

CLINICAL RESEARCH

Factors influencing the progression of noncarious cervical lesions: A 5-year prospective clinical evaluation



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Cervical lesions on a tooth may be carious or noncarious. A noncarious cervical lesion (NCCL) is defined as a loss of tooth tissue in the cervical region with a nonbacterial etiology.¹ The etiology of NCCLs is complex, with erosion, friction, and tooth flexure from occlusal factors contributing at various times to the initiation and progression of the lesion.¹⁻⁸

Erosion is the loss of hard dental tissues due to a chemical process without bacterial interaction, and “biocorrosion” describes the various forms of chemical, biochemical, and electrochemical degradation of tooth substance.¹ The occlusal surfaces of mandibular first molars and the buccal surfaces of maxillary anterior teeth are particularly vulnerable to acid attack during the consumption of acidic foods and drinks.^{9,10} The palatal/lingual surfaces of

teeth are subject to acid degradation from internal sources such as gastric reflux or self-induced vomiting (bulimia).¹¹

ABSTRACT

Statement of problem. The etiology (chemical, friction, abfraction) of noncarious cervical lesion (NCCL) progression is poorly understood.

Purpose. The purpose of this 5-year prospective clinical trial was to measure the relationship between NCCLs and various etiologic factors.

Material and methods. After review board approval, 29 participants with NCCLs were enrolled. Polyvinyl siloxane impressions were made of each NCCL, and casts were poured at baseline, 1, 2, and 5 years. The casts were scanned with a noncontact profilometer, and 1-, 2-, and 5-year scans were superimposed over baseline scans to measure volumetric change in NCCLs. T-scan and Fujifilm Prescale films were used to record relative and absolute occlusal forces on teeth with NCCLs at the 5-year recall. Participant diet, medical condition, toothbrushing, and adverse oral habit questionnaires were given at the 5-year recall. Occlusal analysis was completed on mounted casts to determine the presence of wear facets and group function. Volumetric lesion progression from 1 to 5 years was correlated to absolute and relative occlusal force using mixed model analysis. The Kruskal-Wallis and Mann-Whitney analyses compared lesion progression with diet, medical condition, toothbrushing, adverse oral habits, wear facets, and group function.

Results. The NCCL progression rate over 5 years was $1.50 \pm 0.92 \text{ mm}^3/\text{yr}$. The rate of progression of NCCLs was related to mean occlusal stress ($P=.011$) and relative occlusal force ($P=.032$) in maximum intercuspation position. No difference was seen in NCCL progression between participants with any other factors.

Conclusion. Heavy occlusal forces play a significant role in the progression of NCCLs. (J Prosthet Dent 2016;115:571-577)

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Clinical Implications

The results of this study suggest that heavy occlusal forces contribute to the progression of NCCLs. An analysis of occlusal forces may aid in the diagnosis and treatment of NCCLs.

Toothbrush abrasion, the abnormal wearing of a substance or structure by a mechanical process, was first described by Zsigmondy in 1894.¹² Abrasive lesions typically have well-defined, sharp margins and may be wedge-shaped or grooved with scratched surfaces and sharp line angles. Manly developed a method of measuring the loss of dentin on extracted human teeth exposed to mechanical toothbrushing and dentifrice abrasives in the laboratory.¹³ Several clinical studies have given evidence of toothbrush abrasion as an etiology for NCCLs. For instance, increased cervical lesions were reported in a large cross-sectional study in participants who brushed twice daily compared with those who brushed less frequently.¹⁴ A greater number of NCCLs were reported on the left side of participants who were right-handed, and areas brushed initially were shown to have more abrasive lesions, perhaps due to increased brushing force and duration in that area.¹⁵ Several factors influence the rate of abrasion, including toothbrushing technique, brushing force, brushing frequency, bristle stiffness, and toothpaste abrasiveness.¹⁶ Horizontal brushing produces more tooth loss than longitudinal brushing.¹⁷

Several authors have suggested that factors other than chemical erosion and friction may be important in the pathogenesis of the NCCL.^{18,19} Grippo et al.²⁰ and Lee et al.²¹ proposed that occlusal loading deforms the tooth at the cervical area, causing disruption of the enamel crystals and forming an NCCL. They called this occlusally generated lesion an abfraction lesion. Abfraction lesions as described by Grippo et al are typically wedge-shaped with sharp margins, although secondary erosion or abrasion may alter the appearance of the lesion.²² The correlation between heavy occlusal forces and the progression of NCCLs is controversial, in that some studies state that stress concentration in the cervical areas of the tooth contribute to their occurrence,^{23,24} while others reject dental occlusion and articulation as a factor in NCCL development.^{25,26}

Whereas most authors attempt to ascribe a single etiology to NCCLs, several observations indicate the multifactorial etiology of NCCLs. These factors include the occurrence of NCCLs on the lingual areas of teeth where access with a toothbrush is limited,^{27,28} the occurrence of NCCLs in animals,²⁹ the progression of NCCLs around restorations,³⁰ the observation that

Table 1. Inclusion and exclusion criteria

Inclusion

- Participant age should be 19 years and older
- Should have at least 1 noncarious cervical lesion less than 2 mm in depth which does not require operative intervention because of sensitivity or esthetics
- Test teeth should be in occlusion
- No mobility of test or antagonist teeth should be clinically detectable
- Should be a regular dental attendee who is able to return for assessments
- Should be in good medical health and able to tolerate dental procedures
- Must not have rampant caries
- Must not have chronic periodontitis or carious lesions which could compromise tooth retention

Exclusion

- Participant is enrolled in evaluation of restorative materials
- Participant has noncarious cervical lesions less than 1 mm deep
- Participant is irregular dental attendee or is unable to return for recall appointment
- Participant maintains unacceptable standard of oral hygiene
- Poor general health
- Chronic periodontitis (>3 mm pockets) or rampant caries
- Teeth are mobile
- Other restorative treatment on teeth included in current study
- No antagonist for teeth with abfraction lesions

mobile teeth do not display NCCLs as frequently as nonmobile teeth,³¹ an increased incidence of NCCLs in bruxism,^{14,32-35} the appearance of lesions below the gingiva,³⁶ and the increased prevalence of NCCLs in the teeth of participants whose teeth demonstrate wear^{37,38} and eccentric occlusal contacts in function.^{8,39-42} Braem et al⁴³ pointed out this multicausality of NCCLs and suggested the term “biotribocorrosion” to explain this process. Biotribocorrosion, coming from the words tribology (study of friction, lubrication, and wear) and corrosion (chemical and electrochemical degradation), implies a material degradation process due to the combined effect of corrosion and wear.

The purpose of the current study was to examine the role of 7 factors that may influence the progression of NCCLs: occlusal forces, diet, medical conditions, toothbrushing, adverse oral habits, presence of wear facets, and group function. The null hypotheses were that no difference would be found in the volumetric loss of tooth structure in NCCLs over time in participants with heavy occlusal forces, acidic diets, medical conditions that reduce salivary function, aggressive brushing habits, adverse oral habits, occlusal wear facets, or group function.

MATERIAL AND METHODS

Before participant enrollment, an Institutional Review Board approved the clinical trial protocol. Forty-five participants were recruited from individuals attending the BioHorizons Research Clinic at the University of Alabama at Birmingham. Participants were selected with the inclusion and exclusion criteria presented in Table 1. At the 5-year recall appointment, 29 participants returned for analysis. Because occlusal analysis and questionnaire forms were administered at the 5-year recall, all other participants were excluded from this study.

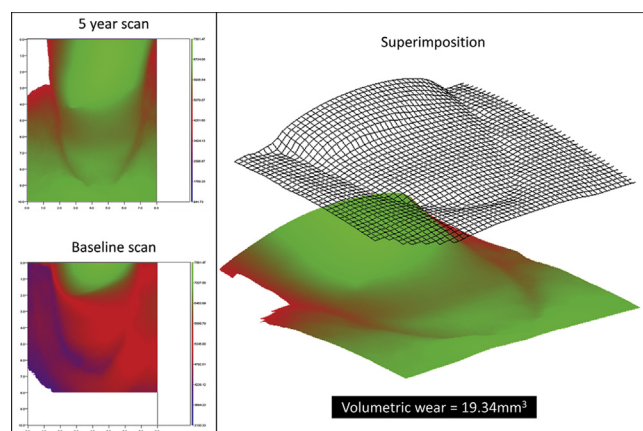


Figure 1. Superimposition of scans using ProForm software (Scantron Industrial Products Ltd).

All NCCLs were evaluated for sclerosis, sensitivity, and shape. Cold sensitivity was assessed with a cotton pellet saturated with a refrigerant spray (Hygenic Endo-Ice Pulp Vitality Refrigerant Spray; Coltène/Whaledent). The saturated pellet was applied on the tooth with the NCCL in the buccal cervical area for 3 seconds and removed. The cold response was measured with a visual analogue scale on a 10-mm line labeled from 0 to 10. The evaluation of dentin sclerosis on teeth with NCCLs was based on the Dentin Sclerosis Scale developed by the University of North Carolina School of Dentistry.⁴⁴ Visual examination and comparison was done by the evaluator (K.S.) to determine the shape of the NCCL lesions.

Impressions of the participant's maxillary and mandibular arch were made using stock complete arch impression trays (Self-adhesive Directed Flow Impression Tray; 3M ESPE) and polyvinyl siloxane impression material (Aquasil Light Body; Dentsply Caulk) at a baseline appointment and at 1-, 2-, and 5-year recall appointments. After 1 hour, the impressions were poured with Type IV die stone (Fujirock; GC America). A portion of each cast containing the NCCL and at least 2 mm of surrounding tooth structure was scanned with a noncontact 3-dimensional profilometer (Proscan 2000, resolution 20×20 μm ; Scantron Industrial Products Ltd). The scans from the 1-, 2-, and 5-year recall appointments were superimposed on the baseline scans using ProForm software (Scantron Industrial Products Ltd) (Fig. 1). This software allowed the change in volume of the noncarious cervical lesions to be measured at each recall.

The absolute value of the occlusal force on the teeth with NCCLs was measured using pressure indicating films (FujiFilm Prescale film; Sensor Products Inc) at the 5-year recall appointment.⁴⁵ The participants were seated in an upright position, and a sheet of Prescale film (thickness of 0.1 mm) was placed on the occlusal surface of the desired tooth with cotton pliers. The participants

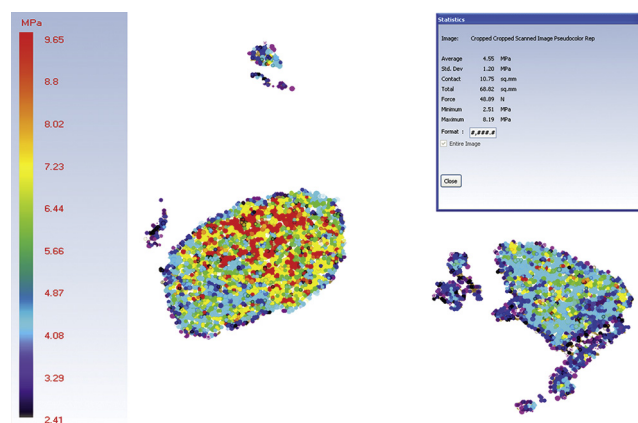


Figure 2. Sample Topaq pressure analysis system (Sensor Products Inc) occlusal stress analysis.

were asked to occlude on the sheet in maximum intercuspation position (MIP), steadily increasing the occlusal force over a period of 3 seconds to the force required to eat a piece of bread (or normal masticatory force). These single use films contain dye-filled pressure-sensitive microcapsules, which rupture to produce a topographical color-based image of force variation across the contact area. The pressure-indicating films were analyzed using a Topaq pressure analysis system (Sensor Products Inc), which converted the color saturation on the pressure indicating film into absolute values of force. The tooth of interest was isolated with the Topaq software, and an average occlusal stress value was calculated from the occlusal contact area and the mean of the forces in that area (Fig. 2).

Relative occlusal force measurements were made using an occlusal force system (T-Scan Occlusal Analysis System; Tekscan Inc). The system contains 8.84 m^2 sensors that record occlusal force and duration. The system was inserted into the mouth, and the participant was asked to occlude in maximum intercuspation and then slide into left and right laterotrusion and protrusive movements. The software recorded the percentage of force applied to the system sensors at the location of the teeth with NCCLs relative to the average of all the other occlusal contacts within the mouth (Fig. 3). Relative occlusal forces were recorded for MIP, left and right laterotrusion, and protrusion. Left laterotrusion and right laterotrusion forces were converted to working and nonworking forces by assigning left laterotrusion force as the working force when the lesion was on the left side of the mouth and vice versa.

Diet, medical conditions, toothbrushing, and adverse oral habits were assessed by using the responses to verbal questionnaires and participant observation (Table 2). The diet questionnaire was designed to include factors that would increase oral acidity. Medical conditions were selected to evaluate the amount and acidity of

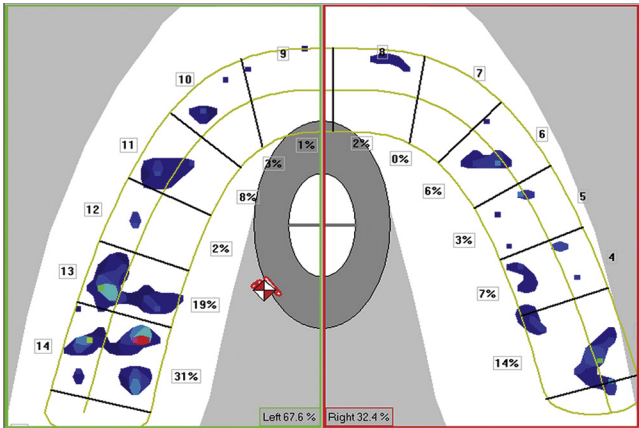


Figure 3. Sample T-Scan Occlusal Analysis System (Tekscan Inc) image showing 31% of occlusal force distribution on tooth with noncarious cervical lesion (maxillary left first molar).

saliva present in each participant. If the participant did not know if his medication caused xerostomia, the side effects were researched. Toothbrushing technique and rigorousness were assessed by recording 1-minute videos of participants brushing their teeth. Two independent observers (K.S. and N.L.) assessed the videos to determine technique and rigorousness. The presence of adverse oral habits was determined by asking whether the participant had a tooth grinding or nail biting habit.

The casts from the 5-year recall appointment were mounted on a semiaadjustable articulator (#2240Q series; Whip Mix Corp) with a facebow (Axioquick Facebow; SAM) to analyze occlusion and detect wear facets. The casts were mounted in MIP without occlusal registration material. From the mounted casts, the participants were categorized based on the type of occlusion (group function or canine protected occlusion) present on the side of the mouth with the NCCL of interest. Canine protected occlusion was defined as anterior guidance sufficient to disclude posterior teeth during excursive movements. Occlusal wear facets on teeth with NCCLs were recorded as mild (<1 mm), moderate (1 to 2 mm), or severe (>2 mm) as determined by 2 independent observers (K.S. and N.L.).

Each participant data set (volume loss at 1 year, 2 years, and 5 years) was analyzed with regression to determine the NCCL progression rate. The slope of the regression line (Δ volume loss/ Δ time) represented the progression rate of the lesion. Mixed model analysis was used to compare the NCCL progression rate per tooth with the mean absolute and relative occlusal force per tooth (in MIP or excursive movements). Because of unequal variance, the Mann Whitney analyses were used to compare the NCCL progression with diet, medical condition, toothbrushing, and adverse oral habits factors. Since these data were obtained from the questionnaires and specific only to the participant (not the tooth), the

Table 2. Questionnaire for diet, medical conditions, toothbrushing, and adverse oral habits

Diet
Q1. Do you keep citrus fruits or sour candy in your mouth for prolonged periods of time?
Q2. Do you drink soda, juice, or wine more than once a day?
Q3. Do you consume acidic dressings or sauces more than once a day?
Medical condition
Q4. Do you have gastric reflux?
Q5. Do you have dry mouth?
Q6. Do you take medicine causing hyposalivation?
Toothbrushing
Q7. Do you brush your teeth more than once a day?
Q8. Do you use a medium or hard bristled toothbrush?
Q9. Do you brush rigorously? (video)
Q10. Do you use a horizontal brushing technique? (video)
Adverse oral habits
Q11. Do you grind your teeth or bite your nails?

Table 3. Wear progression rate, absolute occlusal force, and relative occlusal force

Variable	Mean \pm SD (95% CI)
Rate of noncarious cervical lesion volume change (mm^3/y)	1.50 \pm 0.92 (1.28, 1.73)
Absolute occlusal stress in maximum intercuspation position (MIP) (N/mm^2)	4.00 \pm 1.15 (3.75, 4.26)
Relative occlusal force in MIP (%)	14.9 \pm 7.6 (13.20, 16.51)
Relative occlusal force in protrusion (%)	5.8 \pm 7.5 (4.14, 7.43)
Relative occlusal force on working side (%)	7.2 \pm 8.8 (5.34, 9.17)
Relative occlusal force on nonworking side (%)	1.7 \pm 4.2 (0.85, 2.69)

progression rates of all the teeth in a specific participant were averaged for comparison. The Mann-Whitney and Kuskall-Wallis analyses were used to compare the NCCL progression rate with tooth location, the presence of wear facets, and group function per tooth.

RESULTS

For the 5-year recall, 29 participants returned ($n=29/45$ participants; recall rate=64.4%), with a total of 83 teeth. The prevalence of noncarious cervical lesions was nearly equally distributed between men and women (15:14), with an average age of 60.3 years. The lesions occurred predominantly in premolars (32.2%), followed by canines and molars (23.7% each). The Kruskal-Wallis analysis showed no difference in lesion progression among molars, premolars, and anterior teeth ($P=.691$). The shape of the lesions was mostly obtuse (51.7%) or approximately at right angles to the tooth's facial surface (31%). Moderate sensitivity (cold response >3) on the involved teeth was found in 34.5% of the participants by using the cold test. A moderate to high degree of sclerosis was observed on 68.9% of the lesions.

A single value of slope of volume loss was calculated for each tooth, which represented the progression of the lesion over time (the dependent variable). Table 3 shows the mean, the standard deviation, and the confidence interval for the wear progression rate, absolute occlusal stress, and relative occlusal forces measured in this study. The results of the mixed model analysis revealed a

Table 4. Mean noncarious cervical lesion (NCCL) volume change for each diet, medical condition, toothbrushing, and adverse oral habit factor (significance of difference represented by *P* value)

Question	Yes, n	Rate of NCCL Volume Change, Mean \pm SD		No, n	Rate of NCCL Volume Change, Mean \pm SD		<i>P</i>
Q1 Acidic foods	21	1.06 \pm 0.80		8	1.52 \pm 1.89		.558
Q2 Acidic beverages	16	1.30 \pm 1.44		13	1.04 \pm 0.79		.661
Q3 Acidic sauces	16	1.08 \pm 1.36		13	1.32 \pm 0.95		.272
Q4 Gastric reflux	8	1.09 \pm 1.22		21	1.43 \pm 1.10		.526
Q5 Dry mouth	8	1.21 \pm 1.28		21	1.14 \pm 0.94		.769
Q6 Hyposalivation medicine	7	0.75 \pm 0.49		22	1.32 \pm 1.31		.221
Q7 Brush more than 1 \times /day	22	1.46 \pm 2.01		7	1.10 \pm 0.82		.721
Q8 Medium or hard brush	9	1.06 \pm 0.83		20	1.47 \pm 1.76		.637
Q9 Brush rigorously	14	0.99 \pm 0.71		15	1.40 \pm 1.54		.383
Q10 Horizontal brushing	13	1.24 \pm 1.49		16	1.12 \pm 0.70		.661
Q11 Grind or nail bite	15	1.37 \pm 1.48		14	0.99 \pm 0.74		.432

significant correlation between the NCCL progression rate and the mean absolute occlusal stress ($P=.011$) and the mean relative occlusal force per tooth in MIP ($P=.032$). No significant relationship was found between the NCCL progression rate and protrusive forces ($P=.448$), working forces ($P=.074$), or nonworking forces ($P=.415$). The Kruskal-Wallis and Mann-Whitney analyses revealed that the NCCL progression rate was not significantly associated with any of the diet, medical condition, toothbrushing, adverse oral habit, or occlusal factors (Tables 4, 5).

DISCUSSION

This study investigated the major etiologic factors suspected of causing NCCLs: diet, toothbrushing, medical conditions, adverse habits, and occlusal forces. The null hypothesis that no association would be found between occlusal forces and the progression of NCCLs was rejected. All other null hypotheses investigating potential etiologic factors were not rejected.

Occlusal forces (both absolute and relative values) were significantly related to the progression of NCCLs. This result is in agreement with 2 previous studies that also used the dental prescale system to measure occlusal force quantitatively. The average occlusal force measured was 992.1 N (occlusal contact area =22.9 mm²) and 794.4 N (occlusal contact area =18.9 mm²).^{24,45} The present study recorded the mean occlusal stress as 4 \pm 1.15 N/mm² per tooth and the mean occlusal contact area as 6.45 mm². These values are lower than those obtained in previous studies, which may be attributed to the age of the participants (mean age of 60.3 years) compared with the male military self-defense force officials²⁴ and younger individuals⁴⁵ enrolled in previous studies. Studies that have measured occlusal

Table 5. Mean noncarious cervical lesion (NCCL) volume change by severity of wear facet or presence of group function on side of mouth with NCCL (significance of difference listed in italics)

Variable	Affected Teeth (n)	Rate of NCCL Volume Change (μ m ³ /y), Mean \pm SD
Wear facets		<i>P=.705</i>
Mild	34	1.21 \pm 1.24
Moderate	31	0.99 \pm 0.98
Severe	18	0.98 \pm 0.62
Group function		<i>P=.406</i>
Yes	42	0.90 \pm 0.065
No	41	1.26 \pm 1.30

forces on molars with strain gauge analysis reported mean values of force ranging from 20 to 60 N, which are more similar to the values measured in the current study.^{46,47}

A previous study reported a correlation between the presence of NCCLs and the consumption of citrus fruits, soft drinks, alcohol, yogurt, and effervescent vitamin C. Additionally, the frequency of citrus and soft drink consumption was shown to be related to the presence of NCCLs.¹⁰ The present study did not find a significant association between any dietary factors and NCCL progression. A previous study by Mayhew et al³⁷ also used a dietary assessment focusing on acidic food/beverage intake over the most recent 24-hour period in 43 participants and found no correlation of NCCL prevalence with dietary patterns.

Faye et al²⁷ noted a considerable number of medications causing xerostomia in a non-toothbrushing population and suggested that these medications are a factor in the etiology of NCCLs in this population. Smith et al¹⁰ showed a correlation between the presence of NCCLs and reported gastric reflux. However, the present study did not find any correlation of NCCL prevalence with medications or medical conditions that cause dry mouth or acidic saliva.

Past studies have indicated a substantial association of toothbrush hardness and brushing pressure with NCCLs.^{4,16,24,28} In the present study, however, toothbrush stiffness and horizontal brushing technique did not have a significant effect on NCCL progression. The discrepancy between previous results and the results of the present study might be due to the difference in the way toothbrushing analysis was done in each study. In a study by Takehara et al,²⁴ the examiner brushed the participant's teeth professionally with 3 standard pressures (20, 30, and 40 kPa), and the participants chose the pressure closest to their daily toothbrushing pressure. In the study by Brandini et al,²⁸ toothbrushing force was inferred by image analysis of the deformation of toothbrush bristles.

Bruxism or parafunction may also contribute to NCCLs.^{15,32,33} However, some studies failed to find a

higher prevalence of NCCLs in participants with a bruxing habit than in those without a bruxing habit.^{5,24} This supports the results of the present study, which revealed that there is no significant association between self-reported bruxism and NCCL progression. The reliability of participant surveys is often questionable as sleep bruxism tends to be unreported or underscored.³⁴

Some casts with NCCLs exhibited occlusal wear, while others exhibited severe wear facets but no NCCLs, suggesting that occlusal wear facets and NCCLs are independent responses of teeth to occlusal stress. This is supported by a similar study by Estafan et al²⁶ on 299 dental casts, where NCCL size was not found to be correlated with the wear facet area. In contrast, others have reported that NCCLs coexist almost systematically with occlusal wear facets (82% to 95%), although not necessarily in a causal relationship.^{5,6,37} Several past studies have reported a direct correlation between occlusal wear facets and NCCL progression^{10,36} However, most of these studies used clinical dental examination to classify the wear facets, which may be less accurate than using casts for measurement.

The prevalence of NCCLs has been associated with the presence of group function, which is the contact of multiple teeth in working movements. A study of 156 participants by Smith et al¹⁰ found a positive association between NCCLs and group function. Antonelli et al³⁹ studied NCCLs in 20 participants with mixed excursive guidance (that is, canine guidance on one side and group function on the other) and reported that 22.5% of all teeth contacting on the group function sides showed NCCLs as compared with only 2.1% of teeth on the canine guided sides. In contrast, Wood et al⁸ concluded that reducing the occlusal load in lateral excursion did not decrease the progression of NCCLs. A case control study of 264 individuals by Bader et al⁷ found that working side canine guidance was associated with the presence of NCCLs. Other studies have reported that the occlusal guidance scheme and MIP to centric occlusion slide are of minor importance in the development of NCCLs.^{8,10,26,34}

Most studies have evaluated NCCLs by means of a clinical dental examination^{4-6,10,11,23,25,27,28,35,41} or by measurements on casts^{16,26,32,33,39,42} using a periodontal probe or dental calipers. In some studies, the lesion depth and size were measured on the casts,^{16,33} while in others, simply the presence or absence and the severity of the NCCL were noted.^{26,32,34,36} Previous studies used teeth,^{4,5,8,36,41} participants,^{4,7,10,11,14,15,23-25,27,32} or both^{16,26,31,33,34,39,42} as units of analysis to investigate the association between NCCLs and various etiologic factors. The maximum follow-up period of these lesions in previous studies was 30 months.⁸

The limitations of this study include the limited number of participants, the subjectivity associated with

collecting a single occlusal force measurement, and the information missed by not administering questionnaires and occlusal analysis at the beginning of the study. The absolute value of occlusal force was measured only in maximum intercuspation and not in excursive movements, in that pressure indicating films are a static and not a dynamic record. This study only measured the progression of existing NCCLs and did not assess the formation of NCCLs. Perhaps factors other than occlusal forces are more important in initiating NCCLs; however, occlusal forces are responsible for their growth. The accuracy of the volume loss measurement may be improved in future studies by using digital intraoral scanners in place of conventional impressions and casts.

CONCLUSIONS

Within the limitations of this study, the following conclusions were drawn:

1. NCCL progression (slope of total volume loss) was correlated with absolute occlusal stress ($P=.011$) and relative occlusal forces ($P=.032$) in MIP at 5 years.
2. No significant correlation was found between NCCL progression and the consumption of a more acidic diet, toothbrushing technique/rigorousness, medical conditions causing deficient or acidic saliva output, presence of occlusal wear facets, group function, or adverse oral habits.

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