ORIGINAL RESEARCH

Association of Non-carious Cervical Lesions with Oral Hygiene Aspects and Occlusal Force

Rafael Dario Werneck[1], Daher Antonio Queiroz[2], Mariana Itaborai Moreira Freitas[3], Diana Leyva Del Rio[4], Cecilia Pedroso Turssi[5]

Abstract

Aim: The purpose of this case-control (CT) study was to investigate the association between the presence of non-carious cervical lesions (NCCLs) with occlusal force and other potential risk factors.

Materials and methods: Thirty-nine participants with NCCLs [cases (CS)] and 39 with no NCCLs [control (CT)] attending the dental clinic of the Faculdades Integradas São Pedro (FAESA), located in Brazil, were enrolled in this study. Information was collected through anamnesis, clinical examination, and a questionnaire addressing aspects related to tooth brushing, dentifrice, and mouthwash use. In clinical examination, patients were submitted to four measurements of occlusal force in the maxillary first premolars and maxillary first molars, using a strain gauge sensor of medium intensity, the Flexiforce (Tekscan, South Boston, Massachusetts, United States of America). The sensor was calibrated for the unit of measurement in Newtons (*N*). Data were analyzed using a student's *t*-test and multiple logistic regression, e with a significance level of 5%.

Results: There was no statistically significant difference between the case and CT groups regarding the bite force in the four measured regions. Logistic regression identified sex as a factor significantly associated with NCCLs ($p = 0.020$). The odds ratio showed the female sex had more chance (OR = 6.082; CI = 1.332–27.765) of having NCCLs.

Conclusion: It is concluded that females presented a higher risk factor for NCCLs than men. In contrast, there was no association of occlusal force, as well as aspects related to brushing and deleterious habits.

Clinical significance: Females have a higher risk factor for non-carious lesions than men.

Keywords: Bite Force, Dental Occlusion, Gingival Recession, Tooth Wear.

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Introduction

Non-carious cervical lesions are clinical conditions that cause changes in the morphology of the teeth, in addition to many other complications resulting from increased wear, such as dentin sensitivity, loss of function, and aesthetics.[1] There are several types of dental wear: Abrasion, abfraction, attrition, and erosion.[2,3]

The term abfraction was established by Grippo et al.[4] in 1991, from the Latin ab = out and fraction = fracture. The abfraction hypothesis is based on the biomechanical theory that there is a concentration of stress in the cervical region caused by the flexion during occlusal loading, resulting in the formation of cervical microfractures, ultimately causing the rupture between the apatite crystals of the enamel and the dentin.[5–9] From the clinical point of view, this lesion initially presents as minor grooves, which gradually undergo a process of fatigue wear caused by occlusal load, culminating with the formation of a wedge-like lesion, ending in thin and delicate enamel.

When the abfraction progresses, radiographically it will show an increased thickening of the periodontal ligament and lamina dura. One possible explanation for these lesions is the traction forces in the palatal and buccal alveolar bone region caused by oblique loads during eccentric movements. Once the bone is thinner in the Buccal region, the compressive force may be more critical on the surface, promoting Buccal bone loss accompanied by a gingival recession. This favors the progression of non-carious lesions on the buccal side of teeth once there is a loss of enamel structure in the cervical region, especially in patients with decreased mucosal keratinization and fine gingival biotype.[9–12]

[1]Department of Prosthodontics, College of Dentistry, FAESA - Centro Universitário, Vitória, Espírito Santo, Brazil

[2]Department of Restorative Dentistry and Prosthodontics, The University of Texas Health Science Center at Houston (UT Health); School of Dentistry, Houston, Texas, United States of America

[3]Department of Prosthodontics and Periodontology, University of Campinas – Piracicaba Dental School, Piracicaba, Brazil

[4]Division of Restorative and Prosthetic Dentistry, The Ohio State University College of Dentistry, Columbus, Ohio, United States of America

[5]Division of Cariology and Restorative Dentistry, Sao Leopoldo Mandic Institute and Dental Research Center, Campinas, Sao Paulo, Brazil

Corresponding Author: Mariana Itaborai Moreira Freitas, Department of Prosthodontics and Periodontology, University of Campinas – Piracicaba Dental School, Piracicaba, Sao Paulo, Brazil, Phone: +55 19 2106-5211, e-mail: marianaitaborai@hotmail.com

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Furthermore, according to the Glossary of Periodontal Terms, the term abrasion is the wearing away of tooth structure or restorative material through an abnormal mechanical process.[13] Examples include gingival and dental abrasions due to incorrect brushing. Whereas erosion is an apparent chemical dissolution of

enamel and dentin, unrelated to caries, causing a cavity that has a hard, smooth base.[14–16]

Non-carious cervical lesions have a multifactorial etiology, including mechanical stress, chemical degradation, and friction. In addition, there are risk factors such as teeth clenching, premature contact, overbrushing, and acidic beverages intake that cause NCCLs according to their intensity, duration, and frequency.[17,18]

The occlusal factor is also much discussed in the literature and may be associated with the etiology, and progression of NCCLs. Haralur et al.[19] and Lee and Eakle.[7] stated that occlusal trauma by lateral forces could promote a higher stress concentration in the cervical region, leading to disruption of the thin crystalline structure of enamel being able to initiate the formation of NCCLs.[7,14,18,19]

Knowing that there is still a lack of information correlating factors such as occlusal force, deleterious habits (e.g, biting objects, nail-biting, bruxism, mouth breathing, lip biting, atypical swallowing, and tongue thrusting).[20–22] and oral hygiene habits with the progression of NCCLs, the purpose of this case-CT study was to investigate the association between the presence of NCCLs with occlusal force and other potential risk factors such as sex, brushing, age and deleterious habits.

Materials and Methods

Ethical aspects

This study was approved by the Ethics Committee of the FAESA with the number: 850,991 and validated by the Ethics and Research Committee of the São Leopoldo Mandic School.

Selection and Characterization of the Sample

The sample size was determined based on a pilot study with 15 patients. The parameters used in the calculation were: significance level of 5%, mean of the sample of the case group of 165.3 *N* (SD 33.8 *N*), mean of the CT group sample of 193.3 *N* (SD 41.8 *N*), with 90% test power and 1:1 sample ratio. Thus, a sample size of 39 patients was established in each group. The program used for the calculation was BioEstat 5.0 (Instituto de Desenvolvimento Sustentável Mamirauá, Tefé, AM, Brazil).

The participants were recruited among the patients in attendance at the dental clinics of the undergraduate course in Dentistry of the FAESA, located in Vitoria, Espírito Santo, Brazil. The duration of the study was 4 months, between February and May, and was carried out in 2022.

In the CS group ($n = 39$), the patients were selected by means of a clinical examination performed by one previously trained operator. These patients presented NCCL located in the premolar and lower or mandibular teeth, this diagnosis was based on the clinical characteristics described by Consolaro and Consolaro in 2006 and Hayashi et al.[10,23] According to the authors, lesions were located at the wedge-shaped cervical region and may present grooves resulting from the loss of enamel from the fractures, which can be diagnosed visually or with the aid of a very fine exploratory probe.

The inclusion criteria for this study consisted of American Society of Anesthesiologists (ASA) I patients with at least 28 teeth not considering the presence of third molars, that didn't report any tooth pain, periodontal disease, and temporomandibular disorder. The exclusion criteria consisted of patients aged less than 20 years or older than 59 years, report of hallucinogenic drug use, the use of drugs associated with xerostomia, and patients that reported a history of anorexia bulimia and gastroesophageal reflux disease.

Table 1: Bruxism assessment questionnaire

Has anyone ever heard your teeth grinding at night?
Do you feel your joint fatigued or painful when you wake up?
Do you feel your teeth or gums sore when you wake up?
Do you have headaches when you wake up in the morning?
Have you found yourself gnashing your teeth during the day?
Have you found yourself clenching your teeth during the day?

Source: Pintado et al., 1997

Fig. 1: FlexiForce device connected to the computer via USB cable

Additional exclusion criteria included patients with current or previous orthodontic appliances, high alcohol consumption, smokers, and a history of bruxism. The latter was assessed using the questionnaire proposed by Pintado et al.[24] in 1997, as shown in Table 1.

If the patient responded positively to at least two questions in the questionnaire, they were considered ineligible to participate in the study. After assessing the location and characteristics of the NCCL, the patient responded to a semi-structured questionnaire with questions about oral hygiene habits and deleterious habits such as biting objects (Appendix A). For the selection of the CT group ($n = 39$) patients, all the exclusion criteria determined for the case group were maintained, differentiating only that for the CT group patients did not present any cervical lesions.

Assessment of Axial Occlusal Force

The axial occlusal strength of both groups was measured using a strain gauge sensor of the FlexiForce type (Tekscan, South Boston, Massachusetts, United States of America) (Fig. 1), which consists of a flexible ultra-thin circuit with a thickness of 0.208 mm. In this research, the medium intensity sensor (B201M, Tekscan, South Boston, Massachusetts, United States of America) was used; with sensitivity from 0 to 667 *N*. The active sensing area is a circle with a diameter of 0.375 cm, located at the end of the sensor (Fig. 2). The sensors are constructed of two layers of substrate, with a polyester film.

The measurements of the bite force were always performed in the morning between the hours of 10:00 and 11:00. For standardization, each measurement was performed with the patient sitting in the dental operatory, with the device coated with plastic for biosafety CT and supported by the opposing teeth (Fig. 3). The patient was asked to perform the greatest clamping force possible for 2 seconds.[25,26]

Four measurements were performed for each patient, on both sides of the arch, in the sequence: 14, 16, 24, and 26, allowing for a one-minute interval of rest for the patient between each region. The sensor was calibrated for unit of measurement in Newtons

Fig. 2: Circular measurement sensor with 0.375 cm diameter

Fig. 3: Measurement in the left first molar region

(N). All methods were performed in accordance with the relevant guidelines and regulations.

Statistical Analysis

The descriptive analysis was performed by means of absolute and relative frequencies, measures of central tendency, and dispersion. The comparison of bite force between the group of patients with NCCLs CS and without NCCLs CT was analyzed with a student's *t*-test for independent samples. The logistic regression was used to verify if any factor had an influence on the outcome. The likelihood ratio (OR) was also analyzed in the present study. The statistical software, SPSS Statistics version 21 (Armonk, New York, United States of America), was used to perform the statistical analysis.

Results

Tables 2 and 3 describe the variables assessed in this study. Females were 80.8% of the total sample. The most observed type of brushing was horizontal (46.2%). Most patients (61.5%) brush their teeth three times a day. The type of toothpaste with abrasive particles was observed in 30.8% of the patients, 62.8% of patients reported the use of a mouthwash and from those, 52.0% reported daily use. Of the total sample, 32.0% had some deleterious habit, and 67.9% used brushes with soft bristle consistency. There was no statistically significant difference ($p = 0.188$) in age an when comparing the participants of the CT group (mean = 31.2 years; SD ± 11.0 years) in relation to the case group (mean = 28.2 years,

Table 2: Gender and clinical profile of patients with and without NCCLs

	Control		*Case*		*Total*	
	n	*%*	*n*	*%*	*n*	*%*
Gender						
Male	12	30.8	3	7.7	15	19.2
Female	27	69.2	36	92.3	63	80.8
Brushing technique						
Horizontal	15	38.5	21	53.8	36	46.2
Vertical	12	30.8	8	20.5	20	25.6
Vibratory	8	20.5	9	23.1	17	21.8
Charter technique	4	10.2	1	2.6	5	6.4
Frequency of brushing per day						
2 times	2	5.1	0	0.0	2	2.6
3 times	23	59.0	25	64.1	48	61.5
More than 3 times	14	35.9	14	35.9	28	35.9
Type of toothpaste						
With abrasive	16	41.0	8	20.5	24	30.8
Nonabrasive	23	59.0	31	79.5	54	69.2
Do you use mouthwash?						
Yes	27	69.2	22	56.4	49	62.8
No	12	30.8	17	43.6	29	37.2
If so, how often?						
Daily	15	53.6	11	50.0	26	52.0
weekly	13	46.4	11	50.0	24	48.0
Do you have any harmful habits (such as biting objects)?						
Yes	15	38.5	10	25.7	25	32.1
No	23	59.0	27	69.2	50	64.1
Don't know	1	2.5	2	5.1	3	3.8
What consistency of the bristles of your toothbrush?						
Soft	24	61.6	29	74.4	53	67.9
Average (medium)	13	33.3	10	25.6	23	29.5
Hard	2	5.1	0	0.0	2	2.6

Table 3: Age (years) and bite force (*N*) results

	Minimum	*Maximum*	*Average*	*Standard deviation*	*p-value**
Age					
Case	20	59	28.2	8.8	0.188
Control	20	57	31.2	11.0	
First right upper premolar					
Case	99.0	230.3	152.6	33.3	0.724
Control	90.0	233.8	155.6	41.0	
First upper right molar					
Case	103.5	250.1	167.2	33.0	0.790
Control	103.7	256.8	169.6	44.9	
First left upper premolar					
Case	85.0	220.7	153.1	33.2	0.964
Control	100.2	225.5	152.7	30.5	

Table 4: Comparison of the means of bite forces (*N*) in the sites evaluated between the two genders

Group	*Tooth*	*Gender*	*Average*	*Standard deviation*	*p-value**
Patients with cervical lesion	Maxillary right first premolar	Male	183.83	28.78	0.091
		Female	150.02	32.61	
	Maxillary right first molar	Male	192.17	29.66	0.176
		Female	165.12	32.82	
	Maxillary left first premolar	Male	185.43	15.85	0.079
		Female	150.38	32.93	
	Maxillary left first molar	Male	209.90	17.91	0.104
		Female	177.82	32.68	
	Total average strength	Male	192.83	18.10	0.069
		Female	160.83	28.90	
Control	Maxillary right first premolar	Male	184.42	35.33	**0.002**
		Female	142.81	37.04	
	Maxillary right first molar	Male	196.68	48.52	**0.010**
		Female	157.53	38.21	
	Maxillary left first premolar	Male	165.42	28.10	0.084
		Female	147.12	30.33	
	Maxillary left first molar	Male	188.85	42.17	**0.020**
		Female	159.54	30.97	
	Total average strength	Male	183.84	34.45	**0.006**
		Female	151.75	30.02	
Total	Maxillary right first premolar	Male	184.30	33.15	<**0.001**
		Female	146.93	34.48	
	Maxillary right first molar	Male	195.78	44.49	**0.002**
		Female	161.87	35.14	
	Maxillary left first premolar	Male	169.42	26.93	**0.024**
		Female	148.98	31.63	
	Maxillary left first molar	Male	193.06	38.97	**0.021**
		Female	169.98	32.99	
	Total average strength	Male	185.64	31.51	**0.001**
		Female	156.94	29.49	

SD ± 8.8 years). When comparing the bite force between the CS and CT groups, no statistically significant difference was observed between them either when the measurement was conducted in the first right upper premolar ($p = 0.724$), in the upper right first molar ($p = 0.790$), in the left upper first molar ($p = 0.964$) or in the left first molar ($p = 0.142$).

Table 4 shows the bite force load in premolars, molars, or overall, and did not present any statistically significant difference between men and women in the CS. In the CT, bite force was significantly higher in males, except for the first left upper premolar, where there was no significant difference in bite force between males and females. If CT and CS patients were considered jointly, for all evaluated teeth, bite strength was significantly higher among men. There was no difference in the means of the bite forces between individuals of the CS and CT groups. Likewise, no significant difference was found when comparing males and females for bite force (Table 5).

Logistic regression was used to verify the association between the factors (questionnaire questions) and the outcome (patients with NCCLs). The regression showed statistical significance for sex ($p = 0.020$), with the female having increased chances of NCCLs by 6.1 times compared to men (Table 6).

Table 5: Comparison between the means of bite forces (N) between male and female and case and CT groups

Gender	*Group*	*Average*	*Standard deviation*	*p-value**
Male	Case	192.83	18.10	0.675
	Control	183.84	34.45	
Female	Case	160.83	28.90	0.229
	Control	151.75	30.02	
Total average	Case	163.29	29.35	0.818
	Control	161.62	34.43	

*Student's *t*-test for independent samples

Therefore, the occlusal force, brushing technique, and deleterious habits did not show a statistical difference between the CS and CT groups, however, the females had a higher risk for the development of NCCLs when compared to the males.

Table 6: Association between the factors and the outcome

			95% confidence interval for Odds Ratio (OR)	
Carriers of non-carious cervical lesions	*p-value*	*OR*	*Inferior limit*	*Upper limit*
Age	0.398	0.975	0.918	1.034
Gender				
Female	0.020	6.082	1.332	27.765
Brushing technique				
Horizontal	0.217	4.954	0.390	62.894
Vertical	0.658	1.813	0.130	25.294
Vibratory	0.289	4.130	0.300	56.769
Frequency of brushing per day				
2 times	0.999	0.000	0.000	
3 times	0.633	0.748	0.227	2.465
Type of toothpaste				
With abrasive	0.125	0.405	0.128	1.284
Do you use mouthwash?				
Yes	0.515	0.695	0.232	2.079
If so, how often?				
Daily	0.802	0.867	0.283	2.651
Do you have any harmful habits? (such as biting objects)				
Yes	0.754	0.639	0.039	10.573
No	0.937	0.894	0.056	14.294
What is the consistency of the bristles of your toothbrush?				
Soft	–	1	–	–
Average	0.964	1.030	0.287	3.690
Hard	0.999	0.000	0.000	

Discussion

In the literature, there is a lack of consensus regarding the role of occlusal forces in the etiology of NCCLs. Among the main hypotheses that may contribute to the origin of these lesions are occlusal forces, malocclusion, horizontal forces, abrasion, and erosion. Therefore, the purpose of this study was to investigate the association between the presence of NCCLs with occlusal force and other potential risk factors such as sex, brushing, age, and deleterious habits.

In this study, the selection of patients was based on several factors that included age and number of teeth. Additionally, it was decided to include participants from 20 to 59 years of age since according to Helkimo et al.[27] in 1977 for this age group, the maximum bite force remains constant, while the normal aging process past this age is known to cause loss of muscle strength and therefore yield lower occlusal forces. Additionally, patients also had at least 28 teeth in the dental arch to standardize the sample and maintain maximum bite force.[28–30]

An important exclusion criterion was any pain reported by the patient that originated from the periodontium since according to Alkan et al.[31] in 2006, patients with healthy support tissues show significantly greater bite force compared to patients with compromised periodontium.[32] Furthermore, patients with temporomandibular joint pain or pain at the masticatory muscles were ineligible because according to Pereira-Cenci et al.[33] in 2007, the overall bite force of patients with any temporomandibular disorder is significantly lower. Also, the presence of pain or discomfort could limit the execution of the maximum bite force.[33–36] Finally, individuals diagnosed with bruxism were also excluded from the study, according to some authors.[37–39]

To measure force, the medium intensity sensor was used because it has a wide range (0 to 667 N), with a diameter of 0.37 cm, which allows precision when placing intraorally, and a thickness of 0.208 mm thus allowing the complete closing of both arches during the measurement of the patient's maximum bite force. The most modern system for measuring maximum bite force is based on the action of the strain gauge's electrical resistance. This methodology can also be found in other studies.[35,40–45]

Based on the results of the present study, there was no association between the presence of NCCLs and the mean occlusal force measured at the first right and left premolars and molars. In a study by Wood et al.[12] in 2009 the authors evaluated the occlusal force of patients who had NCCLs in two teeth, in one of these teeth the occlusal load was reduced by occlusal adjustments during excursive movements, and they also did not find a relationship between occlusal load and the progression or existence of NCCLs.[12,46]

On the other hand, the association between occlusal load and the initiation and progression of NCCLs has been mentioned on several occasions in the literature.[47] Munari et al.[9] in 2015 stated that the higher the strong concentration in the cervical area of the enamel the greater the probability of fracture.[6] Sawlani et al.[48] in 2016, in a 5-year prospective clinical trial, tried to measure the

relationship between NCCLs and various etiologic factors. It was concluded that the progression of NCCLs was related to occlusal load and not correlated to other factors such as a heavily acidic diet, toothbrushing techniques, and adverse oral habits.[46,49–50]

In the present study, when comparing the bite force between men and women, it was observed that in case and CT groups the mean values of bite force were higher for males. These findings are in accordance with several studies, where a higher bite force was also found in men.[45,51–53] Bonakdarchian et al.[45] evaluated the mean maximum bite force in adults with normal occlusion, in which they observed that men had significantly higher bite force than women, the authors justify that this is probably because in men the muscle mass and size are generally higher than in women.

This result was also found in patients with full natural dentition, traditional complete dentures, overdentures, and edentulous patients. Manzon et al.[51] identified that bite force is higher in males than females, regardless of the teeth presence or absence. Koç et al.[52] evaluated the mean maximum bite force in individuals with normal occlusion, and examined the effect of gender on it, in which men had statistically higher bite force values than women, the authors identified that this fact was due mostly to the higher muscle potential of men compared to women. Furthermore, Calderón et al.[53] analyzed the influence of gender and bruxism on the maximum bite force, in which, regardless of the presence of bruxism, the mean maximum bite force was statistically higher for males (587.2 N) when compared to females (424.9 N) (<0.05).

However, Linderholm H et al.,[54] evaluated the isometric bite force in children and its relation to body build and muscle force, where no difference was found between the bite force of boys and girls. This study agrees with Helkimo E.[55] in which they observed the bite force in patients with functional disturbances of the masticatory system, and no statistical difference was found between the bite force compared to both genders, these results can be due to an inadequate gender distribution or small sample size.

Regarding the NCCLs, Table 5 shows did not show a statistical difference between females and males having NCCLs. Sawlani et al.[48] in 2016 and de Araújo et al.[20] in 2022, did not observe a statistically significant difference between men and women in the prevalence of NCCLs. Although it was determined by Shinogaya et al.[26] in 2001, that men had a greater area of contact, bite force, and arch size (both in width and height), which may generate a higher clamping force.[56–57] Patients included by these authors presented neutral occlusion or minimal malocclusion and had no restoration covering the occlusal surface of the teeth evaluated.

Patients included in the present study were interrogated about their use of mouthwash, brushing habits such as frequency, hardness of bristles, type of toothpaste, and brushing technique. A significant association between the mentioned factors and NCCLs was not found. After NCCLs onset, other factors may influence the progression of the lesion, including erosion. It has been pointed out in the literature, that not only occlusion is related to NCCLs, but also chemical agents could be related to the etiology of erosion and physical factors such as abrasion.[14–15]

In the literature, Senna et al.[14] in 2012, it has been a focused to associate occlusion and NCCLs, wherein this review of the type of occlusion was not considered, whereas, in the present study, a physiological (non-parafunctional) occlusion was a main criterion for the inclusion criteria. Studies such as Koç et al.[53] in 2011 and Turkistani et al.[58] in 2020 found no relationship between bite force and type of functional occlusion. In addition, Lee and Eakle in 1984 stated that the type of occlusion, when parafunctional, generates lateral forces yielding compression and traction loads larger than what natural dentition can withstand, thus suggesting that physiological occlusion is not a risk factor for NCCLs.[7]

In this study there was no association between bite force loads and NCCLs, therefore a prospective study is suggested since this case-CT study cannot establish the cause-and-effect relationship between occlusal force and NCCLs. This is because occlusal strength may be the cause and/or consequence of NCCLs. Additionally, it would be noteworthy to evaluate additional factors such as erosion, abrasion, horizontal forces, and malocclusion and their relationship with the etiology and progression of NCCLs.

Conclusion

Based on the results of this clinical study, it was concluded that no association was found between the presence of NCCLs with occlusal force and other factors such as brushing technique and deleterious habits. However, it was observed that women had a higher risk of developing NCCLs compared to men.

Orcid

Rafael Dario Werneck https://orcid.org/0000-0002-4862-1354
Daher Antonio Queiroz https://orcid.org/0000-0002-1477-8599
Mariana Itaborai Moreira Freitas https://orcid.org/0000-0001-7729-8536
Diana Leyva Del Rio https://orcid.org/0000-0001-7584-4302
Cecilia Pedroso Turssi https://orcid.org/0000-0002-0078-9895

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Appendix A

Semi-structured questionnaire addressing habits of oral hygiene and deleteric habits as bite objects

A	Full name:	
B	Date:	
C	Birth date:	
D	Age (years)	( )
E	Gender:	
	1) Male 2) Female	( )
F	Address:	
G	City (State):	
H	Zip code:	
I	Home phone	
J	Cell phone	
K	Type of brush	
	1) Horizontal 2) Vertical 3) Vibratory 4) Charters 5) Bass	( )
L	Brushing Frequency per Day	
	1) 1 time 2) 2 times 3) 3 times 4) More than 3 times	( )
M	Consider your abrasive dentifrice	( )
	1) Yes 2) No	
N	Do you use mouthwash?	
	1) Yes 2) No	( )
P	If yes, what frequency?	
	1) Daily 2) Weekly	( )
Q	You have some deleterious habit (such as biting a pen cap or pencil)	
	1) Yes 2) No 3) DO NOT KNOW	( )
R	What consistency of your tooth brushes?	
	1) Soft 2) Average 3) Hard	( )