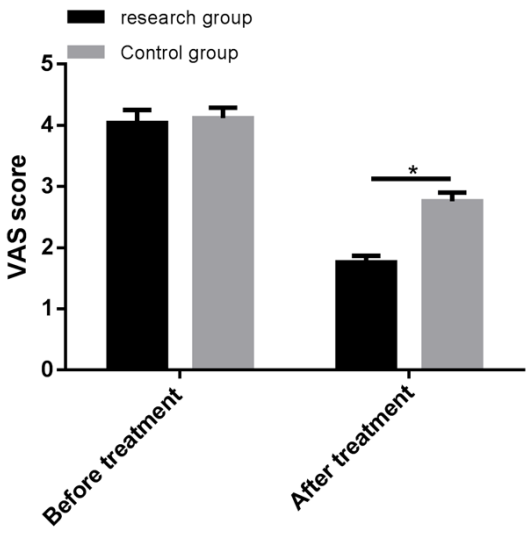

Figure 1. VAS score of the two groups during treatment. Before treatment, there were no significant differences between the two groups in VAS score (P > 0.05). While after treatment, both groups had a significantly lower VAS score, and the research group had a significantly lower VAS score than the control group (P < 0.05). Note: *P < 0.05 vs. the control group after treatment.

Comparison of OHIP-14 score between the two groups

The OHIP-14 score of the research group before and after treatment was (18.93±2.56) points and (10.53±2.16) points, respectively, and the OHIP-14 score of the control group before and after treatment was (18.25±2.56) points and (14.26±2.02) points, respectively. So before treatment, there was no significant difference between the two groups in OHIP-14 score (P > 0.05), while after treatment, both groups had a lower OHIP-14 score (P < 0.05), and the research group had a significantly lower OHIP-14 score than the control group (P < 0.05) **Figure 2**.

Discussion

Periodontitis is a chronic oral disease with irreversible damage to the PTs of patients [15]; and its prevalence rate is positively related with age [16]. Some studies have revealed that the pathogenesis of periodontitis is linked to the increase of inflammatory index levels [17, 18]. If it is not treated in a timely manner, it can aggravate the patient's tooth deformity [19]. Therefore, it is pivotal to find a treatment for periodontitis to promote the rehabilitation of patients' teeth.

Orthodontic treatment is becoming more and more popular in adults, but fixed orthodontic appliances have always been associated with an increase of bacterial colonization, and plaque accumulation, etc. [20]. In addition, orthodontic treatment may also change the coronal anatomical structure of bare teeth,

Table 4. Comparison of inflammatory factor levels between the two groups (x ± sd)

Group	n	hs-CRP (mg/L)		IL-6 (pg/mL)		TNF-α (pg/mL)	
		Before treatment	After treatment	Before treatment	After treatment	Before treatment	After treatment
The research group	36	4.34±0.21	2.13±0.15*	7.81±0.55	4.08±0.34*	4.56±0.26	1.27±0.14*
The control group	30	4.42±0.22	2.88±0.18*,#	7.87±0.54	5.61±0.29*,#	4.62±0.27	2.54±0.18*,#
t	-	1.508	18.470	0.445	19.440	0.917	32.230
P-value	-	0.136	< 0.001	0.657	< 0.001	0.362	< 0.001

Note: *indicates P < 0.05 vs. the situation before treatment. #indicates P < 0.05 vs. the control group after treatment.

Table 5. Effective rate of the two groups after treatment [n (%)]

Efficacy	The research group (n=36)	The control group (n=30)	χ^2 value	*P*-value
Patients with marked effective treatment	24 (66.67)	12 (40.00)	-	-
Patients with effective treatment	9 (25.00)	10 (33.33)	-	-
Patients without effective treatment	3 (8.33)	8 (26.67)	-	-
Total effective rate	33 (91.67)	22 (73.33)*	3.960	0.047

Note: *indicates P < 0.05 vs. the control group.

Table 6. Adverse reactions in the two groups during treatment [n (%)]

Item	The research group (n=36)	The control group (n=30)	χ^2 value	*P*-value
Oral inflammation	1 (2.78)	2 (6.67)	0.570	0.450
Tissue edema	1 (2.78)	1 (3.33)	0.017	0.895
Pain	1 (2.78)	2 (6.67)	0.570	0.450
Total incidence of adverse reactions	3 (8.33)	5 (16.67)	1.067	0.302

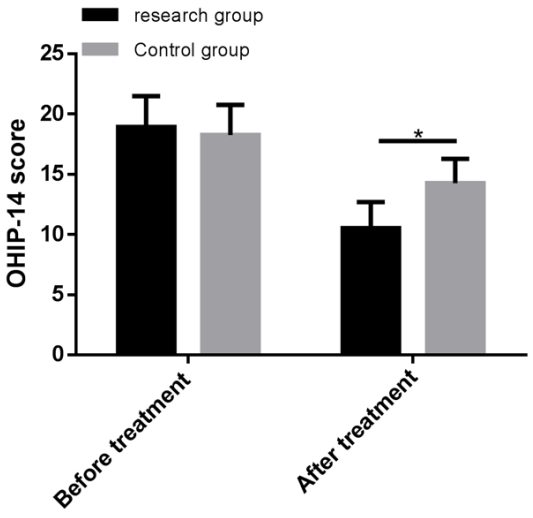

Figure 2. Comparison of OHIP-14 score between the two groups. Before treatment, there were no significant differences between the two groups in OHIP-14 score (P > 0.05). While after treatment, both groups had a significantly lower OHIP-14 score (P < 0.05), and the research group had a significantly lower OHIP-14 score than the control group (P < 0.05). Note: *P < 0.05 vs. the control group after treatment.

resulting in an increase in the number of reserved surfaces, eventually leading to the formation and adhesion of dental plaque thus exacerbating periodontitis [21]. One study found that patients' demand for orthodontic treatment has increased for aesthetic appliances during treatment [22]. In this study, invisible orthodontic appliances and straight wire appliances were applied to treat periodontitis, and it turned out that after treatment, the research group showed significantly lower periodontal functional indexes than the control group; indicating that the convenience of invisible orthodontic appliances in being able to wear and taking off the device is more conducive to the cleaning of the patients' oral cavity. Furthermore, one study has shown that invisible orthodontic appliances can strongly improve the plaque and gingival indexes of PTs and can also significantly improve the periodontal health of patients [23]. In this study, the research group showed significantly lower index levels compared to the control group; implying that invisible orthodontic appliances cause less

stimulation of PTs, contributes to better tolerance in the patients, and lower the trauma to the PTs. Orthodontic treatment can seriously impact the life, psychology and behavior of patients due to pain [24]. Therefore, in this study, we used VAS to score the pain degree between the two groups during treatment, finding that the VAS score of the research group was significantly lower than that of the control group, which suggested that invisible orthodontic appliances can effectively reduce tooth pain in periodontitis patients.

The pathological features of periodontitis include high infiltration level of inflammatory cells. Therefore, prevention of periodontitis and inhibition of related pathogens to control inflammatory reactions contribute to the regeneration of PTs [25]. In our study, we detected the levels of inflammatory factors before and after treatment in the two groups: hs-CRP, IL-6 and TNF-α. It came out that after treatment, the research group showed significantly lower inflammatory factor levels than the control group, implying that invisible orthodontic appliances lowered the damage of PTs in periodontitis patients, and was helpful for oral cleaning and reducing inflammatory reactions. Moreover, after treatment, the research group showed a significantly higher total effective rate than the control group, and there was no significant difference between the two groups in adverse reactions. This suggested that invisible orthodontic appliances are more effective and safer, and cause a more controllable incidence of adverse events in the treatment of periodontitis patients. One study has concluded that periodontal diseases directly affects the quality of life related to oral health, including eating discomfort, halitosis, speech difficulties, and taste disorders [26]. In this study, we scored the two groups using OHIP-14 after treatment, finding that the OHIP-14 score of the research group was significantly lower than that of the control group after treatment, implying that invisible orthodontic appliances can effectively improve the PTs of patients and promote healing.

Although this study confirmed the high efficacy of invisible orthodontic appliances in treating periodontitis, it still has room for improvement. For example, we can further evaluate the treatment compliance of periodontitis patients and analyze the risk factors for poor prognosis of the patients, which will help to identify clinical risk factors requiring more attention. We will gradually carry out supplementary research from the above perspective in the future.

To sum up, invisible orthodontic appliance therapy is not only beneficial to the alleviation of periodontitis and maintenance of oral health of periodontitis patients, but also helpful to the recovery of periodontal function, alleviation of pain, and improvement in quality of life.

Disclosure of conflict of interest

None.

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