Association of Bone Loss Severity with Signs of Occlusal Trauma in Teeth with Reduced Periodontium

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Abstract

Decreased adaptive capacity of periodontium enhances susceptibility to injury from occlusal forces. This study aimed to identify the association between bone loss severity and signs of occlusal trauma in teeth with reduced periodontal support.

Periodontal assessment, radiographic examination and relative maximum force in chewing movements using T-scan III occlusal analysis system were determined in 312 teeth from 15 periodontitis subjects, who received non-surgical periodontal therapy. Comparison of periodontal parameters and occlusal trauma indicators was performed between groups with and without $\geq$ 60% proximal bone loss. The correlation was investigated among each assessed parameter and signs of occlusal trauma including fremitus, advanced tooth mobility and widened periodontal ligament space.

Bleeding on probing, gingival recession and clinical attachment loss in the group with $\geq$ 60% bone loss were more severe than those with less bone loss ($p<0.05$). Fremitus, advanced mobility, and widened periodontal ligament space were different between groups ($p<0.05$) although distribution of relative maximum force was not different. The extent of proximal bone loss was found to correlate with fremitus, advanced mobility, and widened periodontal ligament space at r= 0.219, 0.418, 0.318 respectively ($p<0.05$).

In conclusion, all significant signs of occlusal trauma were significantly associated with $\geq$ 60% proximal bone loss.

Clinical article (J Int Dent Med Res 2024; 17(1): 196-202)

Keywords: Secondary occlusal trauma, reduced periodontium, T-scan.

Received date: 28 September 2023 **Accept date:** 25 October 2023

Introduction

Secondary occlusal trauma is an injury of attachment apparatus, which is caused by occlusal forces beyond adaptive capacity of reduced periodontal support.[1] Despite studies for over a century, specific criteria for diagnosing occlusal trauma remains challenging in a clinical practice owing to superimposing signs with other oral problems especially periodontitis, an infectious disease affecting periodontium.[1] Another predisposing factor that complicates the detection of secondary occlusal trauma is the amount of residual supporting periodontal tissue to withstand occlusal force. In vitro studies using finite element analysis suggested that the decline of bone support by 60-80% resulted in elevation of occlusal stress on surrounding periodontal ligament. Therefore limited amount of residual supporting bone could create a triggering condition for occlusal trauma.[2,3]

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Pathophysiology of occlusal trauma depends on dynamic interaction between occlusal forces and adaptive capacity of the periodontium. Magnitude, frequency and direction of occlusal force which induced occlusal trauma were studied extensively in distinctive models from in vitro to animal/human investigations.[1] Jiggling force and premature contacts were confirmed their deleterious role in secondary occlusal trauma from animal studies with different species and diverse approaches to increase occlusal force.[1,4-6]

Excessive occlusal loads beyond the adjustment ability of periodontium and supporting bone led to tooth mobility, widened periodontal ligament and loss of bone density.[5] When the excessive occlusal force was accompanied by weakened periodontium due to plaque-induced inflammation, the progression of periodontitis was accelerated with more clinical attachment loss, more bone destruction and hypermobility. Under the resolution of periodontal inflammation circumstance, occlusal trauma did not enhance more bone destruction, but hypermobility continued as a response toward excessive force in a dog model.[7] However, animal models could not mimic secondary occlusal trauma in human with successfully treated periodontitis due to the limitation of research duration and distinctive tooth morphology.

The magnitude of occlusal force, that provokes secondary occlusal trauma, varies in relevant to the quantity and the quality of residual supporting tissues. Most of current human studies are in patients with untreated periodontitis, that correlates with the quality of periodontal tissue in regards to dysregulated inflammation.[8-11] Occlusal trauma is considered as an aggravating factor of periodontitis disease progression.[11] A relationship was found between premature contacts/relative high occlusal forces and common signs of occlusal trauma.[8-9] The investigations of the impact of the quantity of reduced periodontal tissue on occlusal trauma were limited to in vitro and animal studies.[2-4] The purpose of this study aimed to determine the association between level of proximal bone loss and significant signs of occlusal trauma in teeth with reduced periodontium.

Materials and methods

This cross-sectional study was conducted with approval of Naresuan university ethical committee (IRB No. P10126/64). The study was carried out from October 2021 to May 2022. Periodontitis patients with at least 20 natural teeth and 5 pairs of occluding teeth from Dental hospital, Faculty of Dentistry, Naresuan university were recruited into the study. The volunteers were patients who were diagnosed with periodontitis stage III/IV according to AAP classification.[12] All volunteers received completed non-surgical periodontal therapy 1-2 months before data collection. Volunteers who had problems to bite stably or active temporomandibular disorders and those who had medical conditions which were at risk for emergencies or infections, were not recruited into the study. Samples were natural teeth with clinical attachment loss which had opposing teeth. The exclusion criteria were teeth which were splinted with other teeth; teeth which received occlusal adjustment within the last 2 months; teeth without opposing teeth; teeth with lesions from pulpal disease or periodontal abscess; and teeth which could not be interpreted in radiographic pictures. Prior to participation, written consent was obtained. All clinical and radiographic assessments were performed by one calibrated examiner.

Radiographic examination

Periapical radiographs were taken by a standardized parallel technique using intraoral dental imaging plate size 2 (Ultraspeed™ 31×41 mm, Eastman Kodak Co., Rochester, NY, USA). Film digitization was obtained with a radiographic scanner at resolution 18 LP/mm (Carestream CS 7600 Scanner, Carestream Health, Canada). The assessment was carried out using the UniWeb Server computer program. Proximal bone loss and widened periodontal ligament space were assessed on each sample tooth.

Proximal bone loss was measured parallel to the tooth axis on both mesial and distal sides of each tooth. Reference points for measuring bone loss included cemento-enamel junction (CEJ), root apex, alveolar crest, and deepest extension of infrabony defect. Level of bone loss was a distance from CEJ to alveolar crest for horizontal bone defect and to the deepest point of infra-bony defect for vertical bone defect. The greatest level of bone destruction was designated as the level of proximal bone loss for individual tooth. According to the designated values, samples were divided into 2 groups with the degree of alveolar bone loss greater and less than 60% of root length.

The periodontal ligament space was assessed from alveolar bone crest to root apex on every tooth sample. The surface of the root was divided into three sections, the alveolar crest area (coronal section), the middle area (including furcation area), and the apical area. Widened periodontal ligament space was recorded when the individual sample demonstrated a legibly thickened periodontal ligament space around entire root or any of each section.

Periodontal examination

Periodontal parameters consisted of probing depth (PD), bleeding on probing (BOP), gingival recession, clinical attachment level (CAL). Periodontal assessment was performed and recorded 6 sites per tooth; Mesio-buccal, Disto-buccal Mesio-lingual, Disto-lingual, Mid-buccal, and Mid-lingual using periodontal UNC-15 probe (Hu-Friedy, Chicago, USA). Clinical attachment level was measured from CEJ to the deepest probing point in gingival sulcus. The severity of PD, gingival recession and CAL were divided into 3 groups, i.e., mild 1-2 millimeters, moderate 3-4 millimeters, and severe $\geq$ 5 millimeters. BOP was recorded as present or absent.

Occlusal examination

Occlusal parameters included total tooth number, posterior occluding pairs of teeth, tooth mobility, fremitus, and relative maximum occlusal force in chewing cycle. Tooth mobility was recorded according to Miller's classification. Fremitus was assessed by placing an index finger on the buccal surface of the teeth when the teeth were in centric and eccentric positions. Fremitus was considered to be present when vibration was detected. Relative maximum occlusal force was determined by using a digital sensor strip (T-scan® Novus sensor, Boston, USA) and was analyzed with the T-scan III system (Tekscan, Boston, USA). Prior to the examination, individual upper tooth widths were measure in a model and data were transferred into the software to estimate dental arch dimensions. The volunteers were instructed to practice their chewing movement in back and forth motion. The sensor strip was then placed into the volunteer's oral cavity at the position which covered occlusal surfaces of all teeth. The appropriate sensitivity was adjusted in chewing mode by limiting the first three high occlusal forces in combination of both centric and eccentric movements. During the examination, volunteers were asked to chew on the sensor strip for 3 seconds and repeated the procedure two more times. The greatest relative occlusal force was recorded as percentage for each tooth.

Statistical analysis

Data analyses were conducted using SPSS for Windows software,version 23.0 (IBM, New York, USA). The intra-class correlation coefficient was applied to calibrate the examiner on clinical and radiographic examinations and the digital T-scan III occlusal analysis system. Mann-whitney U-test and Wilcoxon sign rank test were used to analyze the differences of periodontal and occlusal variables between groups. Spearman correlation was employed to investigate the association between clinical/radiographic parameters and occlusal trauma indicators including fremitus, advanced tooth mobility, and widened periodontal ligament space. The level of significance was considered at $p<0.05$.

Results

The intra-examiner agreement for recording clinical and radiographic conditions was 80%. The intra-examiner reproducibility for using T-scan III in chewing movement was 75%. A total of 312 teeth with reduced periodontium (158 anterior teeth and 154 posterior teeth) were recruited from 15 patients (8 males and 7 females). The average age of volunteers is 56.20 $\pm$ 11.18 years. Each volunteer had at least one tooth containing one or more occlusal trauma indicating signs, i.e., widened periodontal ligament space, functional mobility (fremitus), and non-functional mobility $\geq$ grade 2 (advanced mobility). The average number of natural teeth per person was 22 ± 4 teeth with average 5 ± 2 posterior occluding pairs.

The sample teeth were categorized into two groups according to the severity of proximal bone loss at 60% of root length. The distributions of anterior teeth and posterior teeth in both groups were in similar patterns. Periodontal parameters including BOP, gingival recession, and CAL showed statistically more progression in the group that rendered $\geq$ 60% bone loss (*p*=0.040, p=0.000, p=0.000 respectively) except PD values were comparable between both groups (Table 1). Notably, CAL variable demonstrated clinically difference between groups with and without $\geq$ 60% proximal bone loss (7.14 ± 2.94 mm. vs 4.52 ± 1.48 mm.; p=0.000).

Occlusal trauma conditions in each group were demonstrated in Table 2. In both groups, the distribution of relative maximum force in chewing cycle was not different (59.42 ± 41.87% vs 58.85 ± 37.95%; p=0.961). Conversely, both functional mobility and advanced non-functional tooth mobility were more prevalent in the group with ≥ 60% proximal bone loss (p=0.023 and p=0.000 respectively).

Radiographic interpretation also showed higher percentage of widened periodontal ligament space in the group with more proximal bone loss (95.2 % vs 33.7%).

	Alveolar bone loss < 60% (n=291)	Alveolar bone loss ≥60% (n=21)	
Periodontal status	Mean ±S.D.	Mean ±S.D.	p-value
Bleeding on probing (%)	33.67 ±23.97	44.45 ±21.30	0.040*
Probing depth (mm)	3.26 ±1.03	4.19 ±2.32	0.086
Gingival recession (mm)			
- Proximal recession	1.35 ±1.44	3.00 ±1.61	0.000*
- Marginal recession	1.23 ±1.30	2.76 ±1.18	0.000*
Clinical attachment loss (mm)	4.52 ±1.48	7.14 ±2.94	0.000*

Table 1. Comparison of periodontal parameters between groups with different severity of bone loss at 60% of root length level.
Mann-whitney U-test and Wilcoxon sign rank test, * Significant difference between groups, p<0.05.

	Alveolar bone loss < 60% (n=291)	Alveolar bone loss ≥60% (n=21)	
Common occlusal trauma	Mean	Mean	p-value
Fremitus	17.9	38.1	0.023*
Tooth mobility ≥2 degree	2.4	38.1	0.000*
Widened PDLS	33.7	95.2	0.000*
Relative occlusal force ±S.D.	58.85 ±37.95	59.42 ±41.87	0.961

Table 2. Comparison of percentages of occlusal trauma parameters between groups with different severity of bone loss at 60% of root length level.
PDLS: periodontal ligament space, , Mann-whitney U-test and Wilcoxon sign rank test, *Significant difference between groups, p<0.05.

Variables	Fremitus		Advanced mobility		Widened PDLS	
	r-value	(p-value)	r-value	(p-value)	r-value	(p-value)
Relative occlusal force	0.058	(0.305)	0.078	(0.170)	0.161	(0.000)*
Posterior occluding pair	-0.086	(0.131)	0.006	(0.911)	-0.065	(0.250)
BOP	0.059	(0.297)	0.030	(0.599)	0.167	(0.003)*
PD	0.111	(0.050)*	0.134	(0.017)*	0.108	(0.056)
Proximal GR	0.055	(0.330)	0.258	(0.000)*	0.198	(0.000)*
Marginal GR	0.009	(0.878)	0.238	(0.000)*	0.214	(0.000)*
CAL	0.055	(0.337)	0.618	(0.003)*	0.274	(0.000)*
Proximal alveolar bone loss	0.219	0.023*	0.418	0.000*	0.318	0.000*

Table 3. Correlation analysis among clinical and radiographic parameters and signs of occlusal trauma in all teeth.
BOP: Bleeding on probing, PD: Probing depth, GR: Gingival recession, CAL: Clinical attachment loss, PDLS: Periodontal ligament space, Spearman's correlation test, * p<0.05.

To evaluate the association of bone loss severity and occlusal trauma, Spearman correlation test was performed to describe relationships between periodontal parameters, related occlusal parameters and occlusal trauma indicators in all reduced periodontium teeth samples (Table 3). In perspective of occlusal variables, relative maximum force only showed weak correlation with the presence of widened periodontal ligament space (r=0.161) but no correlations were found with functional mobility and non-functional mobility. Additionally, the significant correlation of the number of posterior occluding pair with occlusal trauma indicators were not detected. Periodontal variables displayed various association levels with occlusal trauma indicators. BOP variable showed weak correlation with widened periodontal ligament space (r=0.167) whereas PD held weak correlation with fremitus and tooth mobility. Periodontal parameters representing level of supporting tissue, including proximal recession, marginal gingiva recession and CAL, positively correlated with non-functional tooth mobility and widened periodontal ligament space (p<0.005). CAL was strongly relevant to non-functional tooth mobility (r=0.618). Proximal bone loss at 60% level demonstrated significant positive results (moderate correlation) to all tested occlusal indicators (p<0.05).

Discussion

Occlusal trauma has an impact on periodontal structure when occlusal force exceeds adjustment ability of supporting tissue around tooth. Occlusal trauma is usually categorized as primary and secondary patterns according to the health status of periodontium.[1] Primary occlusal trauma is defined when an excessive occlusal force acts on a tooth with a healthy periodontal tissue. Secondary occlusal trauma is designated when an occlusal force exerts negative influence on a reduced periodontium which contains compromised adaptive capacity. Teeth with a reduced periodontium can be distinguished in either active periodontal destruction or remission of periodontal pathologic conditions.[1] Several animal and human studies described the impact of secondary occlusal trauma on active periodontal diseases.[4,5,13-15] The direct impact of occlusal trauma on a reduced but healthy periodontium was investigated only in an animal study. [7]

Reduced periodontal apparatus led to lower resistance threshold of individual tooth to occlusal stress which could cause hypermobility, migration, and other signs of occlusal trauma. [8,15] Our study investigated the effect of the extent of reduced periodontium on the secondary occlusal trauma at a clinical level on 312 teeth with control of periodontitis induced inflammatory response. The average BOP value from all volunteers were 33.54 ± 12.57% after completion of hygienic periodontal therapy. Decreased gingival bleeding was the initial sign of successful control of periodontal inflammation after hygienic periodontal treatment as a consequence of reduced amount of periodontal pathogens in periodontal pockets.[16] Bacteria inducing progression of periodontitis was manifested by destructive change of clinical periodontal parameters including gingival inflammation with bleeding upon probing, increased probing depth, and clinical attachment loss.[17] Loss of alveolar bone height remained an irreversible change in periodontitis unless advanced regenerative treatment was involved.[18] The extent of reduced periodontal support could be measured by clinical attachment level, which occasionally was misinterpreted due to challenge of CEJ visualization. Radiographic bone loss/root length ratio illustrated the amount of reduced periodontal tissue in proximal area with clear identification of CEJ.[19] Our study used extent of proximal bone loss to categorize groups for comparison. After hygienic treatment, the average PD between groups were not different. Gingival recession and CAL which represented history of periodontal damage were different between groups. The distributions of severe clinical attachment loss were found 95.2% in the group with more proximal bone loss while the other group contained 48.8 % moderate and 45.7% severe CAL. These findings suggested that proximal bone loss could be a surrogate of the extent of periodontal damage.

Clinical and radiographic criteria for definitive diagnosis of occlusal trauma remained ambiguous especially in secondary occlusal trauma since certain indicative signs superimposed onto signs of periodontitis disease.[1] Proposed indicative signs of occlusal trauma attributed to how excessive occlusal force during masticatory function induced dynamic change within the periodontium. During chewing cycle, occlusal force acted on tooth then the stress was transferred to periodontal ligament. Periodontal ligament absorbed and distributed the occlusal stress to surrounding supporting bone in various directions. Pressure from excessive occlusal force could interfere perfusion of periodontal ligament which led to alteration of vascularization, hyalinization and necrosis.[20] In addition to damage of periodontal ligament, increased bone resorption was induced by excessive occlusal force in relevant to stimulating osteoclasts via RANKL pathway.[21,22] Regarding histological view, prolonged excessive occlusal force resulted in decrease of alveolar bone density with concomitantly increase of periodontal ligament width.[23] This alteration of periodontal ligament and bone structure converted into clinical and radiographic indicators for presumptive diagnosis of occlusal trauma including functional tooth mobility/fremitus, advanced tooth mobility and radiographically widened periodontal ligament space.[9] Our research showed that extent of proximal bone loss had moderate correlation with these occlusal trauma indicators despite the periodontal disease was controlled. Our finding supported early clinical study in 300 periodontitis patients which found that tooth mobility, fremitus, and widened periodontal ligament space related to the severity of periodontitis and less radiographic osseous support.[8] Another study on moderate to severe periodontitis patients indicated that teeth with significant mobility, fremitus, or widened periodontal ligament space displayed further periodontal destruction including more attachment loss, deeper probing depth, and lower bone support than teeth without these signs.[9] Our study additionally revealed that the extent of clinical attachment loss associated with advanced tooth mobility and widened periodontal ligament space but the correlation was not found with fremitus which was the explicative sign in relevant to occlusal function. Our findings were different from previous assessment of secondary occlusal trauma and the severity of mixed periodontitis conditions, at either active or treated condition, that displayed positive correlation between periodontal attachment loss and the prevalence of occlusal trauma based on fremitus and tooth mobility.[10]

Studies of the critical level of reduced periodontium and occlusal trauma were carried through animal and software based investigations.[2,4] The result from finite element analysis suggested that the extent of bone loss at 60% of root length caused significantly increase of stress distribution to residual periodontal ligament along all root surface .[2] Another finite element model suggested that the stress distribution in periodontal ligament increased to a deleterious level when residual bone support was down to 19.2% of root length.[3] The present study found differences of the prevalence of occlusal trauma indicators between teeth with and without proximal bone loss at 60% range. Our findings gave clinical evidences that teeth with $\geq$ 60% reduced periodontal support at disease remission stage were potentially susceptible to develop occlusal trauma although the distribution of relative occlusal force was comparable to the control group, that contained more supporting bone. Proximal bone loss at 60% of root length may be a considerable extent that affects adaptive capacity of periodontium to withstand occlusal force in chewing cycle.

Previous studies have been focusing on the role of occlusal trauma as a cofactor for the progression of periodontal disease. Cumulative evidences disputed that secondary occlusal trauma accelerated supporting bone destruction in existing periodontitis condition.[6,14,24-29] However, most studies were conducted in animal models while clinical studies were performed in observational designs or using indirect variables representing excessive occlusal force as surrogates of occlusal trauma due to ethical consideration and technology limitation.[1,30] Recent studies used a digital occlusal analysis system to clarify a relationship between the severity of periodontitis and occlusal status including relative high occlusal force in static positions including maximum intercuspation, lateral and protrusive contacts in untreated periodontitis patients.[11,31] Results from Zhou et al. revealed that teeth with fremitus showed more severe periodontal status in regards to probing depth, attachment loss, and tooth mobility. The correlation of relative high occlusal force with periodontal destruction including BOP and PD was found only in the posterior teeth.[11] Contradictory results were illustrated in the clinical comparison between untreated periodontitis and healthy periodontal subjects. No correlation was found between relative high occlusal force, probing depth or clinical attachment loss. High occlusal force was significantly related to advanced tooth mobility and position of teeth with more occlusal loads in posterior teeth.[31] Our study used a T-scan III occlusal analysis system to define distribution of relative maximum force during chewing cycle which represented dynamic occlusal contacts. Our findings on teeth with reduced periodontium displayed weak correlation of relative maximum force with widened periodontal ligament space but fremitus and advanced tooth mobility did not obtain any link with the occlusal load.

Within the limitation of small participant numbers, future investigations may be continued with higher numbers of participants. The magnitude of occlusal force that may initiate occlusal trauma on teeth with reduced periodontium should be further studied. Understanding the relationship between occlusal trauma and periodontitis in the post non-surgical treatment phase, can improve the treatment plan for periodontitis patients.

Conclusions

Our tooth-level study suggested that despite resolution of periodontal inflammation, decrease of adaptive capacity to occlusal force remained in relevant to the extent of alveolar bone loss. There was association between the extent of proximal bone loss and indicative signs of occlusal trauma in teeth with reduced periodontium. Data from our study implement into clinical concern that proximal bone loss rendering 60% may increase susceptibility to occlusal trauma.

Acknowledgements

This work was granted by the Research Fund from Naresuan University (R2560C049). We would like to acknowledge Associate Professor Dr. Supawadee Naorungroj for statistical analysis suggestion.

Declaration of Interest

The research is original and free of conflict of interest.

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