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Noncarious Cervical Lesions and Their Association With Toothbrushing Practices: *In Vivo* Evaluation

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Clinical Relevance
Knowledge of the characteristics and etiologies of noncarious cervical lesions assists dentists in selecting an appropriate treatment and improving the prognosis.

SUMMARY

Objectives: This pilot study aims to investigate the prevalence of noncarious cervical lesions (NCCLs) in a student population at the Faculty of Dentistry of Araçatuba–UNESP and to assess the potential relation between buccal hygiene habits and the presence and number of NCCLs.

Methods: This study was conducted with a sample of 58 young volunteers (15 men and 43

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women; mean age, 23.6 ± 1.8 years and 22.3 ± 2.4 years, respectively). The research was divided into three steps: 1) clinical assessment; 2) oral-hygiene practices self-report questionnaire; and 3) analysis of toothbrush filament deformations. After the clinical exam the participants were divided into two groups, a control group (without NCCLs) and a test group (NCCLs), according to NCCL presence. The data were statistically analyzed with SPSS 16.0 software, using *t*-test, χ^2, Fisher exact test, and Spearman correlation.

Results: NCCLs were present in 53% of the subjects. The presence of NCCLs was marginally statistically associated with age (p=0.15) and proportionally more prevalent in male (80%) subjects (p=0.01). NCCLs were more concentrated in the posterior-superior quadrant (93%) in both the right (90%) and left (55%) sides of the mouth. The direct rank correlation was presented between presence of NCCLs and toothbrush firmness; and between number of NCCLs and age and force applied during toothbrushing.

Conclusion: Within the limitations of this pilot study, the use of medium and hard toothbrushes and greater force applied during toothbrushing might contribute to the development and/or aggravation of NCCLs.

INTRODUCTION

A noncarious cervical lesion (NCCL) is the loss of dental hard tissue near the cementoenamel junction without the development of caries. It is a common pathology that confronts dentists with a complex etiology and treatment plan. Abrasion, erosion, and abfraction have been cited as etiological cofactors of NCCLs.[1,2]

Abrasion of teeth surfaces is the result of friction from exogenous materials,[3] like chewing on toothpicks or tobacco pipes, excessively vigorous oral hygiene,[4] and the use of abrasive materials for toothbrushing. Erosion is the loss of dental tissue due to chemical processes;[5] it can be defined as extrinsic when caused by the influence of dietary acids, medical or environmental factors,[6] intrinsic when caused by regurgitation (gastric disturbance, stress-reflux phenomenon, and anorexia),[4,6] and idiopathic or secondary (acid saliva and acid crevicular fluid).[6] Abfraction is defined as the microstructural loss of dental tissue weakened in areas of concentrated stress as a result of biomechanical forces that cause a dental flexure and subsequent fatigue of enamel and dentin.[7,8] The breakdown of the dental tissues is dependent on the magnitude, duration, frequency, and location of the forces. These forces can be static, like the forces produced by swallowing and clenching, or cyclic, like those generated during chewing action.[7]

NCCLs are often mentioned as the patient's main complaint due to discomfort and sensitivity[9] caused by dentin exposure. Excessive hand force during toothbrushing can cause trauma to the protective periodontium, causing gingival recession. The action of these forces in conjunction with the abrasiveness of toothpaste can cause wear in the cervical region of the teeth, which may contribute to the presence of NCCLs,[10] given that oral hygiene and the number of daily brushings are linked with the frequency of NCCL occurrence.[11]

The abrasiveness and pH of toothpaste have been related to the presence of NCCLs.[12–14] The abrasiveness of toothpaste may be the important link between the erosive effect and the mechanical effect of the bristles during the brushing.[2,15,16]

In vitro reproduction of NCCLs in human teeth shows that horizontal brushing with commercial toothpaste has created NCCLs similar to those seen *in vivo*, and the various shapes of the NCCLs created appeared to be due to toothbrush bristle deflection.[14] Brushing without toothpaste does not cause wear in enamel and dentin,[16–19] whereas eroded dentin wear increased with the abrasiveness of the toothpaste slurry and with a smaller toothbrush bristle diameter.[20]

Making a timely diagnosis of NCCLs is of fundamental importance. Nonidentification of the etiological factors of these lesions can lead to inadequate treatment, decreased success of restorative treatments, and increased clinical complaints. It is important to verify the relation between NCCLs and toothbrushing in order to create a better understanding of the involved mechanisms and consequently select the appropriate treatment. This study aims to investigate the prevalence of NCCLs in a student population of the Dentistry School of Araçatuba, UNESP - Univ Estadual Paulista, Brazil, and to assess the potential relation between buccal hygiene habits and the presence and number of NCCLs.

MATERIALS AND METHODS

This cross-sectional pilot study consisted of a clinical survey of NCCLs and oral hygiene habits. A

convenience sample was taken from the senior-year student population of the Dentistry School of Araçatuba. Preceding the research, all interested students gave informed consent. Experimental procedures were approved by the Human Ethics Committee of the Dentistry School of Araçatuba (Process FOA-1142/2008).

Of the 63 examined individuals, 58 young volunteers (15 men and 43 women; mean age, 23.6 ± 1.8 years and 22.3 ± 2.4 years, respectively) participated in this study. The clinical selection of subjects was based on the criteria of complete dentition, not necessarily with the presence of third molars, and absence of cervical caries or fillings.

The research was divided into three steps: 1) clinical assessment; 2) oral-hygiene practices self-report questionnaire; and 3) analysis of toothbrush bristle deformations.

The clinical assessment consisted of a clinical examination form to register personal data, and an intraoral exam that was conducted by one precalibrated dentist. For the intraoral exam, sterile buccal mirrors and exploratory probes to detect the presence of NCCLs as well as the location of the NCCLs in the teeth were used. Losses of dental tissue near the cementoenamel junction without the development of caries were considered NCCLs.

After the clinical exam, the participants were divided into two groups according to the presence or absence of a NCCL: a control group (no NCCL presence) and a test group (NCCL presence).

The participants filled out an oral-hygiene practices self-report questionnaire that included questions about the number of daily toothbrushings (eg. "How many times a day do you brush your teeth?" *One*, *two*, *three*, *four*, or *more than four times a day*), characteristics of the bristles of toothbrushes commonly used by the respondent (eg. "What kind of toothbrush do you use to brush your teeth?" *Soft*, *medium*, or *hard*), toothpaste (eg. "What kind of toothpaste do you use regularly for oral hygiene?" *With* or *without abrasive* and *with* or *without fluoride*), and the intensity of the force applied during toothbrushing (eg. "Do you think that you brush your teeth with excessive force?" *No*, *a little*, or *very much*).

To enable analysis of toothbrush bristle deformation, ie. the collapse under force of bristles on an individual brush head, all participants were provided with new and identical extrasoft toothbrushes (Colgate Professional, Colgate-Palmolive Ind Com Ltd, São Paulo, SP, Brazil), in combination with Colgate Total toothpaste (Colgate-Palmolive). The quality of the toothbrushes and their packaging were verified prior to distribution among participants. Only brushes with uniform tufts, placed perpendicularly to the base of the head, were used. The participants were requested to use the toothbrush and toothpaste for their normal daily toothbrushing for a period of 30 days, keeping the brushes dry during nonuse. After this period, the toothbrushes were collected, decontaminated with chlorhexidine gluconate 2% and analyzed.

The brushes were photographed and identified individually, with a millimeter ruler placed beside to provide a parameter of measure (Figure 1). A Canon EOS Rebel XT camera (Canon Inc., Tokyo, Japan) was attached to a tripod in order to get images of a standardized quality. The images were analyzed with the program Image Tool for Windows version 3.00 (Evans Technologies Inc.) to determine the superficial area (in millimeters squared) measured from the top of the bristles, using the ruler present in the image as a reference (Figure 1).

A second analysis was conducted by visual observation of the deformation of the bristles. This deformation was classified according to the following six categories: no deformation, right, left, upward, downward, and deformation in all directions (Figure 2). Two classifications can be assigned simultaneously, with the exception of the classifications "no deformation" and "deformation in all directions." The researchers did not know whether the tooth-

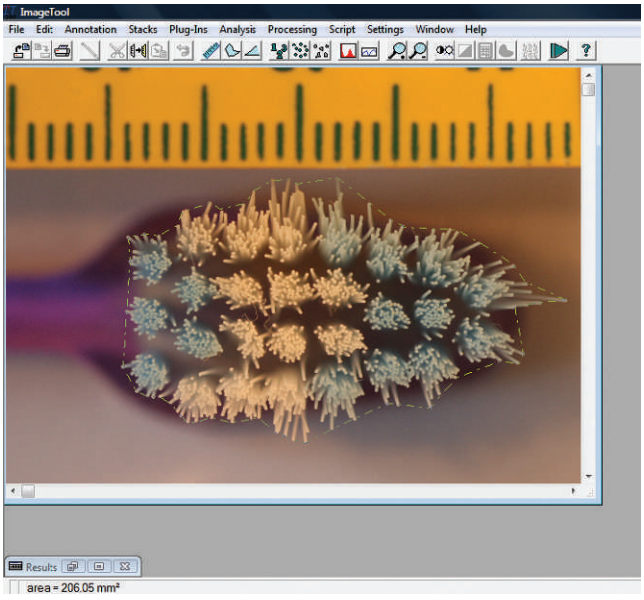

Figure 1. *Measurement of the superficial area (millimeter squared) of brushes, using the program Image Tool (Evans Technology Inc.).*

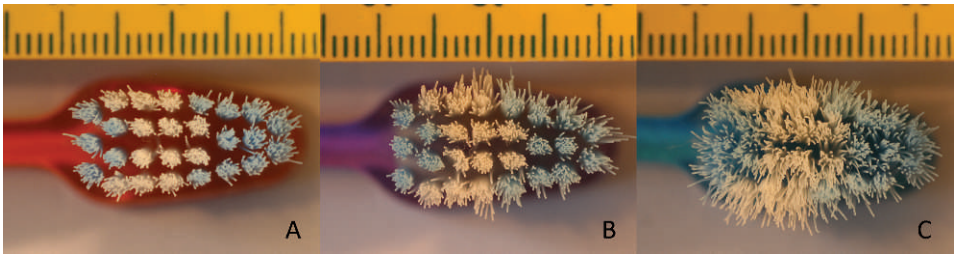

Figure 2. *Images of toothbrushes showing bristle deformation. (A): Light. (B): Moderate. (C): Severe.*

brushes they analyzed belonged to the test or control group.

The data were analyzed using statistical software (SPSS, version 16.0, SPSS Inc, Chicago, IL, USA) with the α value for statistical significance set at 0.05. The analysis of group differences between test and control subjects was performed using the χ^2 test for the predominantly quantitative variables, Fisher exact test for categorical variables, and independent *t*-tests for continuous variables. The nonparametric correlation (Spearman rank correlation coefficient) was used to refer to a linear relationship between two quantities.

RESULTS

Demographic Characteristics

A total of 58 students participated in this exploratory research. NCCLs were present in 31 subjects (53.5%) in a population aged 19–31 years of age, with a mean age of 23.06 ± 2.55 years in the test group and 22.19 ± 1.98 years in the control group. Proportionally, NCCLs were significantly more prevalent in male (80%) than in female (44.2%) subjects (p=0.017) (Table 1).

Prevalence of NCCL by Toothbrushing Practices

The prevalence of NCCL by group of teeth and mouth quadrants is presented in Table 2. It was observed that the majority of NCCLs occurred in the posterior-superior quadrant (93.5%) and in the right upper side of the mouth (90.3%).

Table 3 illustrates the presence of NCCL in relation to oral hygiene practices. Of several independent variables related to toothbrushing practices, toothbrush firmness was the only variable that was statistically significantly associated with the presence of NCCLs (p=0.01). It is interesting that soft toothbrushes were used more frequently by students than medium and hard brushes, and all subjects who used brushes with firm bristles (medium or hard) showed NCCL presence. Frequency of daily toothbrushing (p=0.79), type of toothpaste (p=0.45), and applied force during toothbrushing (p=0.36) were not found to have a significant effect on NCCL presence in the sample analyzed in this study.

Toothbrush deformation, measured by splayed surface area of the brushes, had no statistically significant relation to NCCL presence, applied force during toothbrushing, and frequency of daily toothbrushing (Table 4). Deformation in all directions was most prevalent (36.2%), followed by upward (19%) and no deformation (12%) (Table 4).

The results also showed a direct rank correlation between the presence of a NCCL and toothbrush

Table 1: *Demographic Characteristics of Patients and Presence of NCCL*

Characteristics	Without NCCL	NCCL	Total	*p*-Value
Number of patients	27	31	58	
Age, y				
Mean ± SD	22.19 ± 1.98	23.06 ± 2.55		
Minimum	20	19		
Maximum	29	31		
LQ, UQ	21, 23	22, 25		0.15
Gender				
Male	3	12	15	
Female	24	19	43	0.017[a]

Abbreviations: LU, lower quadrant; NCCL, noncarious cervical lesion; UQ, upper quadrant.
[a] *Denotes statistically significant result;* p*-values are for comparisons between the two groups. Independent* t*-tests were used for continuous variables and* χ^2 *or Fisher exact test as appropriate for categorical variables.*

Table 2: *Prevalence of Noncarious Cervical Lesions by Group of Teeth and Mouth Quadrants*[a]

Intraoral Region Patients With NCCL				
	Absent		Present	
Groups of Teeth	n	%	n	%
Anterior-superior	25	80.6	6	19.3
Posterior-superior	2	6.45	29	93.5
Anterior-inferior	30	96.8	1	3.2
Posterior-inferior	18	58.1	13	41.9
Quadrants of arches				
Right-superior	3	9.7	28	90.3
Left-superior	14	45.2	17	54.8
Right-Inferior	19	61.3	12	38.7
Left-inferior	20	64.5	11	35.5

Abbreviation: NCCL, noncarious cervical lesion.
[a] *Independent* t*-tests were used for continuous variables.*

Table 3: *Toothbrush Practices and Presence of NCCLs*

	Without NCCL		NCCL		
Toothbrush Practices	n	%	n	%	p-Value
Frequency of daily toothbrushing					
3 times a day	5	18.5	8	25.8	
4 times a day	19	70.4	19	61.3	
5+ times a day	3	18.5	4	12.9	0.72
Toothbrush firmness					
Soft	27	100	24	77.4	
Medium	0	0	6	19.4	
Hard	0	0	1	3.23	0.01[a]
Type of toothpaste					
Fluoride and no abrasive	13	48.1	18	58.1	
Fluoride and abrasive	14	51.9	13	41.9	0.45
Force applied during toothbrushing					
No force	15	55.5	12	38.7	
Little force	11	40.7	15	48.4	
A lot of force	1	3.7	4	12.9	0.12

Abbreviation: NCCL, noncarious cervical lesion.
[a] *Denotes statistically significant result;* p*-values are for comparisons between the two groups. Independent* t*-tests were used for continuous variables and* χ^2 *or Fisher exact test as appropriate for categorical variables.*

firmness (p=0.008); and between number of NCCLs, age (p=0.007), and applied force during toothbrushing (p=0.03). On the other hand, indirect rank correlation was found between the presence and number of NCCLs and gender (respectively, p=0.016 and p=0.002) (Table 5). Considering that the data set was 0 for men and 1 for women, the presence and number of NCCLs was significantly higher in male subjects.

DISCUSSION

The prevalence of NCCLs recorded by literature has revealed results as conflicting as 2% to 90%.[11] In this study, NCCLs were observed in 53% of a young adult population with similar dental and oral hygiene knowledge and similar toothbrushing behavior. NCCLs were found to be more prevalent in male (80%) than in female (44.2%) subjects.

Age is also an important factor to be considered. Age represents cumulative NCCL effects, increasing likelihood of its prevalence and severity with age. Therefore, the prevalence and severity of NCCLs are likely to increase with age.[9,11,21,22]

In accordance with available literature in this field, we found that 93.5% of NCCLs were located in the posterior-superior teeth.[22–26]

Many studies show a link between NCCL frequency and oral hygiene.[1,11–13,15,19,23,27] The main etiological factor in this association is abrasion related to toothbrushing habits (eg. toothbrushing frequency, brushing technique, and applied pressure),[28] toothpaste (eg. abrasiveness, pH value, and quantity), and toothbrush characteristics (eg. shape, flexibility, and stiffness of the bristles).[28]

Table 4: *Toothbrush Deformation, According to the Area of Toothbrushes, Presence of NCCLs, and Toothbrushing Behavior*

	Area of the Toothbrush (mm^2)						
Toothbrushing Behavior	**No Answer**	**130 to 160**	**161 to 190**	**191 to 220**	**221 to 250**	**Total**	***p*-Value**
NCCL							
Absent	2	6	12	6	1	27	
Present	7	6	10	5	3	31	0.472
Force applied during toothbrushing							
No force	3	6	13	3	2	27	
Little force	4	6	7	8	1	26	
A lot of force	2	0	2	0	1	5	0.231
Daily toothbrushing							
3 times a day	2	3	4	4	0	13	
4 times a day	7	7	15	6	3	38	
5+ times a day	0	2	3	1	1	7	0.83
Toothbrush deformation							
No answer	9	0	0	0	0	9	
No deformation	0	6	1	0	0	7	
Right	0	0	1	0	0	1	
Left	0	0	1	0	0	1	
Upward	0	1	10	0	0	11	
Downward	0	3	1	0	0	4	
All directions	0	1	5	11	4	21	
Other	0	1	3	0	0	4	<0.001[a]

Abbreviation: NCCL, noncarious cervical lesion.
[a] *Denotes statistically significant result; p-values are for comparisons between the two groups. Independent t-tests were used for continuous variables and χ^2 or Fisher exact test as appropriate for categorical variables.*

Table 5: *Nonparametric Correlation Between Presence and Number of NCCLs and Oral-Hygiene Practices Self-Reported, Presented by Rank Correlation Coefficient*

	Number of NCCL	Gender	Age	Frequency of Toothbrush	Toothbrush Firmness	Type of Toothpaste	Force Applied During Toothbrushing
NCCL Presence	0.913**	−0.314*	0.204	−0.052	0.345**	−0.099	0.195
Number of NCCL	—	−0.399**	0.350**	0.023	0.209	−0.036	0.286*
Gender		—	−0.359**	−0.029	−0.019	−0.001	−0.264*
Age			—	−0.101	−0.013	0.044	0.316*
Frequency of toothbrush				—	−0.298*	0.162	−0.059
Toothbrush firmness					—	−0.241	−0.015
Type of toothpaste						—	0.145

Abbreviation: NCCL, noncarious cervical lesion.
** Denotes significance at* p = *0.05; ** Denotes significance at* p = *0.01.*

Statistical analysis did not reveal a significant relation between toothbrushing and NCCL frequency. These results contradict the findings in literature that relate the frequency of NCCLs to frequency of daily toothbrushing.[23,29]

An *in vitro* study revealed that NCCLs were created by horizontal brushing with common commercial toothpaste, but not by brushing with water only, and that the presence of abrasives in toothpaste increases NCCL frequency.[14] To the contrary, our findings did not confirm the hypothesis that the type of toothpaste is significantly associated with the presence and frequency of NCCLs.[30]

A positive association was found between NCCL presence and toothbrush bristle stiffness on the one hand and between the number of NCCLs and toothbrushing pressure on the other. This strengthens the common dentists' belief that hard-bristled brushes and excessive pressure during toothbrushing are the main etiological factors of NCCLs. At this time, however, it remains premature to consider these factors as the root cause of NCCL development. Studying eroded dentin, Wiegand and others (2009) showed that the abrasion of dentin increased with decreasing filament diameter,[20] which supposedly has greater flexibility and softness. This can be explained by the fact that greater flexion of soft bristles leads to a longer duration and contact between bristles and brushed surface, thus causing an increased quantity of abrasive moving over the surface.

One *in vitro* study indicated that soft, medium, and hard toothbrushes are not capable of abrading enamel, whereas dentin showed changes in surface roughness by the action of medium and hard toothbrushes.[30] Furthermore, the presence of subgingival NCCLs and the fact that lesions can occur in one tooth without affecting an adjacent tooth leads us to conclude that the factors related to brushing habits act merely as catalysts in this process.[13]

However, in clinically evaluating the influence of toothbrushing habits on the development of NCCL, the distribution of these lesions can be useful. NCCL development in a similar arch on adjacent teeth would be a strong indication that brushing practice is the etiological factor in that case.

Despite the limitations of this study due to sample size, it was interesting to assess the considerable difference in results between the two proposed methods of analysis.

Self-report questionnaires have been the most commonly used method in the literature to evaluate clinical parameters such as frequency of daily toothbrushing, characteristics of bristles of toothbrushes used by respondents, type of toothpaste, and applied force during toothbrushing. However, these questionnaires might not be an ideal method to

collect accurate data, because awareness can affect the quality of answers.

On the other hand, the study of toothbrush deformation is limited by a large number of other factors, such as brushing technique, toothbrush storage, humidification of the brush prior to brushing, quantity of toothpaste (which can alter deflection and deformation of bristles), and the commitment of participants to use the toothbrush for the duration of the research. Furthermore, the measurement of toothbrush deformation by calculating the superficial area of the bristles is limited by the fact that this method only captures externally directed deformations, whereas inward deformations remain undetected.

These results show the need for more research to deepen, review, or extend existing knowledge in this field, given that present clinical treatment focuses primarily on dental restorations and instruction to patients with regard to applied force during toothbrushing, even knowing that this does not control NCCL in an efficient way.

Consensus exists among researchers in this field of study that one isolated factor is not able to cause NCCL development.[31–33] Traction forces caused by mastication, malocclusion, or parafunctional habits are the primary etiological factors of NCCLs, conferring secondary importance to other buccal conditions related to the loss of dental structure.[4,30,34,35] In the case of nonideal occlusion, traction forces are generated that are able to break the chemical bonds between the hydroxyapatite crystals. This can lead to microruptures in a dental structure with limited capacity to absorb traction forces. This rupturing creates spaces that are occupied by water molecules that obstruct the establishment of new chemical connections between the crystals, thus leaving crystalline structures that are vulnerable to chemical action and the physical forces generated by mechanical or physiological processes.[34,35]

In dentistry it is up to the practitioner to investigate possible factors contributing to the development of NCCLs. Awareness of these factors will enable meeting the needs of patients in a more accurate and assertive way.

CONCLUSIONS

Within the limitations of this pilot study, the following conclusions were drawn: the prevalence of NCCLs in male subjects was proportionally higher than in female subjects; the use of medium and hard toothbrushes might contribute to the development of NCCLs; and both time and force applied during toothbrushing appear to be related to the aggravation of NCCLs.

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REFERENCES

1. Eisenburger M, Shellis RP, & Addy M (2003) Comparative study of wear of enamel induced by alternating and simultaneous combinations of abrasion and erosion *in vitro Caries Research* **37(6)** 450-455.
2. Levitch LC, Bader JD, Shugars DA, & Heymann HO (1994) Non-carious cervical lesions *Journal of Dentistry* **22(4)** 195-207.
3. Ceruti P, Menicucci G, Mariani GD, Pittoni D, & Gassino G (2006) Non carious cervical lesions: A review *Minerva Stomatologica* **55(1–2)** 43-57.
4. Lee WC, & Eakle WS (1984) Possible role of tensile stress in the etiology of cervical erosive lesions of teeth *The Journal of Prosthetic Dentistry* **52(3)** 374-380.
5. Rees JS, & Hammadeh M (2004) Undermining of enamel as a mechanism of abfraction lesion formation: A finite element study *European Journal of Oral Sciences* **112(6)** 347-352.
6. Passon JC, & Jones GK (1986) Atypical dental erosion: A case report *Gerodontics* **2(3)** 77-79.
7. Grippo JO (1991) Abfractions: A new classification of hard tissue lesions of teeth *Journal of Esthetic Dentistry* **3(1)** 14-19.
8. Rees JS (2006) The biomechanics of abfraction. *Proceedings of the Institution of Mechanical Engineers Part H* **220(1)** 69-80.
9. Lussi AR, Schaffner M, Hotz P, & Suter P (1993) Epidemiology and risk factors of wedge-shaped defects in a Swiss population *Schweizer Monatsschrift für Zahnmedizin* **103(3)** 276-280.
10. Gillette WB, & van House RL (1980) Ill effects of improper oral hygiene procedure *Journal of the American Dental Association* **101(3)** 476-480.
11. Wood I, Jawad Z, Paisley C, & Brunton P (2008) Non-carious cervical tooth surface loss: A literature review *Journal of Dentistry* **36(10)** 759-766.
12. Dyer D, Addy M, & Newcombe RG (2000) Studies *in vitro* of abrasion by different manual toothbrush heads and standard toothpaste *Journal of Clinical Periodontology* **27(2)** 99-103.
13. Litonjua LA, Andreana S, Bush PJ, Tobias TS, & Cohen RE (2004) Wedged cervical lesions produced by toothbrushing *American Journal of Dentistry* **17(4)** 237-240.

14. Dzakovich JJ, & Oslak RR (2008) *In vitro* reproduction of noncarious cervical lesions *Journal of Prosthetic Dentistry* **100(1)** 1-10.
15. Svinnseth PN, Gjerdet NR, & Lie T (1987) Abrasivity of toothpastes: An *in vitro* study of toothpastes marketed in Norway *Acta Odontologica Scandinavica* **45(3)** 195-202.
16. Addy M, & Hunter ML (2003) Can toothbrushing damage your health? Effects on oral and dental tissues *International Dental Journal* **53(3)** 177-186.
17. Braem M, Lambrechts P, & Vanherle G (1982) Stress-induced cervical lesions *Journal of Prosthetic Dentistry* **67(5)** 718-722.
18. Kuroiwa M, Kodaka T, & Kuroiwa M (1993) Microstructural changes of human enamel surfaces by brushing with and without dentifrice containing abrasive *Caries Research* **27(1)** 1-8.
19. Cohen RB (2004) Toothpaste abrasion *Journal of the American Dental Association* **135(11)** 1520-1522.
20. Wiegand A, Kuhn M, Sener B, Roos M, & Attin T (2009) Abrasion of eroded dentin caused by toothpaste slurries of different abrasivity and toothbrushes of different filament diameter *Journal of Dentistry* **37(6)** 480-484.
21. Telles D, Pegoraro LF, & Pereira JC (2000) Prevalence of noncarious lesions and their relation to occlusal aspects: A clinical study *Journal of Esthetic Dentistry* **12(1)** 10-15.
22. Borcic J, Anic I, Urek MM, & Ferreri S (2004) The prevalence of non-carious cervical lesions in permanent dentition *Journal of Oral Rehabilitation* **31(2)** 117-123.
23. Radentz WH, Barnes GP, & Cutright DE (1976) A survey of factors possibly associated with cervical abrasion of tooth surfaces *Journal of Periodontology* **47(3)** 148-154.
24. Lussi A, Schaffner M, Hotz P, & Suter P (1991) Dental erosion in a population of Swiss adults *Community Dentistry and Oral Epidemiology* **19(5)** 286-290.
25. Mayhew RB, Jesse SA, & Marin RE (1998) Association of occlusal, periodontal, and dietary factors with the presence of non-carious cervical dental lesions *American Journal of Dentistry* **11(1)** 29-32.
26. Madani AO, & Ahmadian-Yazdi A (2005) An investigation into the relationship between noncarious cervical lesions and premature contact *Cranio: The Journal of Craniomandibular Practice* **23(1)** 10-25.
27. Bergström J, & Lavstedt S (1979) An epidemiologic approach to toothbrushing and dental abrasion *Community Dentistry and Oral Epidemiology* **7(1)** 57-64.
28. Takehara J, Takano T, Akhter R, & Morita M (2008) Correlations of noncarious cervical lesions and occlusal factors determined by using pressure-detecting sheet *Journal of Dentistry* **36(10)** 774-779.
29. Smith WAJ, Marchan S, & Rafeek RN (2008) The prevalence and severity of non-carious cervical lesions in a group of patients attending a university hospital in Trinidad *Journal of Oral Rehabilitation* **35(2)** 128-134.
30. Azevedo AM, Panzeri H, Prado CJ, De-Mello JDB, Soares CJ, & Fernandes-Neto AJ (2008) Assessment *in vitro* of brushing on dental surface roughness alteration by laser interferometry *Brazilian Oral Research* **23(3)** 319-329.
31. Piotrowski BT, Gillette WB, & Hancock EB (2001) Examining the prevalence and characteristics of abfraction like cervical lesions in a population of U.S. veterans *Journal of the American Dental Association* **132(12)** 1694-1701.
32. Litonjua LA, Andreana S, Busch PJ, Tobias TS, & Cohen RE (2003) Noncarious cervical lesions and abfractions: A re-evaluation *Journal of the American Dental Association* **134(7)** 845-850.
33. Grippo JO, Simring M, & Schreiner S (2004) Attrition, abrasion, corrosion and abfraction revisited: A new perspective on tooth surface lesions *Journal of the American Dental Association* **135(8)** 1109-1118.
34. Lee WC, & Eakle WS (1996) Stress-induced cervical lesions: Review of advances in the past 10 years *Journal of Prosthetic Dentistry* **75(5)** 487-494.
35. Rees JS (2002) The effect of variation in occlusal loading on the development of abfraction lesions: A finite element study *Journal of Oral Rehabilitation* **29(2)** 188-193.