Teeth under High Occlusal Force may Reflect Occlusal Trauma-associated Periodontal Conditions in Subjects with Untreated Chronic Periodontitis

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Objective: *To determine the association of high occlusal force (HOF) with the signs of occlusal trauma and periodontal conditions in periodontitis patients, and elaborate the relevant clinical implications.*

Methods: *Periodontal parameters and signs of occlusal trauma were recorded for 807 teeth in 30 subjects with untreated chronic periodontitis. The T-scan II occlusal analysis system determined the HOF during maximum intercuspation, lateral excursion and protrusive excursion. The correlation of HOF with periodontal parameters and signs of occlusal trauma was analysed.*

Results: *Overall, the teeth with HOF existed mainly in molars and presented with deeper probing depth (PD) and higher frequency of bleeding on probing (BOP) than those without HOF. The fixed-effect analysis showed that HOF was positively correlated with PD and BOP ($P < 0.05$) in posterior teeth; widened periodontal ligament space on radiographs in upper ($r = 0.179$, $P < 0.01$) and lower posterior teeth ($r = 0.205$; $P < 0.05$); as well as functional mobility in upper posterior teeth ($r = 0.168$; $P < 0.05$).*

Conclusion: *This study suggests that the posterior teeth with HOF in subjects with chronic periodontitis may reflect occlusal trauma-associated periodontal conditions that could probably increase the risk of further periodontal destruction. These findings may improve the clinical assessment of occlusal trauma and related periodontal conditions for better patient management and treatment outcomes.*

Key words: *chronic periodontitis, occlusal trauma, T-scan occlusal analysis system*

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Over the years, clinical assessment and management of occlusal trauma remain a complex and controversial issue in clinical practice, and the critical questions are whether excessive occlusal force is harmful to the periodontium and how to appropriately manage the occlusion-associated issues in periodontal patients[1-4]. It is noted from classical literature that occlusal trauma could synergistically aggravate the consequences of infection and inflammation-induced tissue destruction, and account for angular bony defects[4,5-7]. However, angular bony defects and infrabony pockets could occur at the teeth with plaque-induced periodontal inflammation alone without detectable trauma from occlusion[7,8]. Between the 1970s and 1980s, further studies in animal models showed that excessive occlusal force contributed to alveolar bone resorption, widened periodontal ligament space and increased tooth mobility[9-17]. Based upon the accumulated evidence and current notion, excessive occlusal force alone does not cause inflammation and attachment loss in periodontally-healthy individuals. Whether occlusal trauma *per se* could accelerate the

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inflammatory progress and contribute to periodontal destruction in subjects with existing periodontitis has been disputed for many years.

Limited clinical studies are available examining the potential relationship between occlusal trauma and severity of periodontitis, mainly due to the difficulty in identifiying appropriate indicators of occlusal trauma, and clinical challenge in study design and undertaking in humans. Nevertheless, it has been shown that periodontal parameters are aggravated when teeth undergo abnormal mobility, such as functional mobility, or present with widened periodontal ligament space on radiographs[18,19]. Teeth with occlusal discrepancies may exhibit deeper probing depth as compared with those without occlusal problems[20-23]. It is believed that occlusal status is to some extent related to tooth prognosis[19-23]. However, it is difficult to precisely detect active occlusal trauma and then establish a clear diagnostic criteria. Presence of functional tooth mobility, widened periodontal ligament space on radiographs and certain forms of tooth wear are frequently referred to as possible clinical signs of occlusal trauma[19,20]. Currently, a more objective and appropriate approach is imperative and required for analysing biting force and occlusal contacts to facilitate the assessment and management of occlusal trauma-related periodontal lesions.

The T-scan II occlusal analysis system uses an electronic sensor strip to objectively record occlusal force and the overall distribution of occlusal contacts, as well as the time order of the contacts during mandibular movement[24,29]. This diagnostic device has been increasingly applied in prosthodontics, implant dentistry and the effective management of temporomandibular joint disease[30-34]. Until now it has seldom been used in periodontal research and clinical management of periodontally-related occlusal problems. Therefore, the present study attempted to investigate the distribution of the high occlusal force (HOF) in upper and low dentitions by using the T-scan system, and assess its association with common signs of occlusal trauma and periodontal conditions. The relevant clinical implications were elaborated. The current findings could enhance the further understanding of the implication of occlusal trauma in periodontal disease, and thereby improve clinical management of periodontal patients with occlusal problems.

Table 1 The characteristics of 30 subjects and their periodontal conditions.

Variables[a]	
Age	48.0 ± 13.7
Gender (female:male)	10:20
Smoker	8 (27%)
Total number of teeth present (anterior: posterior)	807 (349:458)
PD (mm)	3.9 ± 1.3
CAL (mm)	4.7 ± 1.8
BOP %	79.0 ± 29.0
GR (mm)	0.7 ± 1.0
TM	0.2 ± 0.5

PD: Probing depth; CAL: Clinical attachment loss; BOP: Bleeding on probing; GR: Gingival recession; and TM: tooth mobility.
[a] Mean ± SD or numbers (%).

Materials and methods

Subjects

Thirty subjects (10 females and 20 males with a mean age of 48.0 ± 13.7 yrs) with moderate to severe chronic periodontitis were recruited from the Department of Periodontology at the Second Dental Center of Peking University School of Stomatology. The study protocol was approved by the Ethics Committee at the Peking University, Health Science Center, and written informed consent was obtained from all subjects prior to the study. The inclusion criteria included a) 30 to 74 years of age and systemically healthy; b) at least 3 teeth with probing depth ≥ 6mm, clinical attachment loss ≥ 6 mm and alveolar bone loss ≥ 30% of the root length on periapical radiography; c) presence of the first or second molar in each quadrant and no more than 3 teeth missing in upper or lower jaw; d) no prior periodontal treatment in the past 2 yrs; e) no antibiotic usage for at least 1 month; and vi) no obvious malocclusion, e.g. deep overbite or deep overjet, and f) no history of temporomandibular disorders. The exclusion criteria were i) having complicated restorations, e.g. long or cross arch dental prosthesis, removable partial dentures, large fillings or restoration of cusps; and ii) having history of occlusal adjustment or orthodontic treatment.

Periodontal assessment

The following clinical parameters were assessed and recorded in each subject:

- Probing depth (PD) at 6 sites (mesio-buccal, mid-buccal, disto-buccal, mesio-lingual, mid-lingual and disto-lingual) per tooth (third molars excluded), using a Williams manual periodontal probe.

- Bleeding on probing (BOP) – the presence or absence of bleeding after probing at 6 sites of each tooth.
- Gingival recession (GR) – the distance from the free gingival margin to cemento-enamel junction was recorded to the nearest mm at mid-buccal and mid-lingual sites of each tooth.
- Clinical attachment loss (AL). This was calculated by adding PD and GR at mid-buccal and mid-lingual site, respectively.
- Tooth mobility (TM) was recorded according to Hanamura's classification[35].

Occlusal examination

Occlusal examination consisted of functional tooth mobility (FM) that was detected by manual palpation when placing the index finger on the buccal surfaces of teeth to detect the fremitus and/or visual isation of fremitus, either absent or present, during maximal intercuspation, lateral excursion and protrusive excursion. Each assessment was repeated three times. Teeth with worn facets or abrasive edges or cusps were recorded as presence of tooth wear (TW).

The HOF was determined by using the T-scan II system (Tekscan, Boston, USA), and the teeth-bearing HOF was also recorded by the system. Briefly, an electric sensor strip, presenting with a dental arch shape and 25-µm mylar film covered by silver wire to form X-Y grid of 2000 recording sensels (spacing of 1.25 mm), was placed inside the sensor holder, and connected to the handle into patients' oral cavities. A computer then careuly recorded and analysed the occlusal contacts and force. The software showed the location of occlusal contacts and their relative pressure that was marked in different colours with respect to the intensity of occlusal force detected. The sensitivity of the sensor strip was adjusted appropriately to detect the strongest 2 to 3 pressure points. In addition, all subjects were trained to bite on the sensor strip once or twice for practice before a proper analysis was undertaken, while seating with their heads upright and practicing maximum intercuspation, lateral excursion, and protrusive excursion movements. The stability of individual positions was then checked and secured during the examination. The percentage of the teeth present with HOF in various occlusal positions was calculated respectively. All clinical examinations were undertaken by a single examiner (H.M). Prior to the T-scan examination, a periodontal probe was used to measure the horizontal width of the maxillary central incisor between the mesial and distal contact points with its neighbouring teeth. The reading was then entered into the dimension box. The teeth in both the upper and lower arches were then assessed for any high occlusal points present by using 40µ micro-thin articulating papers (Dr Jean Bausch GmbH & Co. KG, Köln, Germany).

Radiographic examination

Standardised periapical radiographs in posterior teeth were taken by an experienced technician. Digital dental radiographs were evaluated at magnification × 6.0 on the computer screen. Any radiographs without clear images were excluded from the study. Widened periodontal ligament space (PDLS) around mesio-, disto-, and periapical zones of the root was recorded when present and detectable.

Statistical analysis

The periodontal parameters were presented as mean ± SD. Chi-square test was used to determine the difference in percentage of HOF teeth in different occlusal positions. Mann-Whitney U test was applied to analyse the difference between teeth with or without functional mobility, tooth wear, widened PDLS and HOF. The sample size was estimated on the basis of anticipated difference between the sub-groups. In order to assess the potential effects of confounding variables on the measurement of periodontal parameters, the fixed-effect analysis as one of the multilevel models was undertaken. The explanatory variables included age, gender, history of smoking, HOF and common indicators of occlusal trauma (e.g. tooth mobility, functional mobility, tooth wear and widened PDLS). Pearson's correlation analysis was employed to examine the association of HOF with common indicators of occlusal trauma. $P < 0.05$ was determined to be statistically significant.

Results

The intra-examiner agreement for recording the presence or absence of functional mobility and widened or normal PDLS was 91.6% and 74.4%, respectively. The intra-examiner reproducibility for detecting HOF in maximum intercuspation, lateral excursion, and protrusive excursion movement using the T-scan II system was 89.5%, 92.3% and 90.7% respectively. A total of 807 teeth (349 anterior teeth and 458 posterior teeth) from 30 patients with chronic periodontitis were included in the study. The characteristics of all subjects and their periodontal conditions are shown in Table 1. An overall symmetrical distribution of teeth with HOF on the left and right side dentitions was found in both maxillary and mandibular arches. Notably, the largest percentage

Table 2 The distribution of teeth with high occlusal force.

	Right side			Left side			P-value[a]	Total			P-value[b]	
	Teeth (N)	Teeth with HOF	%	Teeth (N)	Teeth with HOF	%		Teeth (N)	Teeth with HOF	%		
Maxillary												
Central incisor	29	9	31.0%	30	12	40.0%	0.480	59	21	35.6%	0.080	
Lateral incisor	29	7	24.1%	29	4	13.8%	0.324	58	11	19.0%	0.386	0.257
Canine	29	9	31.0%	30	7	23.3%	0.515	59	16	27.1%		
Premolars	58	10	17.2%	57	12	21.1%	0.697	115	22	19.1%	**0.019**	
Molars	58	24	41.4%	58	24	41.4%	1.00	116	48	41.4%		
Mandibular												
Central incisor	27	9	33.3%	29	9	31.0%	0.857	56	18	32.1%	0.197	
Lateral incisor	29	7	24.1%	30	4	13.3%	0.297	59	11	18.6%		0.473
Canine	29	6	20.7%	29	7	24.1%	0.758	58	13	22.4%	0.751	
Premolars	57	7	12.3%	59	15	25.4%	0.183	116	22	19.0%		
Molars	55	29	52.7%	56	29	51.8%	0.974	111	55	49.6%	**0.010**	

N: number of teeth; HOF: high occlusal force.
[a] Comparison between left and right side; [b] Comparison among anterior and posterior teeth.

of teeth bearing HOF occurred in the molars (Table 2). When the percentage of teeth with HOF was compared in anterior teeth, no significant difference was found among them in both upper and lower arches. However, the percentage of teeth withstanding HOF in molars was 41.4% (upper arch) and 49.6% (lower arch), which was significantly higher than that of premolars 19.1% (upper arch, $P = 0.019$) and 19.0% (lower arch, $P = 0.010$).

The periodontal conditions in different occlusal status were analyzed in both anterior (Table 3) and posterior teeth (Table 4). In the anterior area, the teeth with FM had greater mean of PD, AL, BOP% and TM, but not GR, than those without FM ($P < 0.05$). No significant difference was found between the teeth with and without HOF, as well as those with and without tooth wear. In the posterior area, the teeth with FM exhibited greater mean of PD, AL, GR and TM, but not BOP%, than those without FM ($P < 0.01$). Similar findings were noted between the teeth with or without TW. Meanwhile, the teeth with widened PDLS were more severe in all periodontal parameters than those without widened PDLS ($P < 0.01$). The teeth with HOF presented with deep PD and great BOP% as compared with those without HOF ($P < 0.01$).

The results of fixed-effect analysis regarding the related variables to periodontal conditions in anterior and posterior teeth were presented in Tables 5 and 6, respectively. In anterior teeth, there was no correlation between HOF and periodontal parameters; while in posterior teeth HOF was positively correlated with BOP and PD ($P < 0.05$). TM was positively correlated with most of periodontal parameters both in anterior and posterior teeth ($P < 0.05$). TW was positively correlated with PD, AL and GR in posterior teeth ($P < 0.05$). FM was strongly correlated with TM both in anterior and posterior teeth ($P < 0.01$). Age was positively related with PD and GR in anterior teeth ($P < 0.01$), and with PD in posterior teeth ($P < 0.01$). In addition, widened PDLS on radiograph was positively related to PD, AL and GR in posterior teeth ($P < 0.05$). Pearson's correlation analysis further examined the link between HOF and common indicators of occlusal trauma. The results revealed that HOF was positively correlated with FM in upper posterior teeth (r: 0 168; *P*-value: 0.011) and widened PDLS for both upper (r: 0.179; *P*-value: 0.001) and lower posterior teeth (r: 0.205; *P*-value: 0.026). No significant correlation existed between HOF and indicators of occlusal trauma in anterior teeth.

Discussion

To our knowledge, the present study is probably the first report on a relationship between the severity of periodontitis and occlusal force recorded by the T-scan II system. Distribution of HOF in 807 teeth of 30 patients with chronic periodontitis was analysed systemically, and the association of HOF with periodontal conditions and common parameters of occlusal trauma was further

Table 3 Periodontal conditions in anterior teeth with or without functional mobility, tooth wear and high occlusal force.

	Functional mobility			Tooth wear			High occlusal force		
Variables[a]	(+) N = 64	(-) N = 285	P-value	(+) N = 52	(-) N = 297	P-value	(+) N = 90	(-) N = 259	P-value
PD (mm)	3.8 ± 1.1	3.3 ± 1.1	**0.002**	3.4 ± 1.1	3.3 ± 1.2	0.610	3.3 ± 1.1	3.4 ± 1.1	0.490
AL (mm)	4.4 ± 1.6	3.8 ± 1.6	**0.011**	4.1 ± 1.5	3.9 ± 1.6	0.510	4.0 ± 1.1	3.9 ± 1.1	0.512
BOP (%)	81.0 ± 26.0	66.0 ± 37.0	**<0.001**	68.0 ± 37.0	69.0 ± 35.0	0.187	73.0 ± 33.0	67.1 ± 36.0	0.152
GR (mm)	0.7 ± 1.1	0.6 ± 0.9	0.532	0.6 ± 0.9	0.6 ± 1.0	0.660	0.6 ± 1.0	0.6 ± 0.9	0.816
TM	0.4 ± 0.7	0.2 ± 0.4	**0.005**	0.2 ± 0.5	0.1 ± 0.3	0.180	0.2 ± 0.5	0.4 ± 0.4	0.165

N: number of teeth; PD: Probing depth; AL: Clinical attachment loss; BOP: Bleeding on probing; GR: Gingival Recession; and TM: tooth mobility.
[a] Mean ± SD.

Table 4 Periodontal conditions in posterior teeth with or without functional mobility, tooth wear, widened PDLS and high occlusal force.

	Functional mobility			Tooth wear			Widened PDLS			High occlusal force		
Variables[a]	(+) N = 98	(-) N = 360	P-value	(+) N = 214	(-) N = 244	P-value	(+) N = 158	(-) N =233	P-value	(+) N = 138	(-) N = 320	P-value
PD (mm)	4.8 ± 1.4	4.3 ± 1.2	**0.001**	4.5 ± 1.3	4.2 ± 1.3	**0.018**	5.0 ± 1.2	4.2 ± 1.2	**<0.001**	4.7 ± 1.1	4.3 ± 1.3	**0.001**
AL (mm)	6.1 ± 2.1	5.0 ± 1.6	**<0.001**	5.6 ± 1.8	4.9 ± 1.7	**<0.001**	6.0 ± 1.8	4.8 ± 1.6	**<0.001**	5.5 ± 2.0	5.1 ± 1.7	0.067
BOP (%)	85.0 ± 20.0	87.0 ± 21.0	0.418	88.0 ± 19.0	86.0 ± 22.0	0.187	91.0 ± 16.0	82.0 ± 24.0	**<0.001**	91.6 ± 16.0	85.2 ± 22.0	**0.001**
GR (mm)	1.3 ± 1.4	0.7 ± 0.9	**<0.001**	1.1 ± 1.1	0.7 ± 0.8	**<0.001**	1.1 ± 1.2	0.8 ± 1.1	**0.002**	0.9 ± 1.1	0.8 ± 0.9	0.228
TM	0.5 ± 0.8	0.1 ± 0.4	**<0.001**	0.2 ± 0.5	0.2 ± 0.5	0.771	0.5 ± 0.8	0.2 ± 0.4	**<0.001**	0.2 ± 0.5	0.2 ± 0.5	0.905

PDLS: periodontal ligament space; N = number of teeth; PD: Probing depth; AL: Clinical attachment loss; BOP: Bleeding on probing; GR: Gingival Recession; and TM: tooth mobility.
[a] Mean ± SD.

Table 5 The fixed-effect analysis of related variables with periodontal parameters in anterior teeth.

Variables	Related parameters	Numerator df	Denominator df	F	Significance
PD	Age	1	22.236	8.099	0.009
AL	TM	3	32.620	15.646	<0.001
GR	Age	1	25.253	10.659	0.003
	TM	3	42.763	15.018	<0.001
TM	FM	1	28.720	9.277	0.005

PD: Probing depth; AL: Clinical attachment loss; GR: Gingival Recession; and TM: tooth mobility; and FM: Functional mobility.

explored. The present data show that the teeth with HOF are distributed mainly in molars. The overall periodontal condition is worse in posterior teeth with HOF than those without it. Furthermore, HOF is significantly correlated, with the severity of periodontitis shown by the fixed effects analysis. These findings support the previous studies well. Takeuchi and Yamamoto[36] investigated the association of biting force with periodontal status in 198 patients with chronic periodontitis, and indicated that height-reduced periodontal support is related to decreased biting forces, and biting pressure is positively associated with attachment loss. Indeed, premature occlusal contacts are frequently detected in subjects with chronic periodontitis and significantly

Table 6 The fixed-effect analysis of related variables with periodontal parameters in posterior teeth.

Variables	Related parameters	Numerator df	Denominator df	F	Significance
BOP	TM	3	429.545	3.210	0.023
	HOF	1	30.566	4.419	0.044
PD	TM	3	76.946	25.322	<0.001
	TW	1	292.197	12.708	<0.001
	Widened PDLS	1	29.732	12.482	0.001
	Age	1	40.125	11.422	0.002
	HOF	1	32.073	4.274	0.047
AL	TM	3	64.493	29.114	<0.001
	TW	1	21.422	16.517	0.001
	Widened PDLS	1	25.757	14.987	0.001
GR	TW	1	21.029	7.234	0.014
	Widened PDLS	1	25.742	4.731	0.039
TM	FM	1	29.130	20.757	<0.001

BOP: Bleeding on probing; PD: Probing depth; AL: Clinical attachment loss; GR: Gingival Recession; and TM: tooth mobility; FM: Functional mobility; HOF: high occlusal force; TW: Tooth wear; and PDLS: periodontal ligament space.

correlated with the severity of periodontitis[37]. A 3-D finite element analysis further demonstrates that traumatic occlusal contacts-generated stress is harmful to the integrity of periodontal structures[38]. Interestingly, these observations and our current findings are well supported by recent animal studies in combined models of occlusal trauma and experimental periodontitis, suggesting that occlusal trauma could accelerate periodontal destruction[39,40]. Notably, in our study, as the sensor strip of the T-scan II system contains about 2000 sensors in the mylar film, the HOF tends to generate the biting pressure in a very small area during different occlusal movements. The observation on the association of occlusal pressure with the severity of periodontal disease implies that monitoring the occlusal force and contacts during periodontal care may contribute to maintenance of appropriate occlusal function in periodontally compromised patients.

The present study could not show significant difference in periodontal parameters between the teeth with or without HOF in anterior teeth, while the severity of periodontal disease is correlated with tooth mobility. Harrel and Nunn[23] have evaluated the tooth-level relation between various occlusal contacts and probing depths, as well as width of keratinised gingiva, and reported that protrusive contacts on anterior teeth are generally non-damaging. Even though the protrusive contacts in their study are possibly different from the HOF detected by the T-scan II system in our study, the exact effects of occlusal force on periodontal conditions in anterior teeth need further investigation.

Few tooth-level studies regarding the link of occlusal trauma with periodontal conditions have been reported. It has been shown that various types of premature contacts are significantly correlated with the severity of periodontal destruction[18,23]. Our previous tooth-level study has showed that the teeth with either significant functional mobility or radiographically widened PDLS present with more attachment loss and alveolar bone resorption than the controls, whereas those with pronounced wear or thickened lamina dura on radiographs exhibit better periodontal status than the counterparts[19]. The present findings confirm the above results on tooth level, and the multiple factor analysis further shows that the periodontal parameters in posterior teeth are positively correlated to the above-mentioned indicators of occlusal trauma. Here, it is worthy to note that multiple factor analysis demonstrates that the teeth bearing

HOF detected by the T-scan II system are significantly associated with the severity of periodontitis.

This study also provides us with the opportunity to explore the relation of HOF with common occlusal trauma indicators. Pearson's correlation analysis reveals that HOF is significantly related to functional mobility in upper posterior teeth, and widened PDLS in both upper and lower posterior teeth. No correlation exists between HOF and tooth mobility, as well as HOF and tooth wear. Various factors may account for tooth mobility and tooth wear. More patients with more detailed occlusal examinations may be helpful to elaborate these points in further studies.

The present study shows a symmetrical distribution of HOF in the dental arch, and that the highest percentage of teeth bearing HOF occurs in the molar region. These results are basically consistent with a previous study that the T-scan II system could reliably assess the distribution of occlusal contact in maximum intercuspation[28]. Another study indicates a good reproducibility of the assessment for repeated lateral occlusal contact[41]. One of the notable advantages of the T-scan II system is its accuracy for detecting HOF contact points in a 1.25 mm space. However, a disadvantage lies in its inability to generate an accurate value of each tooth, only recording 2 to 3 teeth with maximal biting pressure at certain positions. Therefore, the present study on assessment of the association of HOF with periodontal conditions and common signs of occlusal trauma has some limitations.

Within the limitation of the study, the present findings suggest that the posterior teeth with high occlusal force in subjects with untreated chronic periodontitis may reflect occlusal trauma-associated periodontal conditions that could probably increase the risk of further periodontal destruction. The present findings may improve the clinical assessment of occlusal trauma and related periodontal conditions for effective management and treatment outcomes of patients. Further longitudinal studies should be performed to validate the current findings and clarify the relevant clinical implications.

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Conflicts of interest

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

Author contribution

Dr Shuang Ying ZHOU designed the study, analysed data and prepared the manuscript; Dr Hina MAHMOOD carried out the study, analysed data and prepared the manuscript; Prof Cai Fang CAO and Prof Li Jian JIN designed and supervised the study and revised the manuscript.

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