Evaluation of Periodontal Status after Orthodontic Treatment: A Pilot Study on Patients with Stage IV/Grade C periodontitis

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Objective: *To evaluate whether the periodontal status was affected in patients with stage IV/grade C periodontitis after orthodontic treatment.*
Methods: *Twenty-four patients with stage IV/grade C periodontitis who received combined periodontal and orthodontic treatment were included in this study. Probing depth (PD), bleeding on probing (BOP) and percentage of relative bone height (RBH%) were measured and calculated. Parameter changes before and after orthodontic treatment, and their differences between teeth adjacent to extraction sites (TAES) and teeth nonadjacent to extraction sites (TNES) were compared. Three-level analysis was performed to test the influential factors of PD and RBH% reduction after orthodontic treatment.*
Results: *No change of PD, BOP% and RBH% was detected after orthodontic treatment. No difference of PD, BOP% and RBH% was detected between TAES and TNES. BOP negative, excessive horizontal overlap, excessive vertical overlap, crowding, PD at T0 (the last periodontal visit before orthodontic treatment) and RBH% at T0 were positively associated with PD reduction after orthodontic treatment. Being female, excessive horizontal overlap, excessive vertical overlap, crowding, PD at T0 and RBH% at T0 were positively associated with a RBH% reduction. Space was negatively associated with a RBH% reduction.*
Conclusion: *Periodontal stability can be obtained for patients with stage IV/grade C periodontitis after orthodontic treatment. Orthodontic treatment with extraction was safe for patients with severe periodontitis, however, attention should be given to TAES.*
Key words: *periodontitis, orthodontic treatment, stage IV/grade C periodontitis*
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Studies have shown that subjects with advanced periodontitis can benefit from orthodontic treatment to improve their periodontal health[1-7]. Plaque control and periodontal maintenance may be easier after orthodontic treatment for patients suffering from malocclusion such as proclination, irregular interdental spacing, rotation or migration of teeth and malposition of teeth[8]. In addition, occlusal trauma is a local contributing factor of onset and progression of severe periodontitis[9-12] and it may interfere with tissue repair and regeneration after periodontal treatment[13]. This could be ameliorated by orthodontic correction of adverse occlusion and improper loading distribution[14,15].

However, the question still remains whether orthodontic treatment may deteriorate the periodontal status of patients who are experiencing advanced periodontal breakdown. Results from a systematic review revealed the influence of fixed orthodontic appliances on oral microbiota[14]. It was suggested that plaque accumulation may increase probing depth (PD) of periodontally compromised individuals during orthodontic therapy[16]. Inappropriate forces applied to teeth could also add a

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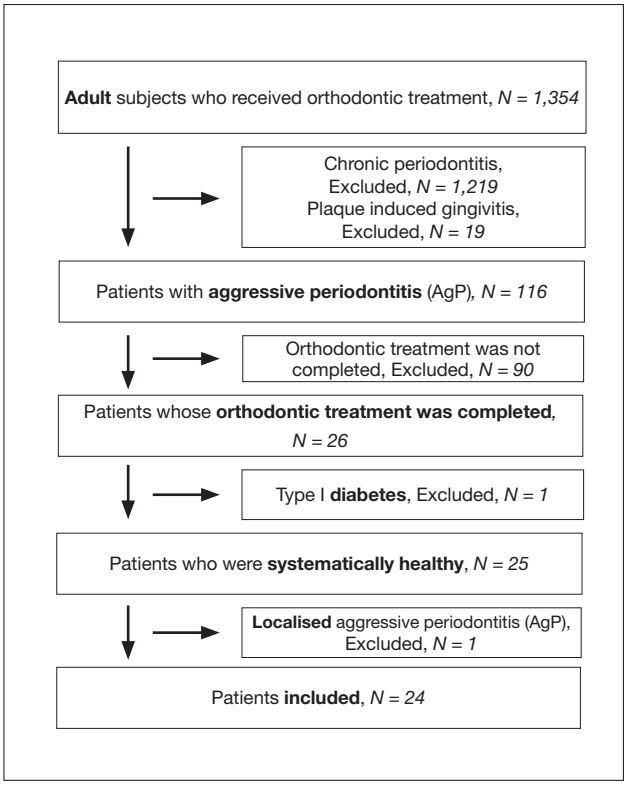

Fig 1 Flow chart of the process of patients' selection and screening.

detrimental effect on periodontal health[17,18]. Results of an in vitro study[19] showed that proinflammatory mediators were induced by cyclic tensile strain, and suggested that orthodontic overloading might contribute to periodontal destruction. In addition, facial tooth movements might result in gingival recession particularly in patients with the thin periodontal biotype[20].

Although case reports have indicated that comprehensive periodontal and orthodontic treatments may result in significant improvements in patients with severe periodontitis[21-24], limited evidence is available on the detailed clinical and radiographic changes of periodontal parameters, after periodontal-orthodontic interdisciplinary treatment of patients with stage IV/grade C periodontitis. Khorsand et al[25] investigated periodontal parameters before and after orthodontic therapy in eight patients with aggressive periodontitis (AgP). No statistically significant differences of PD, plaque index (PLI), distance between top of the papilla and incisal edge, and width and depth of vertical bone defect were observed before and after orthodontic treatment. However, Khorsand's findings are not conclusive due to a limited sample size. In addition, many factors were not considered such as age, duration of orthodontic treatment and periodontal parameters before orthodontic treatment. Furthermore, whether there was a difference between the periodontal status change between the teeth adjacent to extraction sites (TAES) and teeth nonadjacent to extraction sites (TNES) for orthodontic purposes has not yet been analysed, which might influence the periodontal status after orthodontic treatment. The present retrospective study aimed at evaluating changes of clinical and radiographic periodontal parameters as well as their influential factors before and after orthodontic treatment, in patients with stage IV/grade C periodontitis using multilevel statistical models.

Materials and methods

Patient selection

The retrospective data of patients diagnosed with generalised aggressive periodontitis (GAgP), according to the classification proposed at the International Workshop for a Classification of Periodontal Diseases and Conditions[26] by periodontists, was collected from January 2003 to January 2017, at the Department of Periodontology and received orthodontic treatment by an experienced orthodontist of the Department of Orthodontics, at the Peking University School and Hospital of Stomatology. According to the latest classification, all patients belonged to stage IV/grade C periodontitis[27].

The inclusion criteria included:

- Adults diagnosed with GAgP according to the classification proposed at the International Workshop for the Classification of Periodontal Diseases and Conditions in 1999[26];
- 18 to 35 years of age;
- At least eight teeth had probing PD > 5 mm and attachment loss (AL) > 3 mm and at least three of them were not first molars or incisors;
- The clinical diagnosis was confirmed by evidence of inter-proximal bone loss on full-mouth periapical radiographs;
- At least 20 teeth remained;
- Nonsmokers;
- Other considered factors involving family aggregation, rapid progression and imbalanced relationship between local irritation and periodontal destruction;
- Active periodontal therapy was completed before orthodontic treatment: full mouth number of sites with $2\ mm \leq PD \leq 5\ mm$, $BOP\% \leq 20\%$, plaque score $\leq 30\%$;
- Completed orthodontic treatment.

Table 1 Patient data extraction.

Category		N	%
Patient characteristics			
Gender	Female	16	66.7
	Male	8	33.3
Orthodontic treatment	Extraction	7	29.2
	Non-extraction	17	70.8
Total		24	100.0
Orthodontically extracted teeth			
Maxillary lateral incisor(s)		1	7.7
Maxillary first premolar(s)		2	15.4
Mandibular central incisor(s)		4	30.8
Mandibular lateral incisor(s)		3	15.4
Mandibular first premolar(s)		3	23.1
Total		13	100.0

The exclusion criteria included:

- Systemic disease (e.g. diabetes mellitus, nephrosis, hepatopathy, hypertension, neutropenia), pregnant, or under medication known to affect the periodontal status.

The process of patients' selection and screening is presented in Figure 1.

Clinical and radiographic examination

The data of the full-mouth periodontal examination was performed by a Williams periodontal probe, and periapical films of the last periodontal visit (T0) before orthodontic treatment (within 1 month) and the first periodontal visit (T1) after orthodontic treatment finished (within 1 month) were extracted. In detail, PD was measured at six sites (mesial, distal, and middle sites of buccal and lingual surfaces) and bleeding on probing (BOP) of buccal and lingual surfaces were recorded 30 seconds after probing. Full-mouth periapical radiographs were taken via the bisecting-angle technique at T0 and T1. The percentage of relative bone height (RBH%) of the interproximal sites was measured and calculated following a method by Lü et al[28]. All measurements were conducted by one examiner (Dr Jian JIAO). Self-calibration was carried out and the inter-class correlation coefficient (ICC) was 0.92. Intraoral and extraoral photos were taken at T0 and T1.

Data extraction

The patient data extraction is shown in Table 1. There were 16 female patients (66.7%) and 8 male patients (33.3%) in total. Among all patients, 7 patients (29.2%) received extraction orthodontic treatment, and 17 patients (70.8%) were treated without extraction. The specific number and percentage of different teeth extracted are listed in Table 1.

Ethnic approval

The study was approved by the Ethics Committee of the Peking University School and Hospital of Stomatology (approval no. PKUSSIRB-201310066).

Treatment procedures

For all subjects, the same treatment process was followed:

1. An oral hygiene instruction was given at baseline and reinforced on every visit. Scaling and root planning for all sites and periodontal surgery for teeth with PD $\geq$ 7 mm sites was performed according to periodontal treatment plans.
2. Periodontal maintenance treatment for each patient was performed at 3-month intervals. The orthodontic treatment did not start until at least 6 weeks post periodontal re-evaluation when patients had no site with PD > 5 mm and acquired proper methods of selfcare.
3. For subjects with the orthodontic extraction treatment plan, the teeth were extracted before the orthodontic treatment.
4. Fixed appliances were placed on both arches; the buccal tube, instead of the band, was used to affix the appliances on molars.

Table 2 Characteristics of tooth and site level.

Category		N	%
Tooth level			
Buccal-lingual relationship	Normal	548	84.6
	Increased horizontal overlap	76	11.7
	Reverse articulation	24	3.7
Vertical relationship	Normal	514	79.3
	Excessive vertical overlap	129	19.9
	Open bite	5	0.8
Mesial-distal relationship	Normal or slight tipping	635	98.0
	Severe tipping	13	2.0
Total		648	100.0
Site level			
Adjacent relationship	Normal	994	76.7
	Crowding	152	11.7
	Space	150	11.6
Total		1,296	100.0

5. A nickel-titanium (NiTi) wire was used for aligning and levelling. The intrusion and retraction of the migrated anterior teeth were achieved by using a 0.018-inch Australia wire. A light force was applied (10 to 20 g per tooth) depending on the amount of residual periodontal support.
6. The orthodontic treatment was continued for an average of 18 months.
7. At the end of all treatments, all patients received fixed lingual retainers (resin-bonded splint) and removable retainers (vacuum formed retainer) for retention.

Data analysis

The data collected were analysed using IBM SPSS Statistics 20 software (IBM Corp. 2011, NY, USA). The mean and standard deviation (SD) of clinical and radiographic parameters were calculated and analysed. Differences of measurement values between T0 and T1 and measurement values of site adjacent to extraction sites and site nonadjacent to extraction sites of TAES were evaluated using the paired *t* test. Differences of value changes between TAES and TNES were evaluated using student's *t* test (all continuous variables were in Gaussian distribution as determined by the Kolmogorov-Smirnov test). To explain the hierarchical and clustered structure of the periodontal measurements, multilevel linear regression models were constructed. The PD reduction and the RBH% reduction at tooth-level at T1 were analysed by multi-level linear regressions. Three-level models were constructed with three independent variables (gender, orthodontic duration and age at T0) at patient-level, five independent variables (BOP, location relationship with orthodontic extraction sites, buccal-lingual relationship, vertical relationship and mesial-distal relationship) at tooth-level and three independent variables (adjacent relationship, PD at T0 and RBH% at T0) at site-level. Sensitivity analysis of cases according to their mean PD reduction, RBH% reduction and 11 independent variables in regression models was conducted by the Cronbach's alpha coefficient. The level of significance was set at $P < 0.05$.

Results

Demographic and clinical characteristics at baseline

A total of 24 patients with stage IV/grade C periodontitis were included in the present study. Clinical and radiographic measurements of 648 teeth were taken and analysed. The clinical characteristics at tooth and site level are presented in Table 2. Among all the remaining teeth, 76 teeth (11.7%) had increased horizontal overlap and 24 teeth (3.7%) had isolated reverse articulation. Vertically, 129 teeth (19.9%) had increased vertical overlap and 5 teeth (0.8%) had an open bite. When it comes to adjacent relationship, 152 sites (11.7%) out of 1,296 sites were crowded, while 150 sites (11.6%) had space.

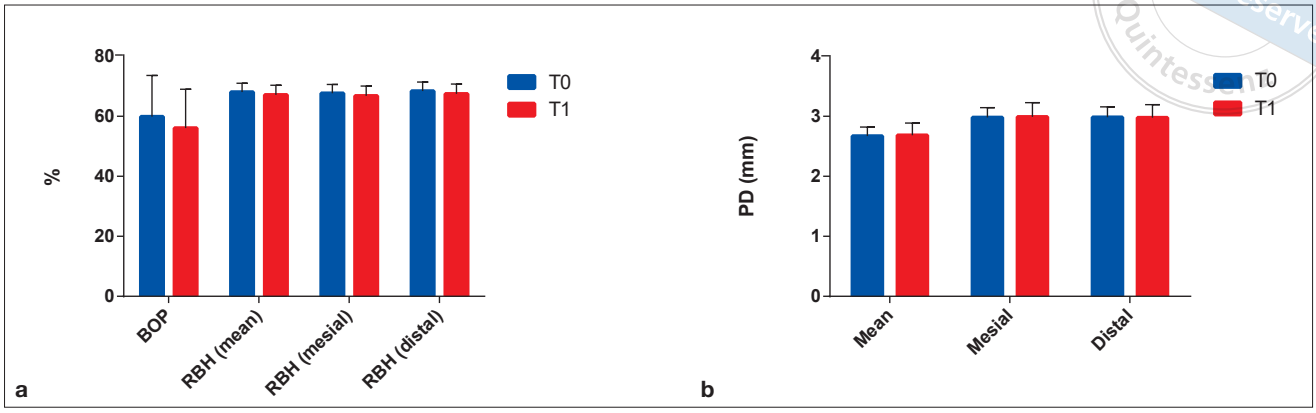

Fig 2 Mean values and 95% confidential intervals of periodontal parameters at the last periodontal visit (T0) before orthodontic treatment (within 1 month) and the first periodontal visit (T1) after orthodontic treatment finished (within 1 month).

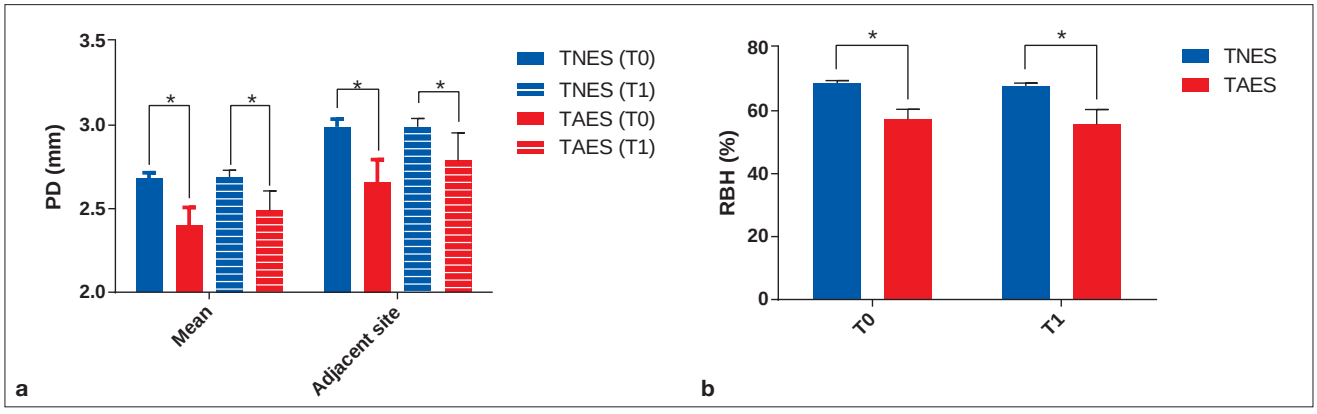

Fig 3 Comparison of probing depth (PD) and percentage of relative bone height (RBH%) between teeth adjacent to extraction sites (TAES) and teeth nonadjacent to extraction sites (TNES) at the last periodontal visit (T0) before orthodontic treatment (within 1 month) and the first periodontal visit (T1) after orthodontic treatment finished (within 1 month).

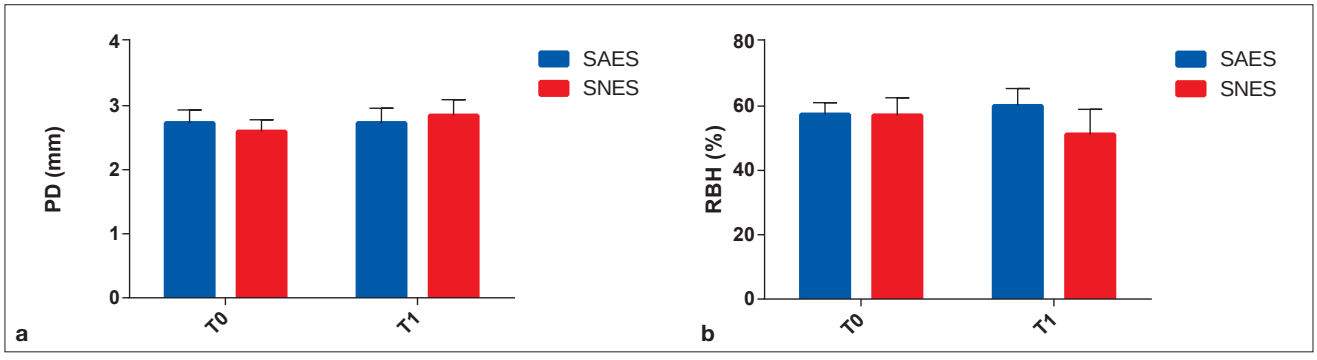

Fig 4 Comparison of probing depth (PD) and percentage of residual bone height (RBH%) between site adjacent to extraction sites (SAES) and site nonadjacent to extraction sites (SNES) at the last periodontal visit (T0) before orthodontic treatment (within 1 month) and the first periodontal visit (T1) after orthodontic treatment finished (within 1 month).

Clinical and radiographic parameters before and after orthodontic treatment

The patient-level changes of the mean BOP%, mean RBH% (distal, mesial and all sites), mean PD (distal, mesial and all sites) at T0 and T1 are presented in Figure 2. No differences before and after the orthodontic treatment were detected for all the three parameters.

At tooth level, comparison of mean PD, mean adjacent PD and RBH% and their changes at T0 and T1 between TAES and TNES of orthodontic extraction sites, are presented in Figure 3. Significant differences of mean PD at T0 ($P = 0.002$), mean PD at T1 ($P = 0.037$), mean adjacent PD at T0 ($P = 0.005$), RBH% at T1 ($P < 0.001$) and RBH% changes ($P < 0.001$), were detected. Regarding teeth adjacent to extraction sites, differences of mean PD and RBH% of T0, T1 and its change between sites adjacent to extraction sites and sites not adjacent to extraction sites were insignificant, which are shown in Figure 4.

Multiple linear regression analysis of factors associated with PD and RBH% changes before and after orthodontic treatment

Results of three-level statistical analysis of nine independent variables are presented in Figures 5 and 6. Excessive horizontal overlap ($P < 0.001$), excessive vertical overlap ($P = 0.014$), crowding ($P = 0.021$), PD at T0 ($P = 0.003$) and RBH% at T0 ($P < 0.001$) were positively associated with PD reduction after treatment. BOP positive ($P = 0.029$) was negatively associated with PD reduction after treatment. Gender ($P = 0.042$), excessive horizontal overlap ($P < 0.001$), excessive vertical overlap ($P < 0.001$), crowding ($P = 0.002$), PD at T0 ($P < 0.001$) and RBH% at T0 ($P < 0.001$) were positively associated with RBH% reduction. When it comes to sensitivity analysis, the Cronbach's alpha coefficient of 25 cases was 0.997, which means that the internal consistency and generalisability of the results was excellent.

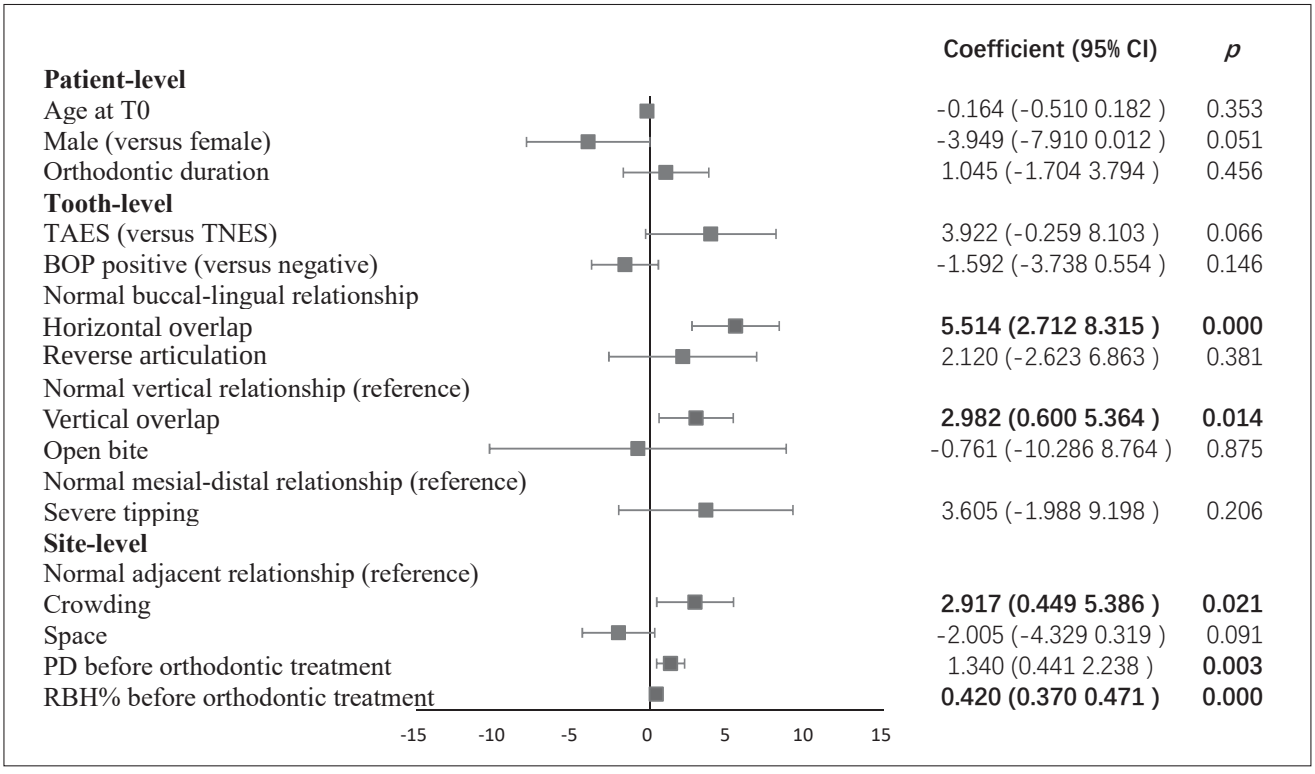

Fig 5 Forest plot of multilevel liner regression model for probing depth reduction (the dependent variable). Significant independent variables were highlighted in bold. PD, probing depth; RBH%, percentage of relative bone height; TAES, teeth adjacent to extraction sites; TNES, teeth nonadjacent to extraction sites.

Discussion

New classification of periodontal disease

According to the classification proposed at the International Workshop for the Classification of Periodontal Diseases and Conditions in 1999, AgP is a type of periodontal disease that causes extensive attachment loss and periodontal bone resorption in young subjects[26]. A severe tissue destruction of periodontal tissue may lead to a pathologic migration of the anterior teeth, causing aesthetic and functional problems to these patients[29]. Improvement of function and aesthetics in patients with AgP has been accomplished by appropriate periodontal treatment and maintenance in conjunction with orthodontic treatment, which has been described by several case reports[21,24,30-36]. The 2017 World Workshop has reported the latest classification of periodontal diseases, which is mainly based on stages defined by severity and grades that reflect the biologic features of the disease[27]. According to the new classification, patients included in this study who were diagnosed with AgP belonged to stage IV and grade C.

Stability of periodontal status can be achieved after orthodontic treatment

Several case reports[21,24,31-33,35] have indicated that the improvement of function and aesthetics, as well as periodontal stability, after orthodontic treatment may be accomplished. However, the present study is the first attempt, to the best of our knowledge, to evaluate the clinical and radiographic parameters before and after orthodontic treatment in patients with stage IV/grade C periodontitis. Previous studies investigated changes of PD and PLI during the orthodontic treatment[25] and no significant differences were found for these two clinical parameters. However, so far, there are no studies including possible influential factors to better assess the periodontal status after orthodontic therapy in patients with stage IV/grade C periodontitis. In the present study, no significant changes of PD, BOP% and RBH% were found between T0 and T1 at patient-level (Table 2). The results obtained here suggest that the stability of the periodontal tissue can be achieved during the orthodontic treatment, in spite of a severe bone loss observed before the orthodontic treatment, in patients with stage IV/grade C periodontitis (Fig 7).

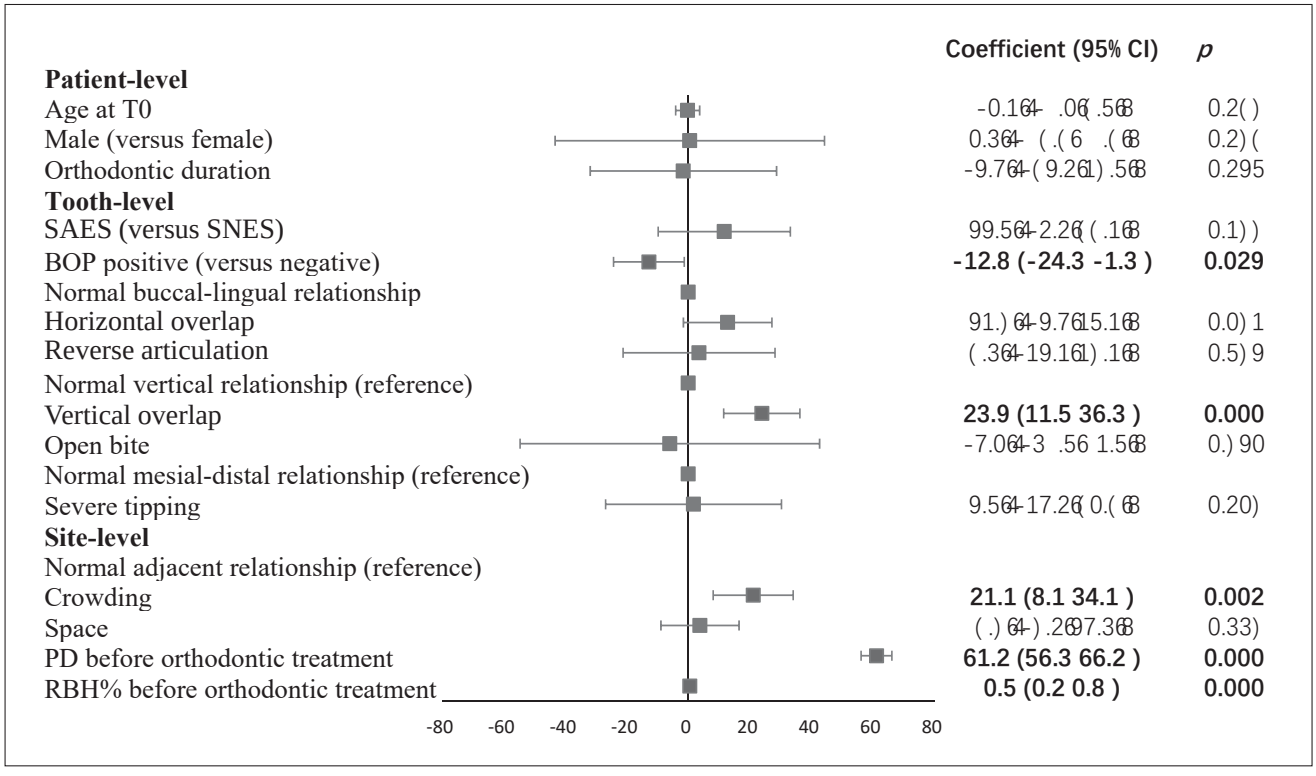

Fig 6 Forest plot of multilevel liner regression model for percentage of relative bone height (RBH%) reduction (the dependent variable). Significant independent variables were highlighted in bold. PD, probing depth; SAES, site adjacent to extraction sites; SNES, site nonadjacent to extraction sites.

Fig 7 Photos of two patients (a, b respectively) with stage IV/Grade C periodontitis before (left column) and after (right column) orthodontic treatment. Periodontal status was maintained while occlusion was improved.

Teeth adjacent to extraction sites (TAES) show more root resorption

For patients with orthodontic treatment, TAES may move longer distance than TNES. Besides, the periodontal status before orthodontic treatment is an important factor for the orthodontist to decide whether to retain or to extract a tooth. The orthodontist may tend to extract periodontally hopeless teeth, if any, rather than teeth with better periodontal prognosis. Severe bone loss of extraction sites may also affect the periodontal status of TAES. Results from the tooth-level data showed that significant differences of mean PD, mean adjacent PD and RBH% of TAES and TNES were detected before the orthodontic treatment but no significant differences of changes of these parameters were found during the orthodontic treatment (Fig 3). However, the mean RBH% reductions of sites adjacent to extraction sites and sites nonadjacent to extraction sites of TAES were 5.89% and –2.71%, respectively, and a significant difference of them was also detected (Fig 4).

Regarding the multilevel analysis, no significant difference of PD was detected between TAES and TNES but a tendency was observed for TAES, which may undergo more RBH% reduction during the orthodontic treatment ($P = 0.058$, Fig 5). It should be noted that 26 TAES and 622 TNES were included for analysis and the markedly difference between the two groups may affect the final results. In addition, longer moving distances of TAES may also result in more root resorption, which can influence the RBH% of teeth and bring bias when considering bone loss during orthodontic treatment. Root resorption may be the leading cause of the RBH% reduction. A study investigated apical root resorption in 22 Angle Class II division 1 patients who underwent orthodontic treatment using cone-beam computed tomography (CBCT)[37], and observed that the root length was reduced following treatment in patients who underwent orthodontic treatment both with and without extraction; a statistically significantly greater extent of root resorption was detected in cases with extraction. Therefore, studies analysing the difference of real alveolar bone change during orthodontic treatment by excluding the impact of root resorption, for example, measurement of bone height by CBCT, are needed to determine the differences of parameter changes between TAES and TNES.

Nevertheless, greater RBH% reduction does not mean that the orthodontic treatment with extraction should be a contradiction for patients with stage IV/grade C periodontitis. About 6% of bone level reduction (Fig 3) of a tooth was still within the limit of periodontium compensation. However, attention should be given to TAES and a potential further RBH% reduction should be considered when a multidisciplinary treatment plan is made. Studies are also needed to test long-term prognosis of TAES of patients with an advanced periodontitis history.

Higher risk of bone loss for teeth with excessive vertical overlap and crowding

Multilevel analysis showed that significantly more PD reductions were found for teeth with excessive horizontal overlap, teeth with excessive vertical overlap and crowding teeth (Fig 5). The improvement of the periodontal status may be due to the elimination of occlusal trauma and facilitation of oral hygiene by the orthodontic treatment. However, the multilevel analysis also shows that significant more RBH% reductions were found for teeth with excessive vertical overlap and crowding teeth (Fig 6). For teeth with excessive vertical overlap, especially anterior teeth with pathological migration, the reduction of RBH% may be due to the fact that intrusion and retraction of teeth, which make teeth move towards alveolar bone, result in more root resorption. For crowded teeth, the difficulty of self and professional cleaning results in higher risk of bone loss during the orthodontic treatment. To prevent further bone loss and root resorption, a light force on round wire is suggested, rather than an active torque control on stainless steel wire.

Extraction plans for patients with severe periodontitis

It should be noted that the extraction plans for orthodontic patients with severe periodontal attachment loss are different from those for subjects with little periodontal damage. Generally, premolars are often the preferred choice to extract by orthodontists when considering orthodontic extraction plans to correct sagittal discrepancy and/or convex profiles. However, for subjects with previous severe periodontal destruction, teeth with the worst periodontal prognosis or those already missing due to a periodontal reason might be considered as the first choice. This is also the reason why eight incisors and only five pre-molars were extracted before orthodontic treatment (Table 1).

Periodontal monitoring during orthodontic treatment

Successful orthodontic treatments for patients with stage IV/grade C periodontitis require an interdisciplinary collaboration of periodontists and orthodontists and good compliance of patients. Adequate plaque control and periodontal health should be ensured by periodontists before initiation of the orthodontic treatment, and proper treatment design and close observation of the periodontal status should be done by periodontists and orthodontists[38]. Furthermore, continued periodontal re-evaluation in a 3-month interval is also required during the orthodontic therapy.

A prospective study with larger sample size is needed

The present study has several potential limitations. First of all, the findings are limited by the retrospective nature of the analysis. In addition, the utilisation of non-standardised periapical radiographs made it difficult to acquire accurate measurements of bone loss in millimetres. Therefore, the RBH%, instead of the distance from the cementoenamel junction to the bone crest, was used to evaluate changes of bone level in percentage. A previous study[28] also reported that RBH% can work as a useful and accurate method to compute and assess the bone level change in patients with severe periodontal

damage. In addition, the sample size of the present study was small (24 subjects and 648 teeth) which may limit the statistical power of the present explorative study to some extent. Therefore, the power simulation model was used to evaluate the power of the different sample size, and the results showed that the sample size of the present study should be sufficient to draw a conclusion. Another limitation of the study was the lack of a control group. An ideal control group would comprise patients diagnosed with stage IV/grade C periodontitis and with similar age and gender composition as the treatment group. Furthermore, this group of patients (control) should not have received orthodontic treatment after the periodontal treatment, so that the exact influence of the orthodontic treatment on patients with stage IV/grade C periodontitis could be determined. However, this ideal control group of patients is extremely difficult to gather due to ethical issues. In the future, prospective studies with a larger sample size, stricter inclusion criteria, proper control group and standardised periapical radiographs with accurate measurements of bone level should be performed to determine the long-term influence of orthodontic treatment on the periodontal condition and prognosis of patients with stage IV/grade C periodontitis.

Conclusion

Stability of periodontal parameters during orthodontic therapy for patients with stage IV/grade C periodontitis can be maintained by proper combined periodontal and orthodontic treatments. In addition, more PD and RBH% reduction was found in teeth with excessive horizontal overlap, teeth with excessive vertical overlap and crowded teeth. The orthodontic treatment with an extraction design was safe for patients with stage IV/grade C periodontitis, however, special attention should be paid to TAES. More studies should be performed to determine the long-term influence of the orthodontic treatment on the periodontal condition and prognosis of patients with stage IV/grade C periodontitis.

Conflict of interests

The authors declare no conflicts of interest related to this study.

Author contribution

Drs Jian JIAO and Tian Yi XIN acquired and analysed the data and drafted the manuscript; Prof. Huan Xin MENG did the periodontal treatment and supervised the study; Dr Jie SHI designed and supervised the study, performed the orthodontic treatment and revised the manuscript. All authors approved the final manuscript.

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