

Original Article

The use of self-ligating appliance can reduce inflammatory response to orthodontic force and keep periodontal health in orthodontic treatment

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Abstract: Objective: Orthodontics, as a common way of orthodontic treatment, is usually to maintain oral health and protect periodontal tissue. The self-ligating appliance technique, since its advent in the 1930s, have been rather popular among the majority of orthodontists. This study was to determine that self-ligating appliance can reduce inflammation in gingival crevicular fluid (GCF) of patients receiving orthodontic treatment and keep periodontal health. Methods: The clinical data of 97 orthodontic patients admitted to the Department of Stomatology of Fujian Provincial Hospital, Fujian Provincial Clinical College of Fujian Medical University from March 2019 to March 2020 were analyzed retrospectively. Among them, 42 patients receiving orthodontic treatment with traditional MBT straight-wire appliance (SWA) were included in the control group (CG) and 55 patients treated with self-ligating appliance were collected as the observation group (OG). The two cohorts were compared with respect to the following aspects: curative effect, pain degree on the 1st, 2nd, 3rd, 5th and 7th day after wearing the appliance, oral related quality of life (QoL) before and after orthodontic treatment, satisfaction with the orthodontic treatment, periodontal condition, and GCF and inflammatory factor contents before, 3 months and 6 months after orthodontic treatment. Results: OG had significantly higher therapeutic efficacy of orthodontic treatment than CG ($P < 0.05$). At the initial stage of treatment, the pain degree in OG was obviously lower than that in CG ($P < 0.05$). Compared with CG, the plaque index (PLI), sulcus bleeding index (SBI), gingival recession (GR), periodontal probing depth (PPD) and clinical attachment loss (CAL) were better in OG after orthodontic treatment, and the differences were statistically significant ($P < 0.05$). The contents of GCF, prostaglandin E₂ (PGE₂), tumor necrosis factor- α (TNF- α) and interleukin-1 β (IL-1 β) in OG were lower than those in CG after orthodontic treatment, with significant differences between the two groups ($P < 0.05$). Oral related QoL and orthodontic satisfaction were higher in OG, and the differences were statistically significant ($P < 0.05$). Conclusions: Compared with traditional SWA, the self-ligating appliance in orthodontic treatment contributes to higher efficacy and satisfaction, less local inflammatory reaction, and significantly improved periodontal condition and oral health of patients.

Keywords: Self-ligating appliance, orthodontics, gingival crevicular fluid, inflammatory factors, oral related quality of life

Introduction

Dentognathic deformity covers a variety of deformities caused by the incongruous relationship between teeth and craniofacial features, usually including anomaly of dental arch and transposition of teeth [1-3]. It refers to malformations such as irregular tooth alignment, dislocation of the upper and lower dental arches, abnormal position and size of the upper and lower jaws, and incoordination between the dental jaw and the facial skull due to con-

genital or acquired factors during human development [4, 5]. Congenital factors include heredity [6], which means that the dental malformation of parents has a great influence on the dental morphology of their children. Acquired factors mainly include bad behavior habits (unilateral chewing, open-mouth breathing and biting of the lower lip), and malnutrition [7-9]. Dentognathic deformity has a certain impact on aesthetics, which adversely affect the local development and physical and mental health of patients [10]. With people's growing awareness

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Table 1. Baseline data of patients

	Control group (n=42)	Observation group (n=55)	χ^2/t	P
Gender [n (%)]			0.2486	0.6181
Male	20 (47.6)	29 (52.7)		
Female	22 (52.4)	26 (47.3)		
Average age (years)	24.12±4.37	24.87±5.03	0.7695	0.4435
Average dentition crowding (mm)	5.42±1.59	5.50±1.71	0.2353	0.8145
Cause of deformity			0.4314	0.8060
Congenital tooth deformity	23 (54.8)	28 (50.9)		
Acquired tooth deformity	16 (38.1)	21 (38.2)		
Others	3 (7.1)	6 (10.9)		
Malocclusion			1.7182	0.4236
Tooth transposition	24 (57.1)	30 (54.5)		
Tooth inclination	18 (42.9)	25 (45.5)		

and pursuit of beauty, increasing patients are seeking orthodontic treatment, during which process the maintenance of periodontal health is gradually concerned by orthodontists [11]. Orthodontic treatment is to relieve malocclusion. Generally, different types of orthodontic appliances are selected for treatment according to the patient's dental and maxillofacial deformities as well as their own needs, so as to achieve the goal of aligning the dentition and improving the facial shape [12, 13]. In virtue of high efficiency and precision, straight-wire appliance (SWA) was extensively used in clinic in the past in orthodontic treatment; However, due to the large contact area with oral mucosa, it was easy to be affected by some poor diet or oral hygiene habits of patients, which led to plaque retention, causing gingival and periodontitis, and ultimately affecting periodontal health [14, 15]. The self-ligating appliance, on the other hand, is simpler and more convenient than the traditional appliance in operation. Although it still cannot avoid the plaque accumulation around the bracket and the mechanical stimulation to the periodontal tissue, it can effectively reduce the friction between the bracket and the archwire [16], and shorten the retention of plaque, which is more beneficial for patients to maintain oral hygiene. During orthodontic treatment, a variety of inflammatory factors in periodontal tissue in gingival crevicular fluid (GCF) can reflect the degree of bone remodeling and periodontal tissue health [17]. Among them, interleukin-1 β (IL-1 β) and tumor necrosis factor- α (TNF- α) are important factors in the process of periodontal inflammation, and have higher sensitivity and specificity for the evaluation of subgingival inflammation [18].

The purpose of this study is to investigate the impact of self-ligating appliance on GCF inflammatory factors and periodontal health indicators of orthodontic patients.

Materials and methods

Research participants

This study retrospectively analyzed the clinical data of orthodontic patients admitted to the Fujian Provincial Hospital, Fujian Provincial Clinical College of Fujian Medical University from March 2019 to March 2020. Using Epi-Info 6, we estimated that a sample of 97 participants was needed for a statistically significant odds ratio (OR) of 2.0, with $\alpha=0.05$ and $\beta=0.2$. Based on the orthodontic methods, they were assigned into control group (CG, n=42; orthodontic treatment with traditional MBT SWA) and observation group (OG, n=55; orthodontic treatment with self-ligating appliance). Inclusion criteria: All the enrolled patients Aged ≥ 18 years, with Angle's Class I, Skeletal Class I, complete permanent dentition and healthy periodontal tissue, no missing teeth, abnormal dental indexes, systemic diseases, nor bad habits such as mouth breathing and smoking and drinking. Exclusion criteria: patients with periodontitis, menstrual period, pregnancy or lactation, or severe mental illness were excluded. The general baseline data of the two cohorts showed no statistical significance and were comparable (Table 1). This study was approved by the ethics committee of Fujian Provincial Clinical College of Fujian Medical University (ethics number: S2020-133). All subjects were informed and signed an informed consent form.

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Methods

Before orthodontic treatment, all patients received oral hygiene education by the same periodontist. Periodontic cleaning was performed with the Bass method prior to routine orthodontic treatment.

Patients in CG were treated with traditional MBT SWA. The upper and lower first molars were bonded with buccal tubes, while the remaining teeth were bonded with MBT straight wire brackets. Then, 0.36 mm nickel-titanium wires were placed in the maxillary and mandibular brackets, ligated and fixed, and the tightness was adjusted according to the actual condition of the patient. The whole treatment was performed by the same orthodontist, and the patients were regularly revisited once a month for 6 months.

Patients in OG were treated with self-ligating appliance. Self-ligating brackets were placed in the patient's maxilla, and the plane guide plate was used to adjust the tightness according to the patient's dentition deformity. Then, 0.36 mm titanium wires were placed for self-ligating. The entire treatment was completed by the same orthodontist, and the patients were regularly revisited once a month for 6 months.

Outcome measures

(1) Evaluation of clinical efficacy [19]: Ineffective: no change in dentition crowding, abnormal coverage, no improvement or even aggravation of symptoms; Effective: ameliorated dentition crowding, normal coverage, and alleviated symptoms; Markedly effective: disappearance of dentition crowding, normal coverage, and disappearance of symptoms such as tooth loosening, gingival bleeding and recession. Total effective rate = (markedly effective + effective) cases/total cases × 100%.

(2) Evaluation of pain degree [20]: The pain degree of patients was scored with the visual analogue scale (VAS) at the initial stage of orthodontic treatment, namely, the 1st, 2nd, 3rd, 5th and 7th day after wearing the appliance. The total points were 0-10, with 0 being the mildest pain and 10 the most severe pain.

(3) Detection of periodontal indexes: According to the re-visits, the sulcus bleeding index (SBI)

[21], clinical attachment loss (CAL) [22], periodontal probing depth (PPD) [23] and gingival recession (GR) [24] of patients before, 3 months and 6 months after orthodontic treatment was evaluate by the same doctor using the Williams periodontal probe. Plaque index (PIL) [25] was measured by the display agent inspection method. Briefly, 2% basic fuchsin solution was selected to stain the dental plaque and the range and width of staining were determined.

(4) Determination of GCF content: GCF was collected before treatment and 3 and 6 months after orthodontic treatment. The plaque and tartar on the patient's gingival sulcus were effectively removed, and a mouthwash was applied to rinse the mouth. After a short rest, sterile dry cotton balls were used to for tooth isolation, and the gums were gently blown with an air gun for about 1 min. After that, a 2 mm × 20 mm filter paper strip was placed in the mesio-distal gingival sulcus on the labial side of the tested teeth for 30 seconds and then taken out, with a measurement interval of 20 min. Then the GCF filter paper of the same patient was placed in the same microcentrifuge tube and weighed by electronic balance. The quality of GCF was obtained after removing the mass of the microcentrifuge tube.

(5) Measurement of inflammatory factors in GCF: The GCF collected was centrifuged for 10 min at 1000 r/min, and the resultant supernatant was obtained for the measurement of prostaglandin E₂ (PGE₂), TNF-α and IL-1β using the enzyme-linked immunosorbent assay (ELISA). All the kits were offered by Wuhan SPBio Co., Ltd., and the tests were carried out in strict accordance with relevant instructions.

(6) The Oral Health Impact Profile (OHIP) [26] was used to evaluate the oral related quality of life (QoL) of patients before and after orthodontic treatment. The scale includes a total of 14 items (0-4 points for each item), covering 7 fields of physical pain, functional limitation, social disability and handicap, physical disability, psychological discomfort, and psychological disability, with a total score of 56 points. The higher the score, the better the oral related QoL.

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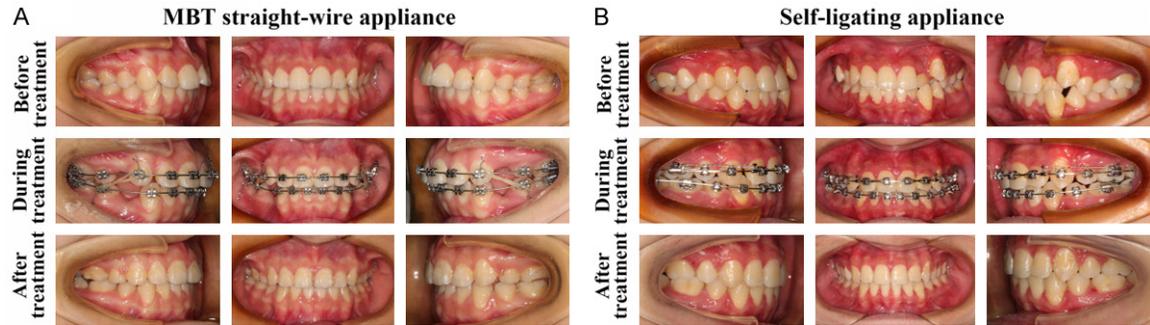


Figure 1. Patients' intraoral photographs during treatment progress. A: MBT straight-wire appliance; B: Self-ligating appliance.

Table 2. Orthodontic treatment efficacy of the two groups

	Markedly effective	Effective	Ineffective	Total effective rate
Control group (n=42)	27 (64.3)	8 (19.0)	7 (16.7)	35 (83.3)
Observation group (n=55)	38 (69.1)	15 (27.3)	2 (3.6)	53 (96.4)
χ^2	0.2487	0.8907	4.8041	4.8041
P	0.6180	0.3453	0.0284	0.0284

Comparison of orthodontic treatment efficacy

The effective rate of OG was 96.4%, which was significantly higher than that in CG (83.3%) ($P < 0.05$, **Table 2**).

Comparison of pain degree at the initial stage of orthodontic treatment

odontic treatment

VAS scores of patients in both groups gradually increased 1-3 days after appliance wearing, with significantly higher scores in CG compared with OG ($P < 0.05$). However, 3-7 days after wearing, the pain gradually decreased, and the pain was less intense in OG compared with CG ($P < 0.05$) **Table 3**.

Comparison of periodontal indexes before and after orthodontic treatment

The periodontal indexes (PLI, SBI, GR, PPD and CAL) were not significantly different between the two cohorts before orthodontic treatment ($P > 0.05$). After three and six months of orthodontic treatment, the PLI, SBI, PPD and CAL decreased gradually in both cohorts, while GR increased gradually, and the improvement of each index in OG was significantly better than that in CG ($P < 0.05$) **Table 4**.

Comparison of GCF content and GCF inflammatory factor levels before and after orthodontic treatment

GCF content and inflammatory factor levels showed no significant difference between the two cohorts before orthodontic treatment ($P > 0.05$). After three and six months of orthodontic treatment,

(7) Satisfaction evaluation: An questionnaire was used to evaluate the satisfaction with a total score of 100 points; Very satisfied: ≥ 87 points, generally satisfied: 57-87 points, dissatisfied: < 57 points.

Statistical methods

SPSS 22.0 statistical software and Graphpad Prism 8.0 were used for data processing and image rendering respectively. The measurement data were represented as mean \pm standard deviation, and the differences between two groups were assessed via independent-samples T test. The counting data were expressed as cases or percentages and compared by Chi-square test. Differences between the means were measured with or without repeated measures using single-two- or three-factor ANOVA, followed by Bonferroni correction (Bonferroni post-analysis) using $\alpha = 0.05$ as the test criterion. $P < 0.05$ indicated that the difference was statistically significant.

Results

Treatment progress of two groups

Two groups of patients' intraoral photographs in the whole treatment progress are displayed in **Figure 1**.

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Table 3. Pain degree at the initial stage of orthodontic treatment

	1 d	2 d	3 d	5 d	7 d
Control group (n=42)	3.84±1.08	4.91±1.38	6.24±1.51	2.74±1.15	1.74±0.97
Observation group (n=55)	3.21±0.99	4.23±1.24	5.49±1.44	2.26±1.17	1.39±0.58
t	2.9854	2.5482	2.4887	2.0168	2.2100
P	0.0036	0.0124	0.0145	0.0465	0.0295

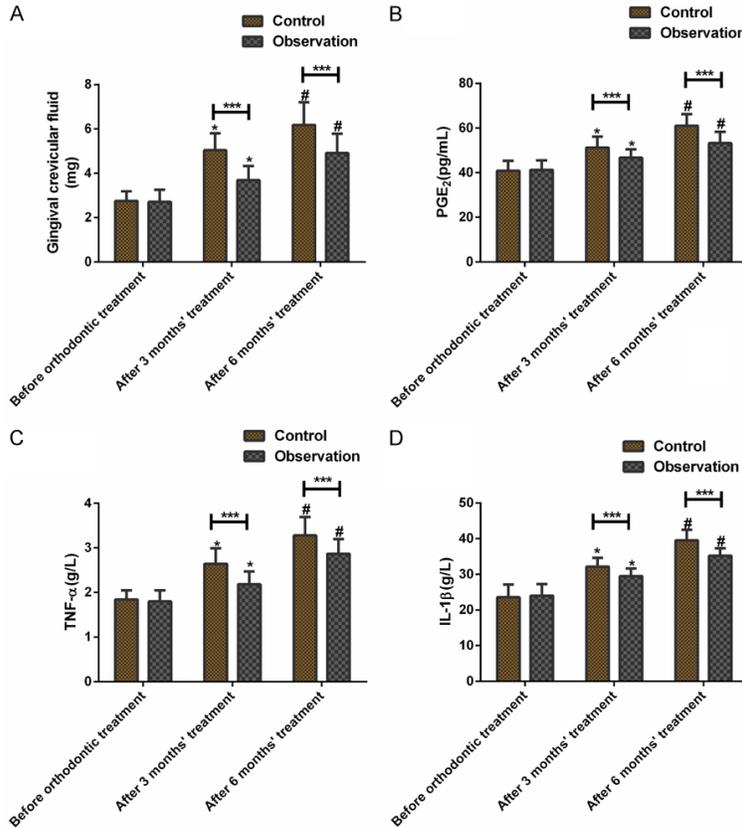


Figure 2. GCF contents and levels of GCF inflammatory factors before and after orthodontic treatment in the two groups. A: Gingival crevicular fluid contents; B: PGE₂ levels; C: TNF-α levels; D: IL-1β levels; * vs the same group before orthodontic treatment, P<0.05; # vs the same group after 3 months' treatment, P<0.05; *** vs the control group, P<0.0001. Note: GCF: gingival crevicular fluid; PGE₂: prostaglandin E₂; TNF-α: tumor necrosis factor-α; IL-1β: interleukin-1β.

odontic treatment, the GCF content and inflammatory factor levels increased in the two cohorts, and were even higher in CG compared with OG (P<0.05) **Figure 2**.

Comparison of oral related QoL

After orthodontic treatment, the oral related QoL of patients were assessed from the aspects of physical pain, functional limitation, social disability, social handicap, psychological discomfort, physical disability and psychologi-

cal disability. It was found that the scores of all the above aspects increased in both groups, with higher scores in OG (P<0.05) **Table 5**.

Comparison of orthodontic treatment satisfaction

The total orthodontic treatment satisfaction was 94.5% in OG, a rate significantly higher than 78.6% in CG (P<0.05) **Table 6**.

Discussion

Dentognathic deformity not only affects the growth and development of the craniomaxillofacial region, but also influences the masticatory function of patients as well as facial beauty. In addition, irregular dentition can affect oral hygiene and easily lead to gingivitis and periodontitis [27, 28]. In the orthodontic treatment of dental deformities, most of the patient are accompanied with periodontal inflammatory reaction. On the basis of controlling the inflammatory response, perfect orthodontic treatment can move the elongated, displaced and tilted teeth to achieve the purpose of aligning teeth, reducing plaque accumulation and restoring normal adjacency, so that the health of periodontal tissue can be restored and maintained, the normal chewing function can be regained, and the facial aesthetics can be improved. At present, orthodontic appliances are mainly used in orthodontic treatment, but the types are diversified, with varying effects on improving periodontal tissue. So, in orthodontic treatment, it is necessary to

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Table 4. Periodontal indexes of the two groups before and after treatment

	PLI			SBI		
	Before orthodontic treatment	3 months after orthodontic treatment	6 month after orthodontic treatment	Before orthodontic treatment	3 month after orthodontic treatment	6 month after orthodontic treatment
Control group (n=42)	0.94±0.11	0.78±0.15*	0.65±0.08*	1.87±0.38	1.34±0.23*	1.03±0.17*
Observation group (n=55)	0.93±0.13	0.62±0.10*	0.46±0.12*	1.83±0.56	1.06±0.20*	0.80±0.11*
t	0.4007	6.2929	8.8617	0.3979	6.4010	8.0687
P	0.6895	<0.0001	<0.0001	0.6915	<0.0001	<0.0001
	GR (%)			PPD (mm)		
	Before orthodontic treatment	3 month after orthodontic treatment	6 month after orthodontic treatment	Before orthodontic treatment	3 month after orthodontic treatment	6 month after orthodontic treatment
Control group (n=42)	0.38±0.08	0.44±0.11*	0.56±0.17*,#	4.15±0.46	3.47±0.33*	2.79±0.29*,#
Observation group (n=55)	0.37±0.10	0.62±0.15*	0.78±0.21*,#	4.08±0.52	3.01±0.45*	2.17±0.13*,#
χ ² /t	0.5309	6.5451	5.5411	0.6901	5.5755	14.1220
P	0.5967	<0.0001	<0.0001	0.4918	<0.0001	<0.0001
	CAL (mm)					
	Before orthodontic treatment	3 month after orthodontic treatment	6 month after orthodontic treatment			
Control group (n=42)	4.17±1.06	3.87±0.84*	3.06±0.94*,#			
Observation group (n=55)	4.12±1.13	3.25±0.71*	2.18±0.67*,#			
χ ² /t	0.2217	3.9355	5.3827			
P	0.8249	0.0001	<0.0001			

Note: PIL: plaque index; SBI: sulcus bleeding index; GR: gingival recession; PPD: periodontal probing depth; CAL: clinical attachment loss. Compared with the same group before orthodontic treatment, *P<0.05; Compared with the same group 3 month after orthodontic treatment, #P<0.05.

Table 5. Oral related quality of life in the two groups

	Physical pain		Functional limitation		Social disability		Psychological disability	
	Before orthodontic treatment	After orthodontic treatment						
Control group (n=42)	34.51±4.43	43.57±3.84*	27.84±3.51	44.51±3.69*	36.84±4.08	48.26±2.68*	33.87±2.61	42.58±2.09*
Observation group (n=55)	35.06±4.89	50.36±2.43*	28.04±2.70	51.25±2.99*	35.94±5.11	52.48±2.06*	33.05±2.95	51.64±1.54*
χ ² /t	0.5714	10.6279	0.3173	9.9359	0.9358	8.7716	1.4249	24.5883
P	0.5691	<0.0001	0.7517	<0.0001	0.3517	<0.0001	0.1575	<0.0001
	Psychological discomfort		Social handicap		Physical disability			
	Before orthodontic treatment	After orthodontic treatment	Before orthodontic treatment	After orthodontic treatment	Before orthodontic treatment	After orthodontic treatment		
Control group (n=42)	37.24±1.97	44.84±2.61*	28.97±2.97	46.15±3.02*	36.21±4.01	42.84±0.97*		
Observation group (n=55)	36.97±2.21	51.11±2.07*	29.15±3.03	53.71±1.14*	35.87±4.55	51.69±0.62*		
χ ² /t	0.6245	13.1970	0.2924	17.0630	0.3836	54.6476		
P	0.5338	<0.0001	0.7706	<0.0001	0.7021	<0.0001		

Compared with the same group before treatment, *P<0.05.

Table 6. Orthodontic treatment satisfaction of the two groups

	Very satisfied	Generally satisfied	Dissatisfied	Overall satisfaction
Control group (n=42)	21 (50.0)	12 (28.6)	9 (21.4)	33 (78.6)
Observation group (n=55)	42 (76.4)	10 (18.1)	3 (5.5)	52 (94.5)
χ ² /t	7.2711	1.4661	5.6051	5.6051
P	0.0070	0.2260	0.0179	0.0179

use intermittent, gentle and mild orthodontic force to avoid excessive periodontal force, and gradually move the teeth to restore the normal dentition structure while protecting periodontal health. Therefore, in this

study, the traditional MBT straight wire brackets and self-ligating brackets were applied in orthodontic treatment to observe the efficacy of the self-ligating appliance.

Our research results identified that the treatment efficacy of the self-ligating appliance group was significantly higher than that of the traditional bracket group; and at the initial stage of correction, the pain degree of self-ligating appliance group was significantly lower compared with the traditional bracket group. During orthodontic treatment, the tooth movement is caused by periodontal tissue reconstruction under the action of orthodontic force, and the tooth moves on the alveolar bone along with the reconstructed periodontal tissue. During the movement, the periodontal ligament first feels the pressure signal, and then the tissue is compressed or pulled to produce an inflammatory reaction, releasing a variety of inflammatory mediators such as neuropeptides and prostaglandins [29, 30]. These inflammatory mediators act on the tissue, which causes blood vessel congestion, dilation and pressure increase in the local tissue of the periodontal ligament, increasing the sensitivity of periodontal ligament nerve endings receptors, and finally forming pain sensation, so that patients will feel pain and discomfort [31]. Previous studies have shown that [32], applying continuous light force to the teeth can achieve more efficient and physiological tooth movement and produce less pain and discomfort. On the contrary, excessive orthodontic force will aggravate orthodontic pain, induce periodontal trauma, affect tooth movement, and even cause root resorption [33]. For self-ligating brackets, the early correction is less intense, and the smaller overall size of brackets also reduces the influence of periodontal tissue blood supply to ensure the aerobic metabolism of periodontal tissue, thus reducing pain. Furthermore, we observed that the contents of GCF, PGE_2 , $\text{TNF-}\alpha$ and $\text{IL-1}\beta$ in patients treated by self-ligating brackets were lower than those of the traditional bracket group, but higher than those before orthodontic treatment. This is mainly due to the fact that the orthodontic force generated by the appliance can become a local promoter of periodontal inflammation [34]. During orthodontic treatment, patients have an increased risk of periodontitis and are prone to recurrent attacks, with the pathological mani-

festations of infiltration of inflammatory cells, exudation of tissue fluid and destruction of periodontal tissue [35]. Among them, inflammatory cells in GCF can secrete a flood of cytokines to mediate inflammatory response. When periodontal tissue is stimulated or damaged, $\text{IL-1}\beta$ secreted by monocytes and macrophages can induce the synthesis of collagenase, plasmin and PGE_2 , which are the main markers of periodontal tissue inflammation [36, 37]. In the pathological process of periodontal tissue, $\text{TNF-}\alpha$ can stimulate the expression of adhesion factors and chemokines, enhance the activity of osteoclasts and promote the apoptosis of stromal cells, leading to the damage of periodontal soft tissue and hindering its repair [38]. Orthodontic gingivitis is an indirect immunopathological injury caused by the host's immune response to infectious microorganisms and toxic products [39]. The results of this study also suggest that the application of self-ligating appliance can reduce the pressure on periodontal tissue blood vessels and maintain the metabolic balance of periodontal tissue microecology, even though the periodontal tissue inflammation is reversible in this process. After orthodontic treatment, it was found that PLI, SBI, GR, PPD and CAL in self-ligating bracket group ameliorated more obviously compared with the traditional bracket group. Studies have shown [40] that plaque and its metabolites are the initiation factors of chronic gingivitis. And the results of this study demonstrate that the self-ligating appliance can minimize the stimulation to periodontal tissue, and reduce bacterial invasion, friction and the amount of dental plaque. The self-locking bracket has the characteristics of small friction and light orthodontic force in use; Thus, the orthodontic force will not compress the blood vessels in the periodontal ligament and cause periodontal tissue ischemia. Intermittent and gentle orthodontic force can promote the rapid alignment of dentition. After adaptive expansion, the dental arch will be increased to provide space for crowded dentition alignment, which will shorten the alignment time and reduce plaque accumulation, thus promoting the recovery of normal adjacent joints of teeth and eliminating bite injury. Finally, higher oral related QoL and total treatment satisfaction were determined in the self-ligating bracket group, which further explained that the self-ligating appliance can significantly improve the

patients' QoL in orthodontic treatment. There are also some limitations in this study. To begin with, the sample data size need to be further expanded, and the follow-up content of patients can be enriched. In addition, the design of follow-up studies needs to be more comprehensive to discuss the effect of different orthodontic methods from multiple angles such as sample selection, outcome measures and statistical analysis, so as to enhance the scientific and rational treatment of periodontitis related diseases.

In summary, the use of self-ligating appliance in orthodontic treatment contributes to less inflammatory reaction in GCF, validly improved periodontal condition and oral health of patients, as well as alleviated pain and bolstered QoL, which is worthy of clinical application and popularization.

Disclosure of conflict of interest

None.

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