Occlusal Factors Influencing Non-Carious Cervical Lesions in Post-Orthodontic Patients: Evaluation Using T-Scan® III

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Abstract

Non-carious cervical lesions (NCCLs) are known as multifactorial diseases. Prevention and therapeutic management of NCCLs necessitate an understanding of the potential risk factors. Thus, the purpose of this study was to evaluate the relationship between the occlusal factors and the occlusal force on the presence of NCCLs by using the T-scan III system (Tekscan, Inc, MA, USA) in post-orthodontic patients. The sample population consisted of 25 completed orthodontic patients who had at least one NCCL. An intraoral examination, questionnaires, and orthodontic records were performed to obtain the subjects' demographic data and risk factors. The occlusal force at both the maximal intercuspal position (MIP) and the eccentric movement was recorded by the T-scan III system. Subject-leveled analysis revealed that age was significantly related to the severity of NCCLs (P= .049). Gender, types of malocclusion, orthodontic treatment approaches, parafunctional habits, brushing habits, acidic food, and gastric diseases were not related to the severity of NCCLs (P> .05). From tooth-leveled analysis, all 656 examined teeth comprised 101 teeth with NCCLs, and 555 teeth without NCCLs. Gingival recession and intense occlusal contacts were significantly related to NCCLs (P= .000), whereas the types of occlusal schemes were not related (P= .05). Teeth with NCCLs had significantly higher occlusal forces at MIP and eccentric movement than controls (P= .02; P= .004, respectively).

In conclusion, post-orthodontic patients with an increasing age tend to have more severe NCCLs. The NCCLs could form on the teeth with high occlusal force loading, intense occlusal contacts, or gingival recession.

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Introduction

Non-carious cervical lesions (NCCLs) are the loss of tooth structure in the cervical regions of teeth by a non-bacterial etiology.[1] The causative factors of the hard tissue lesions of the teeth were classified by their etiology into 4 Non-carious cervical lesions (NCCLs) are the loss of tooth structure in the cervical regions of teeth by a non-bacterial etiology.[1] The causative factors of the hard tissue lesions of the teeth were classified by their etiology into 4 categories composed of attrition, abrasion, erosion, and abfraction.[2] The occlusal force is believed to be one of the etiologies causing NCCLs as seen in abfraction lesions.[2] In most previous laboratory studies of NCCLs and occlusal force, they found an association between non-axial loading force with NCCL formation.[3-5] In addition, most previous clinical studies applied the clinical observation of occlusal factors, including the presence of tooth wear, fracture lines, restorations on occlusal surfaces, dislodgements of restorations, premature contacts, group function occlusion, and parafunctional habits to evaluate the association with NCCLs.[5-13] Only 2 previous in-human studies evaluated the amount of force loading on teeth at the maximal intercuspal position (MIP). They applied the pressure-indicating sheets and the T-scan occlusal analysis to evaluate the amount of occlusal force.[14,15] However, the association between NCCLs and those occlusal factors was also still inconclusive. Also, the occlusal force at the eccentric movement which was the one

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creating the non-axial loading force is not evaluated. The occlusal measurement by using the T-scan occlusal analysis system (Tekscan, Inc, MA, USA) was to collect the occlusal force distribution in percentage on each tooth. It could collect static and dynamic occlusal parameters. The device was composed of a 100-micron-thickness HD sensor and a T-scan recording handle. The occlusal record is illustrated in real-time to the connected device.[16]

According to the orthodontic treatment, force distribution on teeth and occlusal contact area were altered during and after the orthodontic treatment.[17, 18] Different severity and types of malocclusion are treated with different orthodontic treatment approaches, including tooth extraction and a combination with orthognathic surgery.[19, 20]

Hence, with the clinical unclarified correlation between NCCLs and the occlusal force, this study aimed to evaluate the orthodontic treatment factors, risk factors, and the occlusal force between the teeth with NCCLs and the teeth without NCCLs by using the T-scan system III in the post-orthodontic subjects.

Materials and methods

This cross-sectional study was conducted after the approval by the Naresuan University Ethical Committee (IRB No. P100116/63) from September 2020 to February 2022. Through purposive sampling, all subjects were selected from the patients of the Orthodontic Clinic of Naresuan University Dental Hospital, Thailand. The inclusion criteria were as follows: (1) having at least 1 non-carious cervical lesion; (2) completing fixed edgewise orthodontic treatment and entering the retention phase within one year; (3) having no more than 4 missing teeth, not including third molars; and (4) having no edentulous space within the dental arch. This study excluded subjects with either edentulous space, during pregnancy, orofacial pain, joint symptoms, unable to bite stably, or a disorder associated with any muscle weakness syndrome. Informed consent was obtained from participants after the explanation of all procedures and before the data collection.

Obtaining the orthodontic treatment record was to collect the subject-leveled variables, including ages, types of malocclusions, combined surgical approaches, and extraction approaches. The risk factors collected from the questionnaires were composed of acidic foods, brushing habits (brushing hardness, frequency, and duration), parafunctional habits (bruxism/day-time clenching), and gastric disease (gastro-esophageal regurgitation disease/peptic ulcer).

The intraoral examination was explored to record the tooth with NCCLs and the tooth-leveled variables including the presence of gingival recession, and the type of occlusal schemes of each left-and-right eccentric movement divided by (1) canine guidance occlusion, (2) group function occlusion.

The T-scan record was performed with the subject instructed to sit in the upright position with the Frankfort plane parallel to the floor. Bite on the T-scan sensor, and hold for 3-5 seconds to record the occlusal force at MIP. Afterward, the subject was instructed to make an eccentric movement to the side which was determined to record in each round separately. The right-, left-, and protrusive eccentric movements were repeated three times.

The occlusal force at MIP was selected as percentage by using the T-scan software's command. The occlusal force at eccentric movement was selected manually by sliding the cursor (the red arrow: Fig. 1) in the disclusion period (blue double-headed arrow: Fig. 1) to locate where the highest occlusal force of each tooth in each eccentric movement. The highest occlusal force value of all-three movements represented the occlusal force at eccentric movements for each tooth.

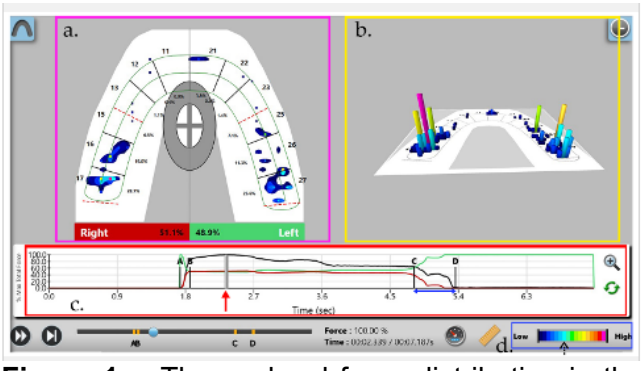

Figure 1. The occlusal force distribution in the upper arch illustrated in percentages by each tooth is shown in the 2-D window (pink box: a.) and the 3-D window (yellow box: b.). The force-vs-time graph (red box: c.) shows the alteration of occlusal forces according to the time selected

by sliding the cursor line (red arrow). The force legend color scale (blue box: d.) with the threshold adjustment slider at the left cornor which could be slided to filter out the force below the adjustment slider.

The intense occlusal contact tooth during eccentric movement was selected in the disclusion period. As the intensity of occlusal contact was illustrated as bars and columns in the 3-D window (yellow box: Fig. 1), ranging from blue to pink as the intensity of the occlusal contact increases (blue box: Fig. 1). Blue, green, and red bars indicate light, intense and close contacts, respectively.[21, 22] The intense occlusal contact tooth was selected by filtering out the contacts which had the intensity less than the greens (intense contact) by sliding the navigation slider at the force legend color scale to the position before the green (dash arrow: Fig. 1). All teeth which were not filtered out in the disclusion period were shown in the 2-D and 3-D windows and were recorded as the intense occlusal contact teeth.

All statistics were conducted using a 95% confidence interval. All subject-leveled variables were analyzed by using Mann-Whitney tests to determine the correlation to the severity of NCCLs. The tooth-leveled analysis divided the examined teeth as follows: 1) tooth with NCCLs; 2) tooth without NCCLs (controls). The categorical variables were analyzed by the chi-square test. The means of occlusal forces at MIP and eccentric movement of the 2 groups were compared by the Mann-Whitney test.

An interexaminer calibration was performed by comparing the occlusal force of each tooth that the operator of this study (NK) and the expert (JP) collected separately from 5 same subjects not included in this study. An intraexaminer calibration was performed by only 1 operator (NK) and compared between 2 sets of occlusal forces of 5 subjects of which the second set was re-collected after 4 weeks from the first one. The intraclass correlation coefficient (ICC) values were in excellent correlations (ICC = 0.974 and 0.924, respectively).[23]

Results

The total of 25 subjects was comprised of 14 males and 11 females (Table 1). Ages ranged from 17.8 to 62.5 years, with a mean age of 27.7 ± 9.9 years. The majority of the subjects were in age 20-29 years (64.0%). According to malocclusion before treatment, there were Class I (40.0%), followed by Class III (36.0%) and Class II (24.0%).

Subjects' characteristic	N (%)	NCCL tooth ± SD	*P*-value
Gender			
Male	14 (56.0)	3.9 ± 3.3	.49
Female	11 (44.0)	4.3 ± 2.8	
Age (years)			
10-19.9	3 (12.0)	1.3 ± 0.6	.049*
20-29.9	16 (64.0)	3.9 ± 3.0	
30-39.9	4 (16.0)	4.8 ± 2.2	
>39.9	2 (8.0)	8.5 ± 2.1	
Pre-treatment malocclusion			
Class I	10 (40.0)	4.3 ± 3.0	.31
Class II	6 (24.0)	3.0 ± 3.5	
Class III	9 (36.0)	4.6 ± 2.8	
Orthodontic treatment approach			
Corrective treatment	19 (76.0)	3.9 ± 3.1	.30
Combine surgery	6 (24.0)	4.7 ± 2.7	
Extraction approach			
With extraction	15 (60.0)	4.7 ± 3.3	.17
Non-extraction	10 (40.0)	3.1 ± 2.3	

Table 1. NCCLs distribution in subject-leveled characteristics (n = 25).
NCCLs, non-carious cervical lesions.
*Statistically significant at *P*< .05 by Mann-Whitney tests for 2-categorical variable, by Kruskal-Wallis tests for more-than-2-categorical variables.

Risk factors	N (%)	NCCL per subject ± SD	*P*-value
Bruxism / clenching			
Yes	8 (32.0)	3.9 ± 3.3	.36
No	17 (68.0)	4.4 ± 2.5	
Brushing technique			
With horizontal	15 (60.0)	4.3 ± 3.5	.84
No horizontal	10 (40.0)	3.7 ± 2.2	
Brushing frequency			
2 times/day	16 (64.0)	3.5 ± 3.0	.09
> 2 times/day	9 (36.0)	5.1 ± 2.9	
Gastric disease			
Yes	9 (36.0)	3.9 ± 2.8	.49
No	16 (64.0)	5.7 ± 4.7	
Acidic food favors			
Yes	10 (40.0)	3.8 ± 2.9	.65
No	15 (60.0)	4.7 ± 3.3	

Table 2. NCCLs distribution in subject-leveled risk factors (n = 25).
NCCLs, non-carious cervical lesions.
*Statistically significant at *P*< .05 by Mann-Whitney tests.

The orthodontic treatments were approached with the corrective treatment (76.0%) and the combination with surgery (24.0%). Most of them had tooth extraction (60.0%). The amount of NCCLs increased significantly while the age increased (*P*= .049). Genders, types of malocclusions, surgical approaches, and extraction approaches were not associated with the severity of NCCLs (gender, *P*= .49; type of malocclusion, P= .31; combined surgical approach, *P*= .30; extraction approach, *P*= .17).

Several subjects showed the presence of risk factors which were parafunctional habits, brushing with horizontal technique, brushing more than 2 times/day, gastric disease, and acidic foods. (Table 2) The amount of NCCLs in the subjects with the risk factors was not significantly different from those without risk factors (bruxism/clenching, *P*= .36; brushing technique, *P*= .84; brushing frequency, *P*= .09; gastric disease, *P*= .49; acidic food, *P*= .65).

	Teeth no NCCLs (n)	Teeth with NCCLs (n)	Total teeth (n)	Odds ratio	95%CI	*P*-value
Gingival recession						
Yes	33	46	79	13.23	7.82 – 22.40	.000†
No	522	55	577			
Intense occlusal contact						
Yes	59	25	84	2.77	1.63 – 4.68	.000†
No	496	76	572			
Occlusal scheme						
Canine guidance	131	15	146	1.77	0.98 – 3.17	.05
Group function	424	86	510			

Table 3. NCCLs distribution in tooth-leveled categorical factors.
NCCLs, non-carious cervical lesions. † Statistically significant at P< .01 by Chi-square test.

From tooth-leveled factors (Table 3), a total of 656 examined teeth were comprised of 101 teeth with NCCLs and 555 controls. Gingival recession was found in 79 teeth (12.0%), and intense occlusal contacts were found in 84 teeth (12.8%). The majority of teeth were in the group function occlusion (77.7%). The association with NCCLs was found with gingival recession and intense occlusal contacts significantly (*P*= .000; *P*= .000, respectively). In contrast, the types of occlusal guidance including canine guidance occlusion and group function occlusion were not. (*P*= .05).

The means of the occlusal force of both positions of the tooth with NCCLs (MIP = 8.36 ± 8.52%; eccentric = 38.60 ± 31.65%) were significantly higher than those of controls (MIP = 7.19 ± 8.74%; eccentric = 28.99 ± 29.25%) (*P* = .02; *P* = .004, respectively) (Table 4).

	Relative occlusal force (%)		*p*-value
	Teeth without NCCLs	Teeth with NCCLs	
MIP	7.19 ± 8.74	8.36 ± 8.52	.02*
Eccentric movement	28.99 ± 29.25	38.60 ± 31.65	.004†

Table 4. Comparing relative occlusal forces between teeth with NCCLs and without NCCLs.
NCCLs, non-carious cervical lesions. MIP, maximal intercuspal position.
*Statistically significant at P< .05; † statistically significant at P< .01 by Mann-Whitney test.

Discussion

Subject-leveled factors related to the severity of NCCLs showed that increasing age was related to the incidence of NCCLs. According to previous studies, increasing age was an important factor in the cumulative effects of both occurrence and severity of NCCLs.[7,10,14,24]

This study found that the presence of parafunctional habits, brushing habits, gastric diseases, and acidic food had no relation with the severity of NCCLs. Examined by self-reports, the parafunctional habits found in this study could be underestimated because the large population of adults and children were unaware of their bruxism habits.[25] Conversely, many previous studies found that the brush hardness[26-29], the horizontal brushing technique[30], and the brushing pressure [14] were found the association with NCCLs. However, the studies aforementioned did not evaluate the brushing habits in a tooth with the attachment of an orthodontic appliance which could hinder the brushing pressure from the bristle to the tooth surface.

Further studies could be done to clarify this disagreement result. According to the Acidic factors which were related to the cause of dental erosion in many previous studies[2,15,31], gastric diseases especially gastro-esophageal reflux disease and bulimia affected the posterior occlusal area or palatal surface of anterior teeth where the refluxing acid from the stomach was applied. In addition, the acidic food consumption mostly eroded the teeth at the labial surfaces of anterior teeth and buccal surfaces of mandibular first molars. Those areas were not at the cervical parts of the tooth where this study examined the NCCLs.

With doubt about the relationship between orthodontic treatment and NCCLs, this study evaluated the association with the

orthodontic treatment approaches by orthognathic surgery and extraction, and the type of malocclusion before orthodontic treatment. Previous studies of the occlusal force distribution among both the type of malocclusion or anteroposterior skeletal patterns found that occlusal force distributions in each region in a mouth were not different among different skeletal types and malocclusion types.[32,33] This could lead to similar NCCL severity on each malocclusion found in this study.

Similar to previous studies,[2,7,11] this study found that the gingival recession was related to NCCLs in the tooth-leveled evaluation. However, other factors could also cause gingival recession; for example, chronic trauma, periodontal disease, prolonged smoking, dental plaque, and root contacts with cortical plates.[34] All these factors should be controlled in further studies to assure the relationship between NCCLs and gingival recessions.

The occlusal force was found an association with NCCLs in both MIP and eccentric movement. Two previous clinical studies also found that the teeth with NCCLs had higher occlusal loads than controls at MIP.[14,15] In the same way, this study found that the intense occlusal contact occurring in the working side and the non-working side of the eccentric movement was related to NCCLs. In addition, the clinical evaluation of both occlusal loading and occlusal contact intensity at eccentric movement and NCCLs was done in this study to assure the previous laboratory studies' results which reported that the non-axial loading could produce more concentration stress at the cervical parts of the teeth.[4,5,35] This study could imply that the more intensity of occlusal contact and non-axial loading force was applied on teeth, the greater chance NCCLs would occur.

Types of occlusal schemes did not have a significant association with NCCLs in our study. Previous studies, in contrast, found that the group function occlusion was associated with NCCLs.[7,12] It was believed that the occlusal contacts on posterior teeth in the group function occlusion could produce stains on the cervical parts of the tooth and lead to NCCLs. Moreover, the canines could support structures from lateral stress during mandibular movements.[26,27]

It may be beneficial to increase the number of subjects for the opportunity of seeing clearer results of occlusal factors related to NCCLs. Subjects without NCCLs could be added to compare the subject-leveled occlusal factors. Additionally, instead of occlusal forces in percentage from the T-scan system, the actual amount of occlusal force could be evaluated the relation to the NCCLs.

The NCCLs could be a sign of occlusal problems such as heavy occlusal forces and eccentric occlusal contacts. By recognizing this problem, dentists could precisely diagnose and treat the patient. Moreover, in the orthodontic treatment, the T-scan system was useful to be applied to assist in re-checking occlusal conditions for minor occlusal adjustment before the debonding process to relieve the heavy loading force area.

Conclusions

Post-orthodontic patients with increasing age are prone to NCCLs, whereas types of malocclusion and orthodontic treatment approaches were not related. The higher occlusal force loading on both MIP and eccentric movement, the intense occlusal contact at eccentric movement, and the gingival recession were also the clinical signs of the occurrence of NCCLs.

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Declaration of Interest

The authors report no conflict of interest.

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