THE PREVALENCE OF NON-CARIOUS CERVICAL LESIONS IN MODERN AND ANCIENT AMERICAN SKULLS: LACK OF EVIDENCE FOR AN OCCLUSAL ETIOLOGY

By

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A THESIS PRESENTED TO THE GRADUATE SCHOOL
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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Abstract of Thesis Presented to the Graduate School
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The abfraction lesion is a relatively recent classification that supposedly is derived from malocclusion. However, many studies have suggested that abfraction lesions are in fact non-carious cervical lesions with a multi-factorial etiology. To date, no research has compared the prevalence of abfraction lesions in populations with and without access to toothbrushes. The purpose of this study was to examine the prevalence of non-carious cervical lesions in modern and ancient populations.

One-hundred-and-ninety-eight modern and 100 ancient American human skulls were examined for the presence of non-carious cervical lesions (NCCLs). The skull specimens were a part of the collection located at the National Museum of Natural History in Washington, D.C. The modern skulls dated back to the early to mid-twentieth century, while the ancient skulls were derived from two Native American Indian tribes from the eleventh and seventeenth centuries. The age, gender, race, and Angle's classification were recorded from each skull. Teeth in each skull were examined for the presence and dimension of NCCL, extent of occlusal wear, width of the periodontal ligament space, distance from the cervical border of the NCCL to the alveolar crest, presence or absence of a lingual NCCL, presence of a dental restoration, and presence of class V caries.

A total of 6,077 teeth were examined. No NCCLs were observed in the ancient skulls, nor were any lingual NCCLs seen in any of the skulls. Fifty-seven NCCLs were documented in 9.6% of the modern skulls, with a prevalence rate of 1.62% of NCCLs in the 3,524 teeth in the modern skulls. A chi-square test of association showed no relationship between extent of occlusal wear and the presence of NCCLs ($p=0.5780$), and no significance of race, gender, or pdl width and NCCLs. The angle's class II relationship was significantly associated with the presence of NCCLs ($p<0.0001$).

The finding that only modern skulls displayed NCCLs may be explained by toothbrush use and/or acid erosion. Conversely, the ancient skulls may have incorporated more abrasive substances into their diet and may not have had an average lifespan long enough to develop NCCLs. Regardless, both collections included many skulls, which showed heavy occlusal wear but failed to show any NCCLs.

From the results of this study it can be suggested that occlusal wear, likely derived from heavy occlusal forces, is not associated with the presence of non-carious cervical lesions. So-called abfraction lesions likely have a multifactorial etiology, rather than an origin in occlusal stress.

CHAPTER 1
INTRODUCTION

Non-carious cervical lesions (NCCLs) have become a controversial clinical phenomenon in recent decades. These wedge-shaped concavities are predominantly observed on the bucco-cervical region of teeth (Imfeld 1996, Piotrowski et al. 2001, Boston et al. 1999), and have in recent years been termed "abfraction" lesions because of certain evidence suggesting an origin in malocclusion.

Since then, several articles have argued for and against the abfraction classification. Recent publications have disputed the existence of a true abfraction lesion, citing that the lesions may be either erosive, abrasive, or multifactorial in nature (Litonjua et al. 2003a, 2003b, Piotrowski et al. 2001).

A lack of understanding of the various forms of noncarious lesions by the dental community has lead to misdiagnosis of lesions as being abfractions (Levitch 1994, Bader 1993). Because not all clinicians have agreed on their origin, researchers have introduced the term "non-carious cervical lesion" and/or "abfractionlike lesion" so as not to presume the etiology of the lesions (Grippo 1991, Litonjua et al. 2003b, Piotrowski et al. 2001).

Non-carious lesions involve the irreversible loss of enamel or dentin, and may be due to any of the following causes: attrition, erosion, resorption, abrasion, and abfraction/malocclusion.

Attrition is the loss of tooth structure due to tooth-to-tooth forces with no intervening foreign objects. Bruxism is a prime example of wear from attrition.

Erosion depicts the gradual etching away of tooth structure due to electrolytic or chemical processes. Typically the pathologic loss of enamel and dentin is chronic, localized, painless, and does not involve bacterial infiltration (Imfeld 1996). Clinically, erosion lesions are confined to the buccal and occlusal surfaces of the mandibular premolars and molars (Imfeld 1996).

External root resorption is the biological degradation of structures previously produced by the body (i.e. host-mediated destruction). Resorption may be due to cementoclastic, dentinoclastistic and/or ameloclastic activity (Imfeld 1996).

Abrasion is the wearing away of tooth structure due to abnormal mechanical processes involving foreign objects, such as toothbrush abrasion (Imfeld 1996, Owens and Gallien 1995, Piotrowski et al. 2001). Toothbrush abrasion may result from incorrect brushing technique, frequency of brushing, time of brushing, force applied during brushing, or even starting point of brushing on the arch (Addy 2000). The hardness of the bristles and abrasiveness of the toothpaste used also make an impact on the extent of these lesions.

Abfraction is derived from the Latin verb *frangere* ("to break"), and defines a wedge-shaped defect at or near the cemento-enamel junction (CEJ) of the tooth (Imfeld 1996, Piotrowski et al. 2001, Boston et al. 1999, Grippo 1991). The hypothesis that described a new sub-class of cervical lesion that originated from tooth flexure from occlusal loading was first introduced by Lee and Eakle in 1984. Grippo was the first to define the term "abfraction" as a new classification of hard-tissue lesions in 1991 (Grippo 1991).

Abfractions are hypothesized to result from eccentric occlusal forces which “flex” the tooth (Grippo 1991, 1992, Adda 2000). Their rationale for the concept of this lesion is as follows: malocclusion due to parafunctional prematurities and hyper occlusion due to bruxism often leads to eccentric occlusal forces, which in turn produce tensile, compressive, and sheering stresses (Owens & Gallien 1992, Rees et al. 2003). These stresses are focused at the CEJ, and microfractures are formed in the enamel and dentin. Over time these microfractures propagate perpendicular to the long axis of the tooth until enamel and dentin break away (Grippo 1992).

The enamel breaks off more easily than the dentin because of its brittleness. Enamel is a very hard substance composed of inorganic crystallites, which can only be subjected to a relatively small amount of deformation before fracturing. Dentin on the other hand has a greater organic component to its structure, is more resistant to deformation, and consequently is much more resilient to the tensile and compressive forces which can cause fracture (Owens & Gallien 1992).

Canines also play a protective role in that they reduce the amount of force distributed to the posterior teeth during excursive movements. Naturally, occlusal schemes where the canines are not involved in guidance offer no protection of the posterior teeth in lateroscursive movements (Owens & Gallien 1992). Group function occlusal schemes would involve the premolars and canines, which coincidentally are the most common teeth demonstrating non-carious cervical lesions. Clinical research has demonstrated that the group function occlusal scheme is more significantly associated with abfraction lesions than canine guidance (Miller et al. 2003).

Miller and colleagues examined 61 patients displaying 309 NCCLs for excessive brushing and occlusal interferences. They also evaluated each patient's occlusal scheme and the presence of plaque, calculus, periodontitis, wear facets, and mobility. Group function was associated with almost three-quarters of the NCCLs, and wear facets were associated with 94.5% of the NCCLs. In addition, balancing side prematurities were associated with approximately 20% of the NCCLs. Interestingly, visible plaque and calculus were found on the buccal surfaces of over 40% of the NCCLs, and 32.5% of the NCCLs exhibited subgingival limits without signs of marginal gingival ulceration. His study supported the notion of the abfraction lesion, which was derived from occlusal disturbances as opposed to excessive toothbrushing (Miller et al.2003).

Computer simulations have also been developed to determine if occlusal forces could cause non-carious cervical lesions. Finite stress analysis studies using computer models have demonstrated that malocclusion could create microfractures in the enamel at the CEJ (Rees 1998, Rees et al. 2003, Lee et al. 2002). These studies have shown that that different teeth in the arch accommodate varying amounts of stress prior to reaching their fracture point (Rees 1998, Rees et al. 2003, Lee et al. 2002). The incisor, canine, and premolar have all been shown to manifest non-carious cervical lesions when heavy excursive forces were directed onto the teeth; however, in all of the finite stress studies, each tooth was evaluated individually, which failed to account for the compensating effect of the other teeth in the arches.

A review of studies conducted by Lyons in 2001 concluded that non-carious cervical lesions were multifactorial in nature, but conceded that occlusal loading was the primary initiating factor (Lyons 2001).

While the much of the research on abfraction lesions has implicated malocclusion as the primary etiology (Owens & Gallien 1995, Lee et al. 2002, Grippo 1992, Rees 1998, Rees et al. 2003), other mechanisms have been described for the formation of abfractions (Boston et al. 1999, McCubbin 2002, Piotrowski et al. 2001).

Piotrowski in 2001 examined 103 teeth with NCCLs and 103 control teeth within a population of U.S. veterans, and recorded each participant's toothbrush habits, the presence and location of NCCLs, the presence of excursive interferences, plaque, and occlusal wear on the teeth with lesions. Teeth exhibiting NCCLs had significantly more surfaces with plaque than the control teeth; however, there were no significant differences in wear-facet dimensions or in occlusal discrepancies between the NCCL and control teeth. The statistical analysis suggested that toothbrush abrasion could be a strong contributing factor, in that at least 75% of the participants reported using a firm-bristled toothbrush and displayed improper toothbrushing technique (Pietrowski et al. 2001).

Litonjua in his review article pointed out that many of the studies advocating the abfraction lesion were based on engineering and computer models that neglected the influence of the periodontal attachment apparatus in absorbing the forces from occlusion. He further noted that many of the clinical models that failed to investigate the participants history of toothbrush abrasion and current toothbrushing technique He concluded that the occlusal etiology for the formation of the abfraction lesion was not solidly founded, and that abfraction lesions are likely NCCLs manifested from multiple causes (Litonjua et al. 2003b).

Boston et al. in their case study implicated a combination of abrasion, erosion, abfraction, linear enamel hypoplasia as the etiology of the non-carious lesions that he observed (Boston et al. 1999). Although the patient exhibited numerous periodontally involved teeth with wedge-shaped lesions, .a histologic examination after their extraction lacked sufficient evidence to support malocclusion as the sole factor in the lesions formation.

Kahn et al. in 1999 examined 122 cervical lesions in 250 patients with tooth wear. Using epoxy resin replicas of their dentitions and scanning electron microscopy, associations of occlusal attrition, erosion, and occlusal wear with cervical lesions were recorded. They concluded that acid demineralization of teeth causes occlusal erosion and attrition, and causes shallow and wedge-shaped cervical lesions. Moreover, Kahn concluded that non-carious lesions have a multifactorial etiology in which erosion and salivary protection play central roles (Kahn et al. 1999).

Indeed "abfraction", abrasive, and erosive lesions do have similarities which could lead to misdiagnosis. All three lesions can be located on the buccal surfaces of the canines and premolars. However, the effects of erosion can be observed in many other places in the dentition, namely the occlusal surfaces of teeth (Imfeld 1996). In addition, "abfraction" lesions have been described as displaying sharp margins along their borders, while most erosion and abrasion lesions exhibit a rounder margin (Piotrowski et al. 2001).

This difference in appearance has been explained by the rationale that the surface of erosive lesions are hypomineralized and consequently are less resistant to abrasive forces from toothbrushing and eating (Imfeld 1996, Lambrechts et al. 1996). The acid degradation, in turn, makes the tooth more susceptible to toothbrush abrasion and/or abfraction lesions (McCubbin 2002).

Abrasion lesions from overzealous toothbrushing have been well established in periodontal literature, and their clinical features are very similar to abfraction lesions (Addy et al. 2003, Litonjua et al. 2003a, Gorman 1967). Like “abfractions”, these lesions are located on the buccal tooth surface along the cemento-enamel junction, are non-carious in nature, and are found in similar teeth in the arch (Addy et al. 2003, Litonjua et al. 2003a).

The distinction between the diagnoses of abfraction versus erosive and abrasive lesions is important because the treatment of the phenomena are different.

The primary treatment of an abfraction lesion involves an occlusal adjustment and possible restoration of the tooth (Imfeld 1996, Grippo 1992). Restorative therapy is recommended particularly if the tooth is susceptible to a fracture or pulp exposure in the near future. Glass ionomers are a popular choice because of the fluoride-releasing capacity; however, microfilled composite resin with a low modulus of elasticity is another viable option (Lambrechts et al. 1996). The low modulus of elasticity allows the restoration to absorb occlusal forces without transferring them to the surrounding tooth structure. According to one author, the most beneficial treatment for abfraction lesions is an occlusal adjustment and nightguard fabrication to eliminate or at least reduce the suspected occlusal etiology (Lambrechts et al. 1996).

The treatment of abrasion lesion, on the other hand, centers on the modification of oral hygiene techniques and may involve the placement of a gingival graft (Litonjua et al. 2003a, Sullivan and Atkins 1968). Recommended treatment of erosive lesions includes changes in dietary or behavior patterns, application of desensitization products, and intensive fluoride therapy (Lambrechts et al. 1996, Owens & Gallien 1995).

A majority of the current research into non-carious cervical lesions has been conducted on human subjects, which is beneficial because an inquiry into the patients' dietary and hygiene habits can be obtained, and parafunctional habits can also be accurately measured and reproduced.

Unfortunately, current studies have failed to include a patient population which does not incorporate toothbrush use. Toothbrush use is a significant factor because it can lead to non-carious cervical lesions, and possibly contribute to the formation of non-carious cervical lesions.

In order to best eliminate the impact of oral hygiene factors on the formation on abfraction lesions, a modern group of subjects with access to toothbrushes and dentifrices was compared to a pre-modern group with no access to toothbrushes. In this regard, the suggested primary etiologic factor of "abfraction" lesions – occlusion – can be more fairly isolated.

In this study, two groups of American skulls were examined for the presence and extent of non-carious cervical lesions and occlusal wear. However, only one of the two groups had access to modern oral hygiene devices. Theoretically by eliminating toothbrush use, any non-carious cervical lesions observed in the pre-modern skulls can be more confidently attributed to occlusal factors. Comparing the prevalence of non-carious cervical lesions in the two groups hopefully will increase the understanding of the non-carious cervical lesion and its etiology.

The purpose of this study was to document the prevalence of non-carious cervical lesions in modern and ancient American human skulls.

CHAPTER 2
METHODS AND MATERIALS

This study was conducted at the Natural Museum of Natural History in Washington D.C. Two hundred modern American human skulls from the early to mid-twentieth century and 100 ancient American Indian skulls from the eleventh and seventeenth century were evaluated. The modern skulls were a part of the Terry anatomic collection, which consisted of 1,760 skeletons consisted of persons who donated their bodies to science or were unclaimed after death. The ancient skulls in this investigation were excavated from American Indian burial mounds from Northern Illinois (11^{th} century) and from South Dakota (17^{th} century). The gender, race, and Angle's classification were recorded from each skull specimen. The age at the time of death was only collected from the modern skulls because the age was not available for the ancient skulls.

The following inclusion criteria were employed:

1. The estimated age of the individual at his/her time of death must have been at least 40 years old.
2. At least 10 teeth must have been intact.
3. Intact but fractured teeth were not included in the data collection.

A non-carious cervical lesion was defined as:

Any lesion located at the cemento-enamel junction of the tooth, which extended axially at least .5mm into the dentin without signs of previous dental caries.

The teeth still intact in the skulls were examined for the following:

1. Presence of a non-carious cervical lesion on the buccal and lingual tooth surfaces. The circumferential border of any lesions detected were classified as having either

sharp or round margins. The height, width, and depth was measured to the nearest half-millimeter using a UNC-15 probe.

2. Presence of caries. Lesions were considered carious if they displayed elliptical as opposed to wedge-shaped defects, were black in appearance, exhibited enamel undercuts, or were soft and “leathery” upon probing with a UNC-15 probe. The height, width, and depth was measured to the nearest half-millimeter using a UNC-15 probe.

3. Presence of restorations. Any artificially created restoration was recorded, including amalgam and gold foil restorations and crowns.

4. Distance from the cervical border of the lesion to the alveolar crest. The distance was measured to the nearest .5mm using a UNC-15 probe.

5. Extent of occlusal wear. The occlusal wear was visually classified according to a four-point scale:

   1 = very minimal to no occlusal wear

   2 = occlusal wear is confined to the enamel

   3 = occlusal wear extents into the dentin

   4 = occlusal wear extents into the dentin involving all cusps and the central fossa, thereby giving a “table top” appearance

6. Extent of pdl width. No radiographs were taken. The pdl width was measured using a UNC-15 probe and was classified according a three-point scale:

   1 = pdl width $< .5$mm

   2 = pdl width $\geq .5$mm and ≤ 1mm

   3 = pdl width > 1mm

The data was analyzed using descriptive statistical analysis (means, averages, etc.), chi-square tests, Mantel-Haenszel chi-square tests, and logistical regression analysis.

CHAPTER 3
RESULTS

Out of 300 specimens, 2 modern skulls were not included because of incomplete collection of data. A total of 6,077 teeth in 298 skulls were examined.

The distribution was as follows for the modern skulls: 59 White males, 57 Black males, 20 White females, 60 Black females, and 2 Asian males. The average age was 53 years old (range: 40-87 years, standard deviation: 11.3 years). 39 restorations and 50 class V carious lesions were observed. 101 class I, 34 class II, and 52 class III Angle malocclusions were observed.

Out of 3,524 teeth in the modern skulls, 57 NCCLs were observed with a prevalence of 1.62%. For the NCCLs, the average width was 4.01mm (range: 2-8mm, sd: 1.54mm), the average height was 1.92mm (range: 1-5mm, sd: 0.69mm), and the average depth was 0.73mm (range: 0.5-1.5mm, sd: 0.34mm). The average distance from the NCCL to the alveolar crest was 2.75mm (range: 2-6mm, sd: 1.15mm), and in 4 teeth (canines) the distance was not recorded because a buccal dehiscence exposed the roots almost to the apices. The average occlusal wear score was 2.49 (range: 1-4, sd: 0.57), and the average pdl score was 1.26 (range: 1-3, sd: 0.25). See Table 1.

Table 1: Measurements for the Non-Carious Cervical Lesions

Parameters	Average	Range	Standard Deviation
Width (mm)	4.01	2-8	1.54
Height (mm)	1.92	1-5	0.69
Depth (mm)	0.73	0.5-1.5	0.34
Distance to Crest (mm)	2.75	2-6	1.15

Of the 3,524 teeth in the modern skulls, 9.6% percent exhibited NCCLs. No lingual NCCLs were observed. The amount of NCCLs per skull ranged from 0 to 10, with the majority having only one lesion. The distribution of the lesions is shown in Table 2.

Table 2: Frequency of NCCLs per Skull

# of Skulls	# of NCCLs	Percentage
179	0	90.4
8	1	4.04
5	2	2.53
2	3	1.01
1	5	0.51
1	6	0.51
1	7	0.51
1	10	0.51

When each tooth type was taken into consideration, the data showed that the canines, premolars, and molars were the most susceptible to developing a NCCL. However, tooth type by itself was not a significant predictor of NCCL formation ($p=0.0429$). The distribution of NCCLs for each tooth is shown in Table 3.

Table 3: Frequency of NCCLs by Tooth Type

Tooth #	# of Teeth	# of NCCLs	Percentage
1	78	0	0
2	116	0	0
3	108	3	2.78
4	117	1	0.85
5	119	2	1.68
6	131	3	2.29
7	73	1	1.37
8	59	0	0
9	56	0	0
10	69	1	1.45
11	121	1	0.83
12	128	1	0.78
13	115	0	0
14	118	1	0.85
15	114	0	0
16	69	0	0

Table 3 contd.

Tooth #	# of Teeth	# of NCCLs	Percentage
17	92	0	0
18	114	1	0.88
19	94	1	1.06
20	140	1	0.71
21	163	5	3.07
22	161	4	2.48
23	135	3	2.22
24	135	1	0.74
25	121	0	0
26	136	0	0
27	150	4	2.67
28	168	8	4.76
29	136	3	2.21
30	99	4	4.04
31	133	3	2.26
32	81	0	0

When pairs of opposing teeth were analyzed, the teeth on the right side of the skull exhibited more NCCLs. Certain pairs of teeth were significantly associated with NCCLs. ($p=0.007$). Table 4 shows the trends in teeth pairing and NCCLs.

Table 4: Opposing pairs of Teeth and Frequency of NCCLs

Teeth Pair	# of Teeth	# of NCCLs	Percentage of NCCLs
1 & 32	159	0	0
2 & 31	249	3	1.2
3 & 30	207	7	3.38
4 & 29	253	4	1.58
5 & 28	287	10	3.48
6 & 27	284	7	2.49
7 & 26	209	1	0.48
8 & 25	180	0	0
9 & 24	191	1	0.52
10 & 23	204	4	1.96
11 & 22	282	5	1.77
12 & 21	291	6	2.06
13 & 20	255	1	0.39
14 & 19	212	2	0.94
15 & 18	228	1	0.44
16 & 17	161	0	0

For the ancient skulls the distribution was 26 Northern Illinois males, 24 Northern Illinois females, 25 South Dakota males, and 25 South Dakota females. The age of death of each specimen was not available. Four carious lesions were observed. Thirty-three class I, 6 class II, and 60 class III Angle's malocclusions were observed.

No NCCLs were present. The average occlusal wear score was 3.32 (range: 1-4, sd: 0.57), and the average pdl score was 1.28 (range: 1-3, sd: 0.25). See Table 5 and figure 1.

Table 5: Comparison of Non-Carious Cervical Lesions, Occlusal Wear Score, and PDL Score Between Modern and Ancient Skulls

Skulls	Parameters	Total #	Average (mm)	Range (mm)	SD (mm)
Modern	# of NCCLs	57			
	Occlusal Wear Score		2.49	1-4	1.26
	PDL Score		1.26	1-3	0.25
Ancient	# of NCCLs	0			
	Occlusal Wear Score		3.32	1-4	0.57
	PDL Score		1.28	1-3	0.25

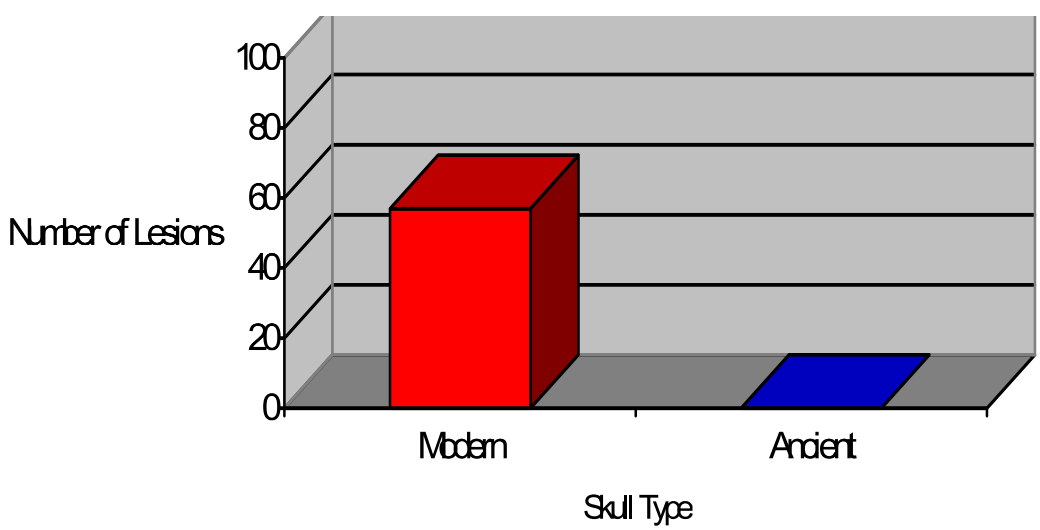

Figure 1. Number of NCCLs vs. Skull Type

The proceeding chi-square and statistical regression analyses are only for the modern skulls.

Of all of the teeth with no occlusal wear (OW score = 1), 4 (1.76%) had NCCLs. In teeth with moderate occlusal wear (OW score = 2), 26 (1.41%) had NCCLs. Of the teeth with severe occlusal wear (OW score = 3), 19 (1.63%) had NCCLs. Finally, 3 (0.72%) of the teeth with very severe occlusal wear (OW score = 4) had NCCLs. The association between occlusal wear and NCCL formation was not significant (p=0.4492). Table 6 and figure 2 visualize these findings.

Table 6: Percentage of Teeth with Non-Carious Cervical Lesions According to Occlusal Wear Score

Occlusal Wear Score	# of Teeth	# of NNCLs	% of Teeth w/ NCCL
1 (no wear)	227	4	1.76
2 (mild wear)	1840	26	1.41
3 (moderate wear)	1167	19	1.63
4 (severe wear)	414	3	0.72

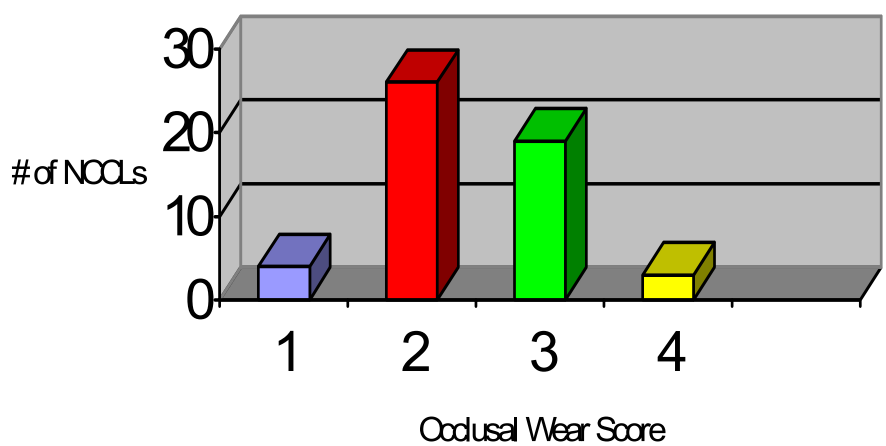

Figure 2. Number of NCCLs vs. Occlusal Wear Score

A Mantel-Haenszel chi-square test of association determined that no significant trend existed between increasing or decreasing occlusal wear scores and NCCL formation (p = 0.0243).

The effect of race was insignificant. Anglo-Americans and African-Americans exhibited approximately the same amount of teeth with NCCLs. Asian skulls had almost half as many NCCLs.The number of African-American teeth displaying NCCLs was 19 (0.83%); the number of Anglo-American teeth displaying NCCLs was 21 (1.61%); and the number of Asian-American teeth displaying NCCLs was 12 (28.57%). These findings are visualized in Figure 3.

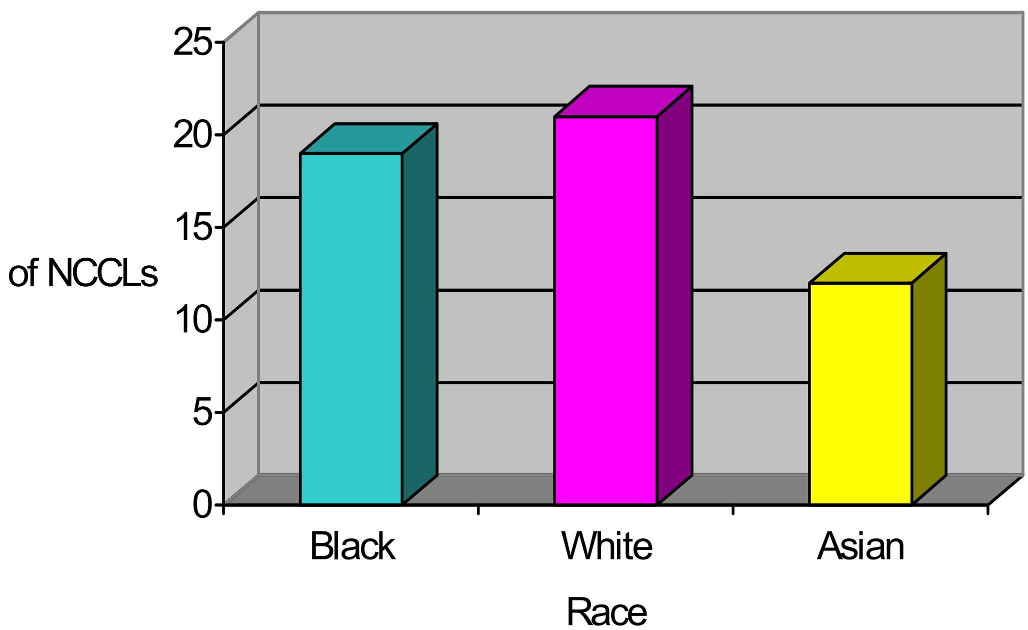

Figure 3. Number of NCCLs vs. Race

Skulls with Angle's class I occlusion had 10 (0.50%) of teeth with NCCLs; Thirty (5.12%) of the teeth in skulls with Angle's class II occlusion showed NCCLs; and 9 (0.97%) of the teeth in skulls with Angle's class III occlusion showed NCCLs. The Angle's class II occlusion was significantly related to the rate of NCCLs ($p < 0.0001$). See figure 4.

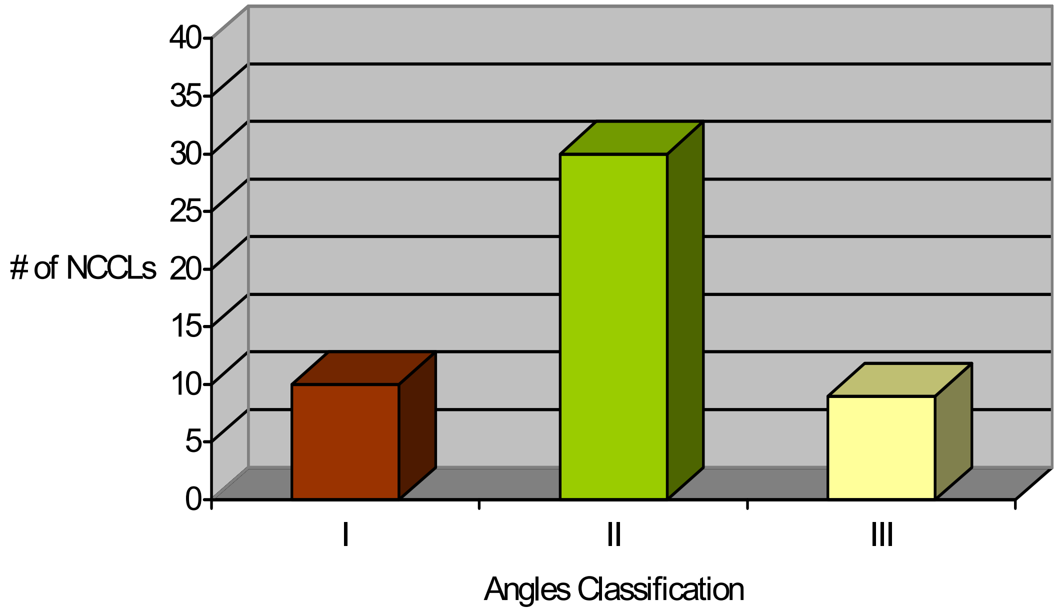

Figure 4. Number of NCCLs vs. Angle's Classification

When gender was taken into account, males and females exhibited similar number of teeth with NCCLs Twenty-seven (1.18%) of the males' teeth displayed NCCLs, while 25 (1.84%) of the females' teeth displayed NCCLs. This was not statistically significant ($p = .1045$). See figure 5.

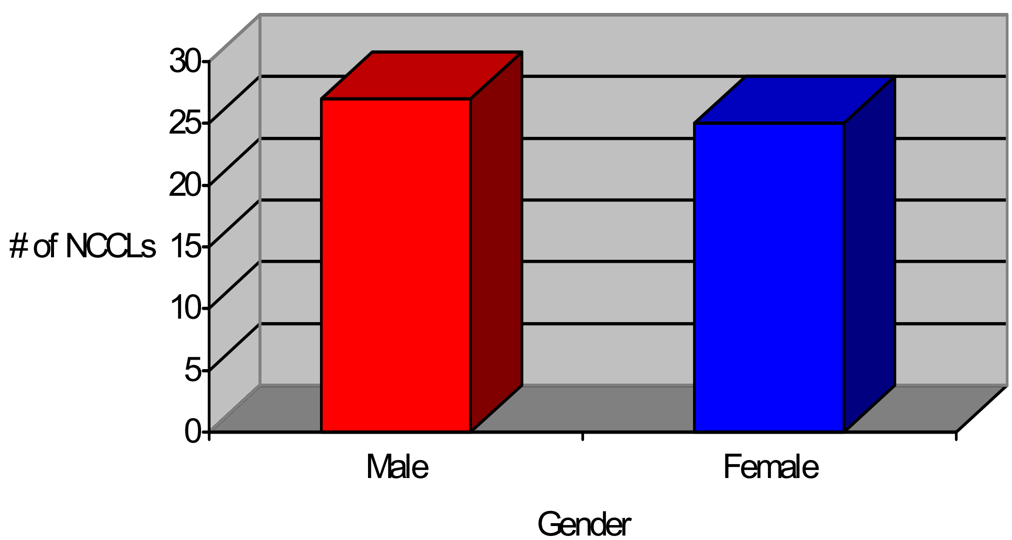

Figure 5. Number of NCCLs vs. Gender

CHAPTER 4
DISCUSSION

Most of the skulls did not have all of their teeth intact, and several teeth had fractured crowns. Teeth that were partially fractured were later excluded from the results. Many skulls had teeth which were glued into the socket, and some of the teeth were glued out of the plane of occlusion. Occasionally, the crania were sagitally split. In most of the cases however, the teeth in the two halves of the skull could be accurately articulated, thereby allowing the Angle's classification to be recorded. Because teeth that were glued into the sockets were not differentiated from teeth that were not glued, the pdl width was not extensively incorporated into the results and discussion.

Because previous studies focused primarily on only those teeth displaying non-carious lesions, the 1.62% prevalence of NCCLs in the modern skulls is without comparison. Out of 6,077 teeth, no lingual NCCLs were observed. There is no previous research citing lingual NCCLs, which implies that NCCLs occur only on the buccal surfaces of teeth or that lingual NCCLs are extremely rare.

Both modern and ancient skull collections demonstrated advanced occlusal wear; however, only the modern skulls displayed NCCLs. In addition, the average occlusal wear score for the modern skulls was *less* than the average occlusal wear score for the ancient skulls. Regardless, in both collections there were numerous teeth which exhibited heavy occlusal wear but failed to show any NCCLs. Perhaps the studies advocating the notion of the abfraction lesion are focusing too much on those teeth with lesions, and are not taking into consideration all of other teeth which display malocclusion without NCCL formation.

Why would only the modern skulls exhibit non-carious cervical lesions despite having a lower overall amount of occlusal wear? This discrepancy may be explained by unique factors found in each of the two populations.

The NCCLs in the modern skulls may have been facilitated by overzealous toothbrushing. Improper toothbrushing technique could form non-carious cervical lesions independent of the extent of occlusal wear.

On the other hand, the Native Americans may have developed advanced occlusal wear without necessarily exerting heavy occlusal forces. According to anthropologists, the diet of the Native Americans was largely meats, grains, and vegetables, which likely were not adequately cleansed of dirt and debris. Incorporating a more abrasive diet would have lead to an increased level of occlusal wear.

The advanced occlusal wear in the ancient skulls may also have been due to bruxism. Perhaps the Native American muscles of mastication may have been hypertrophied compared to modern Americans from eating less tender food. Or, Native Americans may have bruxed their teeth because of the greater stress level associated with survival. Many of the ancient skulls displayed full arch “table-top” occlusal wear. Usually, “table-top” occlusal wear in modern Americans is attributed to bruxism. If the Native Americans had an etiology of bruxism for their advanced occlusal wear, then they should have displayed abfraction lesions according to current dental concepts.

Perhaps the Native Americans would have developed non-carious cervical lesions, but they did not live long enough – on average – to manifest these lesions clinically. The main disadvantage of working with ancient skulls is the lack of demographic and cultural information that is helpful in formulating theories. Without the age at the time of death of each of the skull specimens, the age factor can only be speculative at best.

Based on the finding that only the modern American skulls displayed NCCLs, one could hypothesize that non-carious cervical lesions are a modern phenomenon. In other words, non-carious cervical lesions – including abfraction lesions - are a product of the modern lifestyle.

One obvious facet of the modern lifestyle is an increased awareness about personal oral hygiene. With the advent of the modern toothbrush and dentifrice, people were more likely to brush their teeth in order to remove plaque. However, improper toothbrushing technique has been known to create abrasive lesions at the buccal surfaces of the CEJs of teeth. Just as the current population displays a proportion of toothbrush abrasion, so would the mid-20th century population representing the skulls.

Another phenomenon of modern society is the mass availability and consumption of sugar into the diet. Compared to the ancient populations, modern society certainly has incorporated more food products with a higher sugar content on a regular basis. While too much sugar can lead to dental caries, a sugar consumption below the caries threshold could lead to hypomineralization of the enamel. The hypomineralized enamel would in turn be more susceptible to abrasion from toothbrushing or to the forces that lead to abfraction lesions. This theory however, is minimally supported by publications and would need more dedicated research to access its validity.

The more accepted notion is that occlusal factors are responsible for the non-carious cervical lesions exhibited in modern society. The question arises as to whether the ancient Native Americans had such different occlusion from modern Americans that NCCLs failed to form. There has been no research to suggest that occlusal patterns and forces have spontaneously increased in complexity in the last thousand years, so the idea that abnormal or excessive occlusal forces are unique to modern society is unfounded.

The x-factor in discussing occlusal schemes and abfraction lesions in this study is race. It is possible that the Anglo-Americans, the African-Americans, the Sino-Americans, and the Native Americans all had different dento-skeletal relationships from one another. As the results demonstrated, those modern skulls with an Angle's class II dental relationship where much more susceptible to forming NCCLs than either class I or class III. Moreover, the Anglo-Americans as an independent variable were significantly associated with the proclivity to form NCCLs. Compared to African-Americans and Sino-Americans, Anglo-Americans have a stronger genetic predisposition towards the class II phenotype because of their Northern European ancestry . Perhaps those of Northern European decent have a stronger susceptibility to forming non-carious cervical lesions.

Of course, a small proportion of the ancient skulls had an Angle's class II dental relationship and did not have any NCCLs. Although the Angle's relationship may play a part in abfraction susceptibility, the argument still circles back to occlusion because the Angle's classification ultimately affects the dental occlusion.

The periodontal ligament is a biologic structure which physiologically absorbs the forces from occlusion to an extent. In health, the periodontal ligament is approximately 20 microns wide. Widening of the periodontal ligament is thought to be derived from heavy occlusal forces. This study hoped to include the variations in the periodontal ligament width to help determine the extent of occlusal forces upon each tooth. Unfortunately, many of the teeth were glued back into their respective tooth sockets, so the parameter of periodontal ligament width was not included in the results of this study.

The results of the paper do not eliminate occlusal forces from contributing to the formation of non-carious cervical lesions. The correlation drawn can only describe an association and cannot assign causality. What the results of this research demonstrate however is that *factors* that lead to occlusal wear are probably not justified to create a specific subclass of non-carious cervical lesions, namely the abfraction lesion.

The next step for future research on this controversy would be to examine a live human population that has no access to toothbrushes or dental care. The participants would also be examined for maladaptive occlusal forces and occlusal prematurities. Then perhaps a cause-effect relationship relating to the formation of "abfraction" or other non-carious cervical lesions could be more confidently supported.

CHAPTER 5
CONCLUSIONS

6,077 teeth in 298 skulls (198 modern, 100 ancient) were examined for non-carious cervical lesions. Of the 3,524 modern teeth, 1.62% or 57 teeth exhibited NCCLs. None of the teeth in the ancient skulls demonstrated NCCLs. One-hundred percent of the NCCLs were located on the buccal surfaces, whereas 0% were found on the lingual surfaces. Occlusal wear was not significantly associated with the presence of NCCLs, nor was any trend of an increasing or decreasing amount of occlusal wear associated with the presence of NCCLs. Neither race nor gender were significantly associated with the presence of NCCLs. Finally, the Angle's class II relationship was shown to significantly associated with the presence of NCCLs.

Occlusal wear, derived from factors affecting the occlusion, are not likely to be causative of NCCLs.

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BIOGRAPHICAL SKETCH

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