THESIS- CLINICAL EVALUATION OF NON-CARIOUS CERVICAL LESION- A LONGITUDINAL STUDY

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A THESIS

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ABSTRACT

Non-carious cervical lesions (NCCL) are non-bacterial in origin and defined as the loss of tooth substance at the cemento-enamel junction (Mair, 1992). There is growing evidence that NCCLs may be associated with occlusal and lateral.

OBJECTIVE: To develop a non invasive, highly reproducible technique to measure the occlusal forces (biting pressure) and to correlate it with lesion progression.

MATERIALS & METHODS: Twenty-six subjects and 60 teeth were measured for biting force. Digital images and elastomeric impressions were made at each of three visits (baseline restoration, one and two years). Casts were prepared and a fixture which aligned each patient's cast in the position was made with putty impression material. By positioning the series of casts at same angle scanning accuracy with the Proscan increased in accuracy in lesion progression from baseline to one and two years more consistent. Measurements of biting forces were recorded on a pressure indicating film.

RESULTS: Pearson’s coefficient of correlation correlated lesion progression and biting forces (pressure). Lesion progression from baseline to two years was correlated to the biting forces (p=0.007).

CONCLUSION: Within limitation of this study lesion progression over two year was positively correlated average biting pressure on the tooth.

KEYWORDS: abfraction and non carious cervical lesions
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<td>NCCL</td>
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<td>CEJ</td>
<td>Cemento Enamel Junction</td>
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INTRODUCTION

Non-carious cervical lesions (NCCL) are non-bacterial as tooth substance loss at the cemento-enamel junction. Figure 1.

![Figure 1](image)

**Figure 1.** Teeth (#4-#7) with non-carious cervical lesions at the cervical area with gingival recession.

NCCL are classified according to three different etiologies as erosion, abrasion, abfraction.

**Erosion:** Tooth surface loss caused by chemical or electrochemical action is termed “erosion and can be produced by endogenous and exogenous sources of the acids which produce tooth erosion. Figure 2.
Figure 2. Tooth (#4-#7) showing erosion lesions at the cervical area along the facial surface.

1 Endogenous sources of corrosion: occur during regurgitation as with Bulimia and GERD.

2 Exogenous sources of corrosion are found in highly acidic foods and beverages such as mangoes and other citrus fruits, carbonated soft drinks, sour candies, acidic mouthwashes, chewable vitamin C tablets, aspirin tablets and aspirin powders.  

Abrasion: Tooth loss produced by friction between an exogenous agent causes cervical wear called “abrasion”. Abrasion can occur as a result of mastication of coarse foods, inappropriate or overzealous use of dental hygiene instruments, oral habits such as fingernail biting, pipe smoking, tobacco chewing, and hair pin opening occupational behaviors: severing thread with teeth, blowing glass and playing wind instruments. Dental appliances such as removable denture clasps and rests can also contribute to excessive cervical wear.  

Figure 3
Abfraction is the loss of tooth substance in areas of stress concentration most commonly in the cervical area where flexure leads to fracture of the extremely thin layer of enamel rods, as well as microfracture of cementum and dentin.  

Figure 3. Teeth (#24, #25) with abrasion at the cervical area along the facial surface.  

Figure 4. Teeth (#19-#22) showing abfraction at the cervical area along the buccal surface of the teeth with wear facet.
The etiological factors\textsuperscript{1} for abfraction are:

1. Exogenous factors: parafunction (such as bruxism, clenching) Occlusion: premature contacts, eccentric loading, and deglutition.

2. Endogenous factors: Mastication of hard, resistant foods Habits: biting foreign objects such as pencils, pipe stems and fingernails. Occupational behaviors: playing wind instruments, using teeth to hold foreign objects Dental appliances: orthodontic, removable denture clasps and rests.

The loss of tooth substance\textsuperscript{2-3}, is dependent on the magnitude, duration, direction, frequency and location of the forces applied to the particular tooth\textsuperscript{4}.

Wasting and/or erosion’ were probably the original terms for what is now known as “abfractions”. The first articles describing “Wasting” were in Miller’s articles published in the 1907 Jan, Feb and March issues of Dental Cosmos: Experiments and Observations on the Wasting of tooth tissue variously designated as Erosion, Abrasion, Chemical Abrasion, Denudation, etc.\textsuperscript{4} and now we strongly disagree with the above statement. Erosion produces a saucer shaped lesion while wedged shaped lesion is typical of the abfraction lesion.

According to the principles of leverage\textsuperscript{5-6} the magnitude of tensile stress on the cervical area of a tooth is a function of distance between applied occlusal force and the fulcrum (the CEJ). The greater the distance between the load and the fulcrum, the higher the intensity of the tensile stress that affects the tooth close to the fulcrum and, consequently, the larger the area of rupture and the larger the lesion.
Modeling studies have demonstrated that when teeth are loaded in a horizontal direction the stress becomes concentrated in the cervical region, causing flexure the primary cause of angled notches at the cemento-enamel junction (Hammadeh and Rees, 2001 Lee et al., 2002; Rees et al., 2003) McCoy (1982) proposed that bruxism may be associated with abfraction. Figure 5.

![Diagram showing stress concentration at cervical area](image)

**Figure 5. Tooth showing how abfraction lesion can be formed at the cervical area from applied axial and lateral forces.**

Factors to consider when deciding to restore non-carious cervical lesions are based on the possibility of strengthening the tooth, decrease theoretical stress concentration, decrease flex, halt lesion progression, decrease cold sensitivity, prevent pulp involvement, improve oral hygiene and enhance esthetics. Large wedge-shaped defects that are not indicated for soft tissue coverage can be restored using composite or glass ionomer materials after minimal tooth preparation. Other possibilities include metal restora-
tions for posterior teeth, dentin bonding agents, copal varnishes, fluoride therapy and desensitizing agents, night guard and occlusal adjustments, dietary modification and cessation of oral habits.

Hanaoka and colleagues \(^{14}\) stated that cementum and dentin microcracks may act as the initiator and facilitor of cervical defects. The abfraction theory may initiate the lesion \(^{15}\) and may be the dominant progressive modifying factor in continuing the lesion’s progression. Occlusal loading forces are transmitted to the periodontal supporting tissues, which may cushion and dissipate the resultant stresses. Kuroe and colleagues \(^{16}\) showed a positive correlation between cervical tooth surface lesions with tooth stability and periodontal support. Thus mobile teeth are less likely to have abfraction.

Michael\(^ {16}\) examined 15,000 teeth macroscopically under illumination at 2 X magnification and 542 non-carious cervical lesions which he classified as ‘‘shallow’’, ‘‘concave’’, ‘‘wedge shaped’’, ‘‘notched’’, and ‘‘irregular’’. Figure 6.
Hur\textsuperscript{35} examined 50 extracted teeth which were scanned by micro computed tomography. The location of the internal line angle and proximal exits of the lesions were related to the level of the CEJ which he classified as wedge shaped, saucer shaped and mixed shaped lesion. Figure 7.
Figure 7. Representative samples of three types of non carious cervical lesions: (a) wedge-shaped lesion, (b) saucer-shaped lesion and (c) mixed shape lesion. Left column shows mid-buccal aspect, mid column shows proximal aspect and the right column shows bucco-lingual longitudinal sectional images. Sectional images show the intact sharp enamel margins (SEM) at coronal margins of the lesions.
Various studies to explain abfraction:

Articulated Study Models:

Spranger\textsuperscript{17} recorded the effects of laterally applied occlusal loads using articulated study models. He took a set of upper and lower study models articulated in a semi-adjustable articulator and placed four piezoelectric transducers in the lower left first molar. When realistic occlusal loads were applied, he reported that loads applied in centric occlusion produced lateral deformations of 20 µm in the buccal cervical region. When the loads were applied in lateral excursion, deformations of 200 to 400 µm were recorded. Greater deformation produces more stress at the CEJ.

Photo-elasticity Studies:

Photo-elasticity is a technique whereby a model of a structure is made from a birefringent plastic and viewed in polarized light once loaded.\textsuperscript{18,19} the areas of high-stress concentration are highlighted by areas with multiple concentric rings. Lukas and Spranger and Klahn\textsuperscript{20,21} and colleagues have completed photoelastic studies modeling upper incisors. They reported that the applied loads caused facial bending in the cervical region. Oblique loads applied outside the long axis also caused torsional stresses that concentrated around cervical region of the tooth.
Studies of Strain Gauges:

Strain gauges are widely used as transducers in experimental mechanics to evaluate strain.\textsuperscript{38,51} there are, however, certain limitations to their use in the oral cavity. For instance, they have to be isolated from saliva and blood to prevent short circuits and, in order to measure strain correctly; they must be carefully bonded to the surface of the material under examination. Furthermore, they can only measure strain at one point and in one direction. Figure 8.

![Image showing placement of the strain gauge in a patient.](image)

Nohl and colleagues\textsuperscript{22} placed strain gauges in the cervical region of extracted premolar teeth on buccal surface and loaded them in the region of the centric stops and at various positions lateral to this along the cuspal inclines. They found that loads applied to the cuspal inclines, which mimicked clinical loads applied in lateral excursion, resulted in high surface tensile strains in the cervical region.
Finite Element Analysis:

It is particularly useful in dentistry because it can readily cope with both the complex geometry of a tooth and its supporting structures, together with the large variation found in the physical properties of the tooth, periodontal ligament and alveolar bone. Goel and colleagues developed a three-dimensional finite element model of an upper premolar and reported that the contour of the DEJ and the thickness of the enamel in this region markedly affected the magnitude of the tensile and shear stresses present in the cervical region. They also reported that shear stresses on the buccal side of the tooth were greater than those on the lingual side, which may partly explain why abfraction lesions are not usually found lingually.

Rees developed a finite element model of a lower premolar and applied a point load occlusally of 500N. The cervical stresses were sampled on two horizontal planes in the buccal and lingual cervical enamel, just above the CEJ. They reported that a vertical occlusal load applied in the position of the centric stops produced cervical stresses of around 50 MPa. However, oblique loads applied near the cusp tip produced stresses of about 250 MPa, which exceed the known failure stress for enamel.

Rees and Hammadeh have also developed finite element meshes of an upper incisor, canine, and premolar with sampling planes in the buccal and palatal cervical enamel. The magnitude of the cervical stresses was highest for the premolar, molar followed
by the incisor; stresses were lowest for the canine. This mirrors the findings of clinical studies that report a higher prevalence of abfraction lesions in premolars and incisors. This is probably related to the variation in morphology between these teeth and the area of the periodontal ligament available for absorbing the applied load. Figure 9

Figure 9. Model demonstrating stress in cervical region.

The FEA is widely used in dental research. There are a few limitations to 2D modeling, particularly due to the geometric complexity of the biological structures involved. A 2D model cannot accurately represent-clinical reality because of its simplifications which do not take into consideration some important biomechanical aspects being studied. In contrast, 3D models present advantages such as images of greater and richer detail, the possibility of rotating in space and visualizing internal areas of the models.
The disadvantages of finite element analysis particularly during analyses of the periodontal ligament and alveolar bone, not modeled in previous studies, have shown that those structures may dissipate occlusal loading forces from the cervical areas. In addition, some models may not fully represent intricate dental anatomy and complex occlusal function. Therefore, the key basis of the abfraction theory may be flawed.

**Interaction between Occlusal loading and erosion:**

Erosive agents may exert an influence in many ways

There are several variations in susceptibility to erosion between cervical and occlusal enamel, such as the direct effect of occlusal loading, piezoelectric effects and, stress corrosion effects. Darling and colleagues demonstrated that small organic molecules can penetrate enamel and replace water molecules, so it is possible that simple organic acids are able to access this internal pore system and increase lesion progression.

Non-axial forces on occlusal and lingual tooth surfaces in an acid environment may increase the damage and erosion at the cervical margin. This effect is called stress corrosion. Maxillary and mandibular first and second premolars are most frequently affected by abfractions.

The characteristics of non-carious cervical lesions, with their sharp angles, wedged shapes and frequent sub-gingival locations, have not been explained by the proposed theories to date. Yet, occlusal trauma alone cannot fully explain the phenomenon,
since evidence indicates that many teeth show signs of traumatic occlusion but do not develop cervical lesions. Despite the need for scientific confirmation, the occlusal trauma concept is well-accepted, since it may explain the morphology and location of the lesions.

A basic engineering principal\(^{32}\) is that stress will always follow the material with the highest elastic modulus, as enamel has high elastic modulus like case the enamel. As the buccal enamel was thicker it was probably 'attracting' a greater proportion of the applied load, resulting in a greater stress concentration in the buccal cervical region. Griffith\(^{32, 34}\) proposed theory that explains the nucleation and growth of cracks in a material having pre-existing flaws. His theory was based on the assumption that any brittle material contains inherent flaws which concentrate high stress near their tips, and under loading cracks initiate from these flaws and grow, with the process being repeated for initially less critical flaws as the stress is raised.

Nikolaos\(^{33}\) observed 102 volunteer adult Greek subjects for attrition, abfraction, and occlusal pits on natural teeth, and he found that there was significant association between bruxism and attrition, abfraction, and occlusal pits.

The rate of progression of the destructive process has not been thoroughly investigated. Early studies by Xhonga et al and Xhonga and Sognnaes estimated the rate to be approximately 1 \(\mu\)m per day\(^{36}\). The rates of destruction were reported to be the same in untreated lesions and lesions that were treated with sodium fluoride, which remineralizes tooth structure and renders it less soluble. This finding is consistent with damage caused by tensile stress, which does not depend on the solubility of the tooth structure.
Occlusal loading during mastication can be divided into two phases. The first phase consists of contact of food, during which the food between teeth serves to distribute the forces over the occlusal surface. The spreading of the load helps to minimize the concentration of damaging forces. During the second phase of occlusal loading, teeth that come into contact could result in a virtual point force. This tooth-to-tooth contact is likely to result in a pathologic magnitude of stress, which is evident from the correlation between the contours of wear facets and lesion morphology and by the prevalence of stress-induced lesions in patients with bruxism. The correlation between malocclusion, bruxism and cervical lesion was noted by clinician’s decades ago. U.S. Public Health Service (USPHS) criteria data strongly suggest that stressful occlusion, tooth location, restorative material type, and patient age have significant influence on the retentive failure rates.

The cervical fulcrum area of a tooth might be subject to unique stress, torque, and moments resulting from occlusal function, bruxing and parafunctional activity. Alveolar bone loss changes the position of the fulcrum of bending moment causing more apically placed lesions. Mobile tooth are not affected as mobile teeth dissipates the stress.

**The biomechanics of abfraction:**

1) Theoretical considerations:

The lower anterior teeth usually develop at right angles to the horizontal plane, while the upper anterior teeth develop forwards at around 115–120° to the global horizontal plane.
The consequence of this is that, when these anterior teeth make contact, the upper teeth bend outwards, developing tensile strains in the cervical region, which may contribute to the development of abfraction lesions. A cross-section of the premolar shows the presence of cusps of the posterior teeth produce an inclined plane effect on contact with the opposing tooth. This effect tends to cause the cusps to bend outwards during chewing this along with para-functional activities, produce cervical strain which also contribute to the abfraction lesions development. But this concept suggests that abfraction lesions should develop along lingual cervical region which is not commonly observed.

2) Cuspal flexure:

The increased cusp flexure seen in heavily restored teeth may suggest that abfraction lesions should be more prevalent in teeth with large amalgam restorations as their cusps would deform by up to three times as much as an intact tooth. Unfortunately, this has not been examined clinically not due to the fact that these cusps are often not in occlusion.

3) Structural and physical properties of Enamel:

The surface cervical enamel is structurally inferior with reduced mineral content and higher pore and protein content. The enamelo-dentinal junction in the cervical region is
poorly developed with little scalloping, the feature of this structure that is thought to give rise to the strength of this interface.\textsuperscript{41}

4) Interaction between occlusal loading and erosion:
   a. Difference between the susceptibility to erosion and occurs when a load causes displacement of cervical and occlusal enamel.
   b. Direct effect of occlusal loading.
   c. Piezoelectric effects.
   d. Stress corrosion effects.\textsuperscript{41}

Measuring occlusal forces (MOF):

a. **Force transducer**

   A compressive load transducer is used to MOF in the first molar region. The bite pad containing the load transducer was covered with a hard rubber band, and the set was wrapped with disposable plastic film the subject was asked to bite the equipment five times with maximal effort for 1 to 2 seconds, with rest intervals between trials. The three highest measures were averaged and considered the subject's MOF value (in Newton).\textsuperscript{43, 47}
b. **Hydraulic pressure occlusal force gauge**

Bite force is measured bilaterally in the first molar region using a portable occlusal force gauge that consisted of a hydraulic pressure gauge and a biting element made of a vinyl material encased in a polyethylene tube. Bite force was displayed digitally in Newton. Figure 10

![Figure 10. Hydraulic pressure occlusal force gauge.](image)

Subjects were instructed to bite as hard as possible on the gauge without moving the head. Bite force were measured alternately on the right and left sides with a 15 second resting time between each bite.\(^{44, 48}\)
c. **New Pressure-Sensitive Device:**

A pressure-sensitive sheet was developed for industrial examination by Fuji Photo Film Co (Tokyo, Japan). The device consists of the pressure-sensitive sheet (Dental-Prescale) and its analysis apparatus (Occluzer). Figure 11.

![Figure 11. Pressure indicating film measuring biting forces.](image)

![Figure 12. Occluzer used analyzes pressure indicating film, record biting forces.](image)
The pressure-sensitive sheet is placed between the upper and lower dental arch, and the subjects were instructed to bite as forcefully as possible for about 3 seconds. The sheet was then analyzed with occluser.\textsuperscript{49} Figure 12.

d. \textbf{Jaw force meter:}

Occlusal forces were measured on the right and left sides by a Jaw Force Meter (MPM-2401, Japan) \textsuperscript{50} with a transducer placed between the lingual cusp of the upper first molar and the mesiobuccal cusp of the lower molar.

Measurements were made with the subject seated with the head upright, looking forward and in an unsupported natural head position. The subject was instructed to bite as forcefully as possible. The bite force values were recorded and stored in a computer for analysis. Figure 13.

\textbf{Figure 13. Jaw force meter.}
e. **Gnathodynamometer** (or **occlusometer**):

Snodgrass developed the instrument to measure force exerted in closing the mouth. As per the inventor's design study, the instrument works well in measuring maximal bite force and masticatory efficiency of incisor and molar teeth. But this uses an open bite which will record occlusal forces which may not be accurate. Figure 14.

![Gnathodynamometer](image)

**Figure14. Gnathodynamometer.**
Table 1. The various clinical studies for the proposed etiology for NCCL.

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<td>O. Bernhart, Epidemiological evaluation of the multifactorial aetiology of abfractions, Journal of Oral Rehabilitation 2006 33; 17–25</td>
<td>2707 subjects aged 20–59 years of age: Medical history, dental, and sociodemographic parameters examined</td>
<td>The abfractions are associated with occlusal factors, like occlusal wear facet, inlay restorations, altered tooth position and tooth brushing behavior.</td>
</tr>
<tr>
<td>L.F Pegoraro, Non-carious cervical lesions in adults Prevalence and occlusal aspects, Jada 2005:136.</td>
<td>70 subjects aged 25 - 45 years to determine the presence and type of NCCL, wear facets, tooth contacts in maximal intercuspal position, and lateral and protrusive movements.</td>
<td>Among the teeth the authors evaluated, 17.23 percent had cervical lesions, 80.28 percent of which had wear.</td>
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<tr>
<td>Study</td>
<td>Materials and methods</td>
<td>Results</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
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<td>---------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>E Reyes, Abfractions and Attachment Loss in Teeth With Premature Contacts in Centric Relation: Clinical Observations, J Periodontol. 2009 Dec; 80(12):1955-62.</td>
<td>46 subjects, the mean attachment loss was determined for teeth With and without PCCR and for teeth with and without abfractions.</td>
<td>There were no associations demonstrated between PCCR and the presence of abfractions or increased attachment loss.</td>
</tr>
<tr>
<td>N Tsiggos, Association between self-reported bruxism activity and occurrence of dental attrition, abfraction, and occlusal pits on natural teeth. J Prosthet Dent 2008; 100:41-46.</td>
<td>102 subjects’ adult Greek subjects were classified into 2 groups (50 self-reported bruxers and 52 non-bruxers).</td>
<td>The results demonstrated that there was a significant association between self-reported bruxism and occurrence of the anterior, posterior attrition, occlusal pit and wear facet.</td>
</tr>
<tr>
<td>N.Miller Analysis of etiologic factors and periodontal conditions involved with 309 abfractions. J Clin Periodontol 2003; 30: 828–832.</td>
<td>61 subjects having 309 abfraction were examined.</td>
<td>NCCL coexist almost systematically with occlusal wear facets (94.5%).</td>
</tr>
<tr>
<td>Study</td>
<td>Materials and methods</td>
<td>Results</td>
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<td>----------------------------------------------------------------------</td>
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</tr>
<tr>
<td>C Tar, Characteristics of Non carious cervical Lesions. J Am Dent Assoc 2002; 133; 725-733.</td>
<td>Total of 57 patients and 171 NCCL teeth, was examined shape, dimension, sensitivity, sclerosis and occlusion.</td>
<td>60% had group function or mixed excursive guidance, 141(82%) had wear facets.</td>
</tr>
<tr>
<td>B Faye, NCCLs among a non-tooth-brushing population with Hansen’s disease (leprosy): Initial findings, Quintessence Int 2006; 37:613–619.</td>
<td>Cross-sectional study; N 102; 20-77yrs., clinical examinassions, diet, para-functional habits &amp; drugs. 47% showed NCCLs.</td>
<td>Parafunction and use of medication that causes xerostomia could be the etiology for NCCL.</td>
</tr>
<tr>
<td>P Shah The Prevalence of Cervical Tooth Wear in patients with Bruxism and other causes of Wear, Journal of Prosthodontics 18; 2009: 450–454.</td>
<td>119 subjects, 31 were bruxists, 22 had combined wear and 66 controls aged.</td>
<td>Both bruxist and combined tooth wear group presented cervical tooth wear.</td>
</tr>
<tr>
<td>Study</td>
<td>Materials and methods</td>
<td>Results</td>
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</tr>
<tr>
<td>ID Wood Effect of Lateral Excursive movements on the progression of Abfraction Lesions. Oper Dent, 2009, 34-3,273-279.</td>
<td>N=31, one teeth control and other adjusted, area measured under stereomicroscope.</td>
<td>Occlusal adjustments did not reduce the progression of abfraction lesion. As there could be other factors that could be responsible for progression.</td>
</tr>
<tr>
<td>W. A. Smith, The prevalence and severity of non-caries cervical lesions in a group of patients attending a university hospital in Trinidad. Journal of Oral Rehabilitation 2008; 35: 128–134.</td>
<td>386 male, 30–59 aged, Mediotrusive and laterotrusive contact were examined.</td>
<td>Bilateral mediotrusive-side and laterotrusive- side contacts in incisor-canine-premolar areas were significantly associated with the presence of non-caries cervical lesion.</td>
</tr>
<tr>
<td>J Takehara, NCCLs and occlusal factors determined by using pressure-detecting sheet. Journal of dentistry 36; 2008:774 – 779.</td>
<td>159 male self-defense force officials, an avg age of 36.2, average pressure were measured using pressure-detecting sheet.</td>
<td>NCCLs – 49.1%; aging, tooth-brushing and occlusal factors in the study population were related to prevalence of NCCL.</td>
</tr>
</tbody>
</table>
### Table 2. *In vitro* studies for the proposed etiology of non carious cervical lesion.

<table>
<thead>
<tr>
<th>Study</th>
<th>Materials and method</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estoica, En face optical coherence tomography investigation of pathological dental wear. TMJ 2010, Vol 60, No. 1</td>
<td>42 extracted frontal teeth, 35 teeth from active eccentric bruxism and 7 control teeth were investigated using eFOCT.</td>
<td>Most of teeth with bruxism were associated with abfraction.</td>
</tr>
<tr>
<td>A Estafan, In vivo correlation of NCCLs and occlusal wear, New York University College of Dentistry, J Prosthodont. 2005 Mar 93:221-6</td>
<td>N = 299; casts mounted on a semi-adjustable articulator.</td>
<td>NCCLs are not related to occlusal wear, posterior excursive contacts and occlusal guidance.</td>
</tr>
<tr>
<td>A Asundi, A strain gauge and photo elastic analysis of in vivo strain and in vitro stress distribution in human dental supporting structures. Archives of Oral Biology 45;2000.</td>
<td>Strain gauge exp.1) measure the strain on supporting alveolar bone;2) measure the strain on the root surface; Photoelastic exp. - 1) analyse the stress distribution pattern from the tooth.</td>
<td>Most of the stresses on the root surface were distributed along the cervical and middle thirds, stress patterns diminished towards the apex.</td>
</tr>
<tr>
<td>Study</td>
<td>Materials and method</td>
<td>Results</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
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<tr>
<td>A. Kishena, Digital moiré interferometric investigations on the deformation gradients of enamel and dentine: An insight into non-carious cervical lesions. Journal of Dentistry 2006; 34:12–18</td>
<td>6 freshly extracted non-carious mand. Central incisor teeth; specimens mounted on horizontal loading jig permitted compressive loading along the long axis of the tooth specimen. The loading jig was positioned interferometer - to visualize the resulting load induced deformation.</td>
<td>The strains in the lateral direction within the enamel and the strains in the axial direction within the dentin increased towards the cervical region adjacent to the cementoenamel junction on the facial side.</td>
</tr>
<tr>
<td>N, Noma Cementum crack formation by Repeated loading In Vitro, Journal of periodontology. J Periodontol 2007 Apr; 78(4):764-9.</td>
<td>5 human mand. PMs, compression load – 5kgf, 1,000,000 cycles stereoscopic microscope photograph and SEM @100,000cycles, dye – 2%methylene blue to see cracks.</td>
<td>Cementum cracks initiated in the cervix on buccal, mesial, &amp; distal surfaces after repeated compressive loadings and extended toward the root apex.</td>
</tr>
<tr>
<td>Study</td>
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<td></td>
</tr>
<tr>
<td>Materials and method</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 intact mand 2nd premolar, 3D geometry reconstructed, FEMs developed, 100N load axially &amp; obliquely on inclines of buccal cusp; Strain gauge: 10 intact mand. PMs, 1 gauge at lingual surface &amp; 2 on the buccal surface, 100N load – 45° &amp; 90°.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Results</td>
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<tr>
<td>Strains concentrated near the CEJ at both angles. Strains predicted from FEA model agreed with strain gauge measurement.</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Study</th>
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</thead>
<tbody>
<tr>
<td>Materials and method</td>
</tr>
<tr>
<td>2 intact human mand.2nd premolar &amp; central incisor – FEA model constructed, 100N load at 45° to long axis of teeth.</td>
</tr>
<tr>
<td>Results</td>
</tr>
<tr>
<td>Strains were concentrated near the cementoenamel junction (CEJ) regardless of load direction, and oblique loading showed higher tensile strains.</td>
</tr>
</tbody>
</table>

Soft, medium & firm bristled toothbrushes (n = 2) tested with 3 diff. toothpastes, with & without water on extracted teeth; 70,000 strokes, horizontal brushing.

NCCLs were created by horizontal brushing with toothpaste, while brushing with water only did not create these cervical lesions. Dentin wear appeared at 10,000 strokes.
**The mapping of Non carious cervical lesion:**

Recent studies\textsuperscript{51-52} have focused on a characterization of lesions such as height, depth, location, patient age and gender information. Findings have demonstrated strong correlations with age, dietary acids and toothbrushing \textsuperscript{53}, and the presence of lesions in association with occlusal attrition and erosion\textsuperscript{54}.

In a review of techniques for the measurement of tooth wear and erosion, Azzopardi et al. (2000) concluded that the current methods of quantifying tooth substance loss involving impressions, pouring of models, mechanical or laser digitization and analysis were slow and cumbersome and confined to the laboratory.\textsuperscript{55}

Modern digital photogrammetric to map tooth surfaces and monitor the progression of NCCLs, also provided a suitable optical texture is present on the imaged tooth surface\textsuperscript{55}. The application of optical texture onto or into a dental casting material has not been reported and may offer an alternative path to development of practical technique. It has been proposed that the shape of lesions may be related to the NCCL etiology.\textsuperscript{56} however this has not been confirmed experimentally or clinically\textsuperscript{57}.Figure 15.
Figure 15. Lower left quadrant of a female patient aged 81 years with NCCLs affecting all teeth; 33 lesions extending into pulp chamber now filled with reparative dentine; 34 shows bulk loss of buccal enamel and dentine. Erosion affecting occlusal/incisal surfaces with dentine ‘cupping’ affecting all teeth.

Quantitative measurement systems have traditionally been classified according to the principle by which data are collected, such as contact or non-contact, surface topography or silhouette tracing. The methods reviewed below are:

i. Profile/silhouette tracing
ii. Measuring microscopy
iii. Contact stylus
iv. Photogrammetric
v. Structured light
vi. Laser scanning
vii. Confocal microscopy
viii. Computed tomography and magnetic resonance imaging.
Profile / Silhouette tracing:

The progression of NCCLs has been monitored using this method by obtaining profile tracings of silicone (Dow Corning, Alhambra, CA) replicas of teeth. The object or replica are sectioned regularly, typically 1 mm, then hand traced, photographed or video graphed. Subsequent replicas were orientated manually to the initial replica and three slices, 1 mm thick, were cut through the lesions, parallel to the long axis of the tooth. Profile tracings and measurements of the replicas were obtained at 20x magnification; the slices procured between time intervals were superimposed using the average of three measurements of the lesions of each tooth replica. No accuracy information was reported.

Measuring microscopy:

Measuring microscopes consist of a stereo microscope with an internal mark, cross-hair to view an object mounted on an x, y stage. The internal mark is used to locate the x and y coordinates of a point or feature seen through the microscope. The plane of focus can be used to determine the z coordinate where an appropriate recording mechanism is included in the instrument. Height accuracy is increased with increasing magnification, which also narrows the depth of field.
Contact stylus:

Contact stylus systems have been designed and built in a number of different centers. Tooth replicas are typically profiled one at a time with measurement routines taking several hours. Sequential profiles of the same tooth showed reproducibility of ±7µm.

In recent years commercial contact stylus measurement systems have become commonly available and their use is being reported in the dental literature. While they are typically referred to as ‘profilometers’, they come under the general classification of coordinate measurement machines (CMM) and often have nanometer accuracy. Contact stylus systems are now fully automatic, and while the measurement procedure may take several hours, it does not require actual operator time. However for best results, teeth surfaces need to be mapped individually, requiring that replicas have to be individually prepared.

Photogrammetric:

At its broadest form, photogrammetric takes measurements from images to generate 2D and 3D data. Measurements are taken from natural features appearing in the images or targets placed into the scene. Traditionally, photography was the means of non-contact imaging and found its major application in aerial based land mapping (aerial photogrammetry) utilizing single, very large format (230 mm x 230 mm) cameras and to a lesser extent land based mapping of architectural and engineered structures (non topo-
graphic, terrestrial or close range photogrammetry) utilizing single or stereo large format (e.g. 100 mm x 150 mm) cameras.

Digital photogrammetric systems (DPS) follow a sequential process in which either hard-copy photographs are digitized or the images are directly acquired by digital cameras, then automatic matching takes place, where images are compared digitally, the small differences (parallaxes automatically calculated, and 3D coordinate data generated). Photogrammetric has the significant advantage over all other methods that 3D data acquisition can be instantaneous, given simultaneous acquisition of images from different directions. However a gypsum replica of a tooth did not contain suitable texture for successful mapping.

Structured light:

An alternative approach, known as structured light or active pattern projection, employs a light stripe or grid pattern of known geometry projected onto the object surface and photographed. Methods of pattern projection have included a light stripe combined with object movement through the stripe. The CEREC system was not developed as a research tool and at present there is no easy method of recovering raw data from the system. The CEREC system presents a potential clinical method for mapping NCCLs; however its reported measurement accuracy of 25 μm does not match that of contact stylus systems. Further, the reported accuracy is diminished by the need to render the surface of the tooth opaque prior to imaging. It has the advantage of being fully automatic and 3D reconstruction occurs in a matter of seconds.
**Laser scanning:**

The improved directionality of laser light has been exploited to improve structured light mapping systems, with methods including double-axis laser scanning, telecentric scanning, laser strip projection, optical radar and time of-flight laser rangefinders. A non-contact profilometer with a LASER line and CCD camera at an angle of 25° was developed to measure tooth wear. The light line full width at half maximum (FWHM) was 22 μm and 512 surface points were measured in one video cycle. A step motor advanced the model in the y direction. The tooth surface was scanned at an interval 25 μm between points in x and y directions (250,000 points) in 20 to 40 seconds. Accuracy of (6.0 ± 0.6) μm was reported and precision was (2.9 ± 0.5) μm.

**Confocal Laser Microscopy:**

Confocal microscopy generates a common focal plane for both illumination and imaging and generates optical tomograms, giving thin slices (>1 μm) up to 100μm below the surface of enamel and dentin (Watson, 1997). Reflection imaging of the natural teeth resulted in excessive reflection in many areas, probably due to increased reflection from enamel prisms or small sections of tooth surface perpendicular to the laser source causing significantly more reflection than the rest of the surface. This led to the misrepresentation of the surface position at these points. Staining the surface of a replica with fluorescent eosin gave the strongest signal compared to the low amount of auto fluorescence exhibited by natural teeth and was shown to be more accurate than depositing a layer of eosin dissolved in oil on the surface.
**Computed Tomography and Magnetic Resonance Imaging:**

Computed tomography (CT) utilizes x-radiation to produce 2D sections through the body or radiosensitive material. Conventional CT typically records slices 1 to 2 mm in thickness. Two-dimensional slices are assembled to build 3D models. Magnetic Resonance Imaging (MRI) involves applying magnetic fields to tissues under investigation and recording the differential resonance emitted by different tissue components.

Microscale CT has been applied to an extracted maxillary premolar, fixed in an acrylic glass tube, and placed in a µCT scanner (Scanco MicroCT; Sanco Medical) (Verdonschot et al., 2001). A scan grid of 1024 x 1024 was selected with a resolution of 13 µm and a scan slice thickness of 25 µm. The premolar was scanned with 770 slices, and the exposure time was set at 10 ms. No dimensional accuracy testing was reported. Similar data has also been recently reported.58

Abfraction is derived from the Latin verb frangere (“to break”) and defines a wedge-shaped defect at or near the CEJ of the tooth (Imfeld 1996, Piotrowski et al. 2001, Boston et al. 1999, Grippo 1991) various studies have proposed an association with abfraction and occlusal forces and tooth flexure. But there are very few clinical studies that correlate occlusal forces to rate of progression of the non carious cervical lesion.65
HYPOTHESIS AND AIMS

Hypothesis:
The hypothesis - The occlusal force on teeth with non-carious cervical lesions has the same occlusal forces as adjacent teeth without lesions and that the lesion with heavy occlusal forces does not progress differently.

Aims:

1) To measure the occlusal forces on teeth with NCCL.

2) To measure the lesion progression of NCCL over 2 years.

3) To co-relate the progression of lesion with occlusal forces.
MATERIALS AND METHODS

This study received approval from the University of Alabama at Birmingham Institutional Review Board with a protocol number of CR-07-009. Subjects were informed of the study methods and the procedure. After the subject’s questions were answered they were asked to participate in the study. Their verbal acceptance was followed by a signed informed consent process. Only subjects meeting the inclusion criteria were enrolled in the study. Table 3 and 4.

Table 3. Inclusion criteria.

<table>
<thead>
<tr>
<th>Requirement</th>
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<tbody>
<tr>
<td>19 years of age and older</td>
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<tr>
<td>Have a minimum of three noncarious Class V lesions requiring restoration that are &gt;1.5 mm in depth</td>
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<tr>
<td>Be a regular dental attendee who is able to return for assessments.</td>
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<tr>
<td>Be in good medical health and able to tolerate the dental procedure.</td>
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<tr>
<td>Must not have rampant caries.</td>
</tr>
<tr>
<td>Must not have chronic periodontitis or carious lesions which could compromise tooth retention.</td>
</tr>
<tr>
<td>Must be able to tolerate the dental procedure.</td>
</tr>
<tr>
<td>Have normal salivary function.</td>
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</table>
Table 4. Exclusion criteria.

<table>
<thead>
<tr>
<th>Criteria</th>
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<tbody>
<tr>
<td>They are enrolled in an evaluation of other restorative materials.</td>
</tr>
<tr>
<td>Have fewer than 3NCCL lesions or have lesions less than 1.5 mm deep.</td>
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<tr>
<td>Are not able to tolerate the time required to place the restorations.</td>
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<tr>
<td>There is a history of an adverse reaction to any materials used in the study.</td>
</tr>
<tr>
<td>They are irregular dental attendees.</td>
</tr>
<tr>
<td>They maintain an unacceptable standard of oral hygiene.</td>
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<tr>
<td>They have chronic periodontitis or rampant caries.</td>
</tr>
<tr>
<td>There is severe salivary gland dysfunction.</td>
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<tr>
<td>They are unable to return for recall appointments.</td>
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</tbody>
</table>

Non-carious lesions in anterior and premolar teeth requiring Class V restoration can be included in the study. Teeth must be vital, that is, free of signs and symptoms of periapical pathology both clinically and radiographically.
### Table 5. Study design.

- **Visit 1**  
  Restoration

- **Visit 2**  
  1 year evaluation

- **Visit 3**  
  2 year evaluation

- **Visit 4**  
  Bite force measurement.

### Table 6. Measurement taken and used.

<table>
<thead>
<tr>
<th>Measurement</th>
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<tbody>
<tr>
<td>Bite force using Prescale pressure indicating film</td>
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<tr>
<td>Lesion shape, size and surface profile</td>
</tr>
<tr>
<td>Change in lesion: over one year</td>
</tr>
<tr>
<td>Change in lesion: over two year</td>
</tr>
<tr>
<td>Addition silicon impressions and casts</td>
</tr>
<tr>
<td>Proscan scanned images of cast over one year, two and three year.</td>
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</tbody>
</table>
Method

A) The patient was appointed for a restorative appointment. During the restorative procedure digital images were taken before tooth was prepared, after the tooth was prepared and after it was restored. A conventional impression of the tooth before and after the restoration was made using addition silicone impression material. And tooth with lesion which were not restored

B) Aquasil addition silicone Impressions were disinfected using Biotrol and stored in a coded bag in lab under dry climatic conditions.

C) First recall evaluation was 10-15 days after restoration placement. During that appointment gingival index and plaque index was recorded and a PVS impression of the teeth was made.

D) The second recall evaluation occurred six months after the restoration was placed. Another PVS impression made.

E) The third recall evaluation occurred 1 year after the restoration was placed. Another PVS impression made.

F) The fourth recall evaluation occurred 2 year after the restoration was placed. Another PVS impression made. And bite force measurement were made using prescale measurement.
Table 7. Materials used to measure the lesion progression.

<table>
<thead>
<tr>
<th>Material Description</th>
<th>Manufacturer</th>
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<tbody>
<tr>
<td>Self adhesive Directed Flow Impression Tray</td>
<td>3M ESPE</td>
</tr>
<tr>
<td>Aquasil Ultra Heavy: Type 2: Medium bodied consistency</td>
<td>DENTSPLY Caulk</td>
</tr>
<tr>
<td>Aquasil Ultra XLV: Type 3: Light-bodied</td>
<td>DENTSPLY Caulk</td>
</tr>
<tr>
<td>Fujirock Type 1V Die &amp; model stone</td>
<td>GC America</td>
</tr>
<tr>
<td>Putty impression material</td>
<td>3M ESPE</td>
</tr>
<tr>
<td>Biotrol disinfectant solution</td>
<td>Biotrol International</td>
</tr>
</tbody>
</table>

PVS impression protocol:

The patient was comfortably seated in the dental chair. The dental assistant placed the loaded the Self adhesive Directed Flow Impression Tray (3M ESPE St. Paul, MN 55144) with Aquasil (DENTSPLY) impression material starting from left molar area to
the right molar area avoiding air entrapment. The impression material was dispensed from Pentamix 2 (3M ESPE St. Paul, MN 55144) an automated machine. An air spray was used to dry the teeth while the assistant loaded the impression tray. The facial surfaces of the teeth of interest were covered with Aquasil Ultra XLV prior to tray insertion. The light viscosity impression material was inserted from the left side and rotated into the mouth while retracting the cheek. The impression tray was seated slowly, using the central incisors as guidance. The tray was positioned using the subject’s nose as the reference point. Three and half minutes after seating the tray, the impression was removed and disinfected. Figure 16.

![Figure 16](image)

**Figure 16.** Conventional impressions made of the maxillary and Mandibular arches using elastomeric impression materials.

**Disinfection:**

Biotrol disinfectant solution (Biotrol International, N Salt lake City, UT 85054) was sprayed on the impression. The impression was then placed in a plastic bag with the code written on it. The impressions were stored in a dry area.
Making a cast:

The impressions were washed thoroughly with tap water, to remove any remaining disinfectant and dried with air water syringe to ensure no excess liquid remained. A 100mg of Fujirock (GC America 3737 W. 127th Street, Alsip, IL 60803) Type 1V Die & model stone was spatula mixed for 10 sec and followed by vacuum mixing (Whip Mix Corporation, Model # 6500, Louisville, US) under 27 psi/ hg for 30-40 sec with 20ml of tap water measured in a measuring cylinder at 23 ± 2 º C. The impression was poured at an ambient temperature of 23 ± 2 º C and humidity of 34 ±1 %. All the impressions were poured in the order they were made from the patients. Using the stone vibrator set in slow mode the mixed stone was slowly poured into the impression with the heel of the impression tray touching the vibrator. Care was taken not to touch the impression but the tray on the vibrator to prevent distortion. A small amount of the stone was vibrated through the impression to provide a thin wash of stone in the impression covering the depressions. Subsequent stone was slowly added in small increments to fill the impression while vibrating the impression. The impressions were not inverted. The casts were separated from the impression trays after setting for 30 to 40 minutes. Each cast was trimmed to a desired shape. Every cast base was made to position the cast to the same angulations for the baseline, one year and two year casts. Figure 17.
Making a mold:

Molds were made with putty impression material on the occlusal surface and buccal surface of the same side. The impression materials positioned the cast in the same position to allow repeated impressions of the same patient at the same angle in Z axis. They were positioned in such a way on the surveyor that baseline cast, one year cast and two year cast all are angled in the same way. The impression material fixtures were wide enough to hold and position the cast with no movement of the cast during scanning. Occlusal surfaces of 3-4 teeth were covered with putty impression material and extended lingually and buccally. Figure 18, 19 and 20.
Figure 18. Putty material used to orient the cast with three notches to hold as same angle for baseline, one and two year so it can scan the cast on Proscan.

Figure 19. Mold with three notches positioning the cast in same direction.
Figure 20. The surveyor positioning the cast at same angle for baseline, one year and two year.

Figure 21. The standardized cast at baseline, 1 year and 2 years.
Scanning:

Proscan was used for necessary imaging and scanning:

The Proscan was used to scan the cast at baseline, one year and two year. After scanning than Proscan software was used to superimpose the cast at baseline to one year and baseline to two year to get necessary change in volume at one and two year. Figure 21 and 22

Table 8. Proscan features.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
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<tbody>
<tr>
<td>High speed measurement up to 1,000 points per second coupled with high resolution from 5nm, using chromatic aberration enables the measurement of millions of points on a surface for further analysis within Proscan.</td>
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</tr>
<tr>
<td>Total flexibility with a range of interchangeable sensors with measuring ranges in height from 110µm to 50mm can be used on one system.</td>
<td></td>
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<tr>
<td>Non-contact measurement alleviates damage to highly polished, delicate or soft materials.</td>
<td></td>
</tr>
<tr>
<td>Scantron’s confocal chromatic sensor technology provides unmatched measuring performance.</td>
<td></td>
</tr>
<tr>
<td>With a scanning area of 150mm x 100mm, a diverse range of samples may be measured, making this instrument very versatile and easy to set-up.</td>
<td></td>
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<tr>
<td>Matrix scanning enables arrays of parts to be measured individually or scans can be combined for measuring irregular shapes.</td>
<td></td>
</tr>
<tr>
<td>Proscan software was designed to be used intuitively. New users can achieve very</td>
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</tbody>
</table>
precise scans readily, with little training, thus making the instrument accessible to all.

With a rugged construction, the Proscan 2000 can be used on the shop floor or in a laboratory. The instrument will provide precise measurements for many years.

spots size from just 2µm diameter.

**Figure 22. Proscan 2000 Non contact Profilometer.**

Once a scan is complete Profom software allows a wide range of analytical tasks to be completed, from calculating the surface area of a sample to ISO standard Roughness and Normalised Peak Count. Proscan has a resolution in height measurement as low as 5nm, measured at a rate of up to 1,000 points per second, using its latest non contact sensor technology. Faster scanning is achievable with LASER triangulation scanners which can scan at a rate of 10,000 measurements per second to a height resolution of 100nm. Prosc-
can was used to scan the casts with non carious cervical lesions. The cast were positioned at same angles for scanning and scanned with a 20µm step size at frequency of 100Hz. Figure 21 and 22.

![Figure 23. Measurement principle of chromatic sensor technology.](image)

It works by transmitting safe white light through a lens that has carefully manufactured spectral aberration built into it. It's this effect that takes the white light and divides it into the full spectral field, focusing each of the different color frequencies at a slightly different point through a defined measuring range. Figure 23 and 24.
When an object is then placed within this range, only one particular color frequency reflects back from the surface. This information is then passed back into a processor where a spectrometer analyses the signal and converts it to a measurement. The Proscan combines these measurements with the precise location of a moving X/Y linear table, creating three co-ordinates from which to create a 3 dimensional profile.

![Proscan device](image)

**Figure 24. Scanning under Proscan.**

The scanned image of patient cast: This are scanned images of the patient with tooth number 7. The teeth were scanned from the baseline, one year and two year casts and the change in NCCL over a one and two year period was measured by superimposing. Figure 25, 26 and 27.
At baseline: Scan at baseline patient tooth number 7

Figure 25. Scan at baseline Pt tooth number 7.

At one year: Scan at one year patient tooth number 7

Figure 26. Scan at one year Pt tooth number 7.
At two year: Scan at two year patient tooth number 7

Figure 27. Scan at two year Pt tooth number 7.

**Superimposition:**

Proform software was used to align the baseline image to one year and baseline image to two year if baseline cast was missing than one year cast was superimposed with two year cast.

For superimposing the Proform software was used -The ProForm software enables the comparison of two scans made using the Proscan 2000 non-contact surface profilometer. Ideally suited for applications where it is important to accurately determine the amount and location of material loss for wear or erosion studies. The measurement data can be registered allowing the two surfaces to be easily and accurately aligned in all planes with the differences displayed in a number of different graphic displays. ProForm software
provides dental researchers with a new and easy method to accurately quantify the volume and location of material lost during the study of wear, erosion and abrasion of dental materials. The Proform software was used to superimpose baseline scan to one year scan. Figure 28 and 29.

Features:

- Enables complex non geometric shapes to be compared without the need for careful mechanical referencing.
- Simple method of aligning the two sample scans in all planes.
- Calculates the amount and location of material lost in abrasion and erosion studies.
- Fully compatible with Proscan 2000 measurement files.

![Figure 28. The superimposed images of the baseline scan vs. one year scan.](image-url)
Applications:

Dental research - measuring the direct effect of erosion of tooth enamel caused by the acidity of food or drink.

Dental research - quantifying the amount of material lost during abrasion studies.

Key Feature:

• Enables complex non geometric shapes to be compared without the need for careful mechanical referencing.

• Simple method of aligning the two sample scans in all planes.

• Calculates the amount and location of material lost in abrasion and erosion studies.

• Fully compatible with Proscan 2000 measurement files.

Figure 29. The superimposed images of the baseline vs one year zoomed image.
Proscan:

Then we went back to Proscan software to further get three volume changes total volume change, soft tissue and lesion volume. Proscan software was used to eliminate the gingival and occlusal area of the scan and only lesion area was used to in the final analysis.

By Various steps:

To eliminate the gingival and occlusal area of the lesion. The superimposed image of the lesion was looked very carefully and first gingival area was eliminate using shift key and left key together / control and left key. Than the occlusal/incisal area was eliminating using the same above procedure. After that warpage filter tool was applied so that any we can fill up any defects in the scan. This was followed by flattening all the area except the lesion area. Then finally change in lesion volume and depth was measured from baseline to one year and baseline to two year. Figure 30, 31 and 32.
Figure 30. Scan after eliminating of the gingival area.

Figure 31. Scan after eliminating of the incisal area.
Figure 32. Scan removing the incisal and gingival area with only lesion area

Prescale Pressure indicating film:

Patients were recalled and were asked to bite normally in centric occlusion Dental- Prescale 98 ± 5 mm of thickness is a single use of sheet containing pressure-sensitive material.

The subjects were seated in upright position and then they were instructed to clench on the sheet at the intercuspal position with maximal clenching effort. The subjects were also advised to steadily increase the bite force to its maximum over a period of a few seconds and then release.
When pressure was applied to the sheet, the constituent microcapsules in the sheet collapsed, the color former contained in the capsules leaked out to chemically react with the developer and formed red spots in the sheet. The different densities of color were formed according to the level of the pressure applied. Figure 33, 34, 35 and 36.

Figure 33. Patient was seated in upright position.

Figure 34. Patient was instructed to bite on prescale pressure indicating film on tooth number 8.
The film of low thickness of range 350-1400 PSI was used for all patients. We used this pressure range so that due to tensile stress by Bowen and Rodrigeuzs for enamel is given as 10 MPA that is around 1450 PSI. Fujifilm Prescale is a Mylar based film that contains a layer of tiny microcapsules. The application of force upon the film causes the
microcapsules to rupture, producing an instantaneous and permanent high resolution “topo-
pographical” image of pressure variation across the contact area. Figure 37

Fujifilm Prescale® is extremely thin (4 to 8 mils) which enables it to conform to
curved surfaces. It is ideal for invasive intolerant environments and tight spaces not ac-
cessible to conventional electronic transducers.

![CROSS SECTIONAL VIEW OF FUJI PRESCALE® FILM]

Figure 37. Cross sectional view of Fuji prescale film.

Analysis of the Prescale Pressure indicating film by Topaq:

Topaq consists of a specially calibrated densitimetric scanner and Windows soft-
ware. An essential component of the Topaq system is the force indicating film commonly
known as Fujifilm Prescale. These sensor films change coloration permanently and in-
stantaneously in response to pressure being applied to them. The Topaq scanner and
software is then used to image and interpret the stress marks on the film. From this, To-
paq renders high resolution, color calibrated images and a wealth of statistical information pertaining to the analyzed film.

The pressure indicating film was scanned using Topaq software which generates instantly full-color pressure maps and accompanying statistical data. Even more, Topaq is accurate to within ± 4% — unprecedented in the field of tactile pressure measurement. Figure 38, 39 and 40.

![Scanned image](image1.png)

**Figure 38. Scanned image.**

![3D image](image2.png)

**Figure 39. 3D image.**

![Average pressure](image3.png)

**Figure 40. Showing average pressure.**
RESULTS

For occlusal force measurement n=26 patient returned with total number of teeth=60 returned back. For a given patient total volume of tooth structure loss was averaged along with average biting pressure. Than average pressure was correlated with average teeth structure volume loss and average total teeth structure loss. The average occlusal biting force (pressure) on 60 teeth was measured for 26 subjects. For each tooth the following volume loss was recorded: NCCL, gingival change and total change. These three volume changes were correlated with average biting pressure. Data was analyzed using Pearson correlation coefficient and Fisher‘s test ($\alpha = 0.05$). Table 9.

1. The total volume loss of teeth was correlated to biting force at the one year and one year.

2. The total volume NCCL lesion was correlated to biting force at end of two year

3. The total gum loss was correlated to biting force at end of one and two year.

4. The closer the value of Pearson‘s correlation coefficient $\pm 1$, the stronger the correlation.

5. Fischer exact test was done to finding the statistical significance.

6. The P-value less than 0.05, correlation is significant.
### Table 9. Results

<table>
<thead>
<tr>
<th></th>
<th>Confidence Intervals</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Correlation</td>
</tr>
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</tr>
<tr>
<td>Pressure, Volume, Total 2Yr</td>
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<tr>
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<td>Pressure, Volume, teeth(cervical) 2Yr</td>
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<tr>
<td>Pressure, VOL Gum 1yr</td>
<td>0.604</td>
</tr>
<tr>
<td>Pressure, VOL Gum 2yrs</td>
<td>0.697</td>
</tr>
</tbody>
</table>
The bivariate scattergram:

The bivariate scattergram for total tooth volume loss:

![Bivariate Scattergram for Total Tooth Volume Loss](image)

At one year

At two year

Average biting pressure in PSI

The bivariate scattergram for NCCL volume loss:

At one year

At two year

Average biting pressure in PSI
The bivariate scattergram for gum volume loss:

At one year

At two year

Average biting pressure in PSI
DISCUSSION

The primary goal of this study was to find the correlation between occlusal forces and rate of progression of the Non carious cervical lesion. Despite all the research and attention that NCCLs have received during the past 30 years, there still remain those who believe that the toothbrush/dentifrice is the main, or only, cause of NCCL etiology. But in the study done by Babacar Faye et al found that that toothbrush/dentifrice abrasion was not a factor in the etiology of NCCLs in the population studied that were leprosy study and found that sign of parafunction could be contributing factor for NCCL.64 The study done by Punit Shah suggested that bruxism could be associated with cervical lesion wear.65

In the study done by W. A. J. Smith, significant associations between NNCL with were also found in patients with group function, faceting, clicking joints or those who wore occlusal splints.66 All this above study found that there is relation between occlusal forces and NCCL .This study examines the prevalence and severity of NCCL and it relation to occlusal forces. Any of the previous study has not mentioned the rate of progression of Non carious cervical lesion in term of volume and then co-relates it with biting forces (pressure). The major advantages with this technique are using diagnostic casts which are a part of standard clinical requirement, reducing the additional clinical time and or Volunteer time. Since measuring the progression of lesion under Proscan this is an in-vitro procedure it has the advantage of standardizing the measuring technique and then
Proform software allows comparing of baseline cast to one year and two year. The Proscan 2000 is a fast and accurate non-contact three dimensional surface measurement instrument. Proscan has a resolution in height measurement as low as 5nm, measured at a rate of up to 1,000 points per second, using our latest non contact sensor technology. Faster scanning is achievable with our laser triangulation scanners which can scan at a rate of 10,000 measurements per second to a height resolution of 100nm.

In the study that was done by Dr Junji Takehara, in which they co-related non carious cervical lesion with pressure indicating film. But in that study they have not mentioned pressure range of the pressure indicating film. In our study we have used the pressure range of pressure indicating film 350-1400 PSI, which was close to, we used this pressure range so that due to tensile stress by Bowen and Rodriguezs for enamel is given as 10 MPA that is around 1450 PSI.

Another thing that has not been mentioned in that used tooth wear index. The TWI scores were 0: no change of contour, 1: minimal loss of contour, 2: defect less than 1mm in depth, 3: defect 1–2mm in depth, 4: defect more than 2mm in depth, or pulp exposure, or exposure of secondary dentine. It is a vague way to co-relate it with occlusal forces. We have used Proscan software to scan and Proform software to see the change in progression of lesion over one year and two year. The progression was measured in form of volume and depth changes, which is more reliable. Third thing in that study was restricted to defense people but in our study we didn’t had such restriction.
In study done by ID Wood. Total number of subjects: 39, age range 18-75, two NCCL that did not require operative and were in group function during lateral excursion. Full-arch impressions were taken using a polyether impression material at 6, 18 and 30 months after baseline. The occlusion of the test teeth was marked with red and blue articulating paper and heavy dynamic occlusal marking were checked and removed during follow-up appointment. NCCL progression was measure over 3 years using stereomicroscope in term of area. No statistically significant difference was found in wear rates between the adjusted and non-adjusted teeth having NCCL (p>0.05). They lesion progression was not measured in term of volume which could be more precise method. So we can see here that there could be various other etiological factors other than biting forces that could be responsible for progression on CCL. As various authors have mentioned that non carious cervical lesion as a multi-factorial etiology, so we need to take in consideration other factors also. Figure 41
**Figure 41. Multifactorial etiology for NCCL.**

**LIMITATION**

1) Limited number of patient.

2) The pressure range of pressure indicating film was 350-1400 PSI.

3) Average pressure was under consideration, but the maximum should have also been under consideration.

4) Two year is a limited time period for evaluation of progression of lesion.
CONCLUSION

Based on the limitations of this study:

1. NCCL progression is correlated with biting forces at two years (p = 0.023).
2. Biting forces are correlated with total volume loss (p = 0.0147 at 1 yr and 0.0007 at 2yr) and total gum loss (p = 0.0153 at 1yr and 0.0028 at2yr).
3. Proscan is a precise tool for measuring tooth volume change.
4. Prescale pressure sensitive sheet is an accurate pressure measuring tool.
FUTURE DIRECTIONS

1. T-Scan to measure relative forces—After consent has been obtained; the occlusion of each subject will be analyzed with the T Scan III. The occlusal forces generated for each tooth will be measured and recorded at 3-year recall.

The T Scan technology can not measure absolute force as it cannot describe occlusal forces in Newton’s/cm sq. or lbs/sq. in. It has the advantage of gathering data output from teeth occluding across its recording sensor and is very precise, dynamically changing (in .003 -.005 second increments) relative applied load per occluding tooth. It also produces a variable "percentage of force" at each tooth that changes with each passing.003-.005 second time increment. This data is recorded sequentially as the occlusal contacts apply variable load to each occlusal surface in functional mandibular movements. So T-scan can be used to measure relative forces on the non NCCL teeth

2. Articulating the cast of the patient and then looking for the exact area that could be responsible for causing high occlusal forces. It is difficult to find which cusp of molar would be bearing the maximum force which might be responsible for progression of non carious cervical lesion. So this could be an adjunct to T-can data.

3. Use of strain gauge to find strain at cervical area- This can even give us better idea about the strain in the cervical area but care need to be taken as they have to be isolated from saliva and blood to prevent short circuits and, in order to measure strain
correctly, must be carefully bonded to the surface of the material under examination.

4. Use a range of Pressure indicating film- As subjects might have range of different forces so it would be good to use the range so that we can measure more accurately average force and maximum forces on NCCL teeth.
REFERENCES


58. Mapping the Progression of Non-Carious Cervical Lesions by Malcolm. J. Grenness, Spatial Information Sciences Group School of Geography and Environmental Science (University of Tasmania).


THE FOLLOWING WERE APPROVED:

INVESTIGATOR: John G. Bergman D.D.S., M.S.
School of Dentistry 604
1510 3rd Avenue South
Birmingham, Alabama 35204-0007

SPONSOR: MFG EXPIRY

PROTOCOL NUM: C6-07-009

AIME NO.: 2010-0006

TITLE: Clinical Evaluation of Three Dental Adhesive Systems in Class V Restorations

APPROVAL INCLUDES:
Study and investigator for an additional continuing review period. This approval expires on the date noted above.

WIRB APPROVAL IS GRANTED SUBJECT TO:

IF YOU HAVE ANY QUESTIONS CONTACT WIRB AT 1-800-261-4780

This is to certify that the information contained herein is true and correct as reflected in the records of the Western Institutional Review Board (WIRB). Should the information or the protocol be modified in any way, WIRB must be notified. WIRB accepts full responsibility for compliance with ethical and legal requirements under the U.S. Food and Drug Administration (FDA) and other regulatory agencies. WIRB certifies that it will fully comply with good clinical practices as defined under the U.S. Food and Drug Administration (FDA) regulations, and the International Conference on Harmonisation (ICH) guidelines.
CLINICAL EVALUATION OF THREE DENTAL ADHESIVE SYSTEMS IN CLASS V RESTORATIONS

Sponsor: 3M™ ESPE™, St Paul, MN, USA  
Study ID: 3M ESPE #CR-07-009  

Document Date: 15 October 2009  
Document Version: 2 (study extension)  

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RESEARCH SUBJECT INFORMATION AND CONSENT FORM

TITLE: “CLINICAL EVALUATION OF THREE DENTAL ADHESIVES IN CLASS V RESTORATIONS”

PROTOCOL NO: CR-07-009

SPONSOR: 3M ESPE

INVESTIGATOR: Dr. John O. Burgess

SITE: UAB School of Dentistry

STUDY RELATED PHONE NUMBER(S): 205-996-5795

SUMMARY
You are being asked to volunteer as a participant in a research study. This written material is designed to provide you with the information about this study and to answer any related questions or concerns you might have. If you decide to be in this study then change your mind, you can leave the study at any time. You will be in this study for about 3 years and have 6 study visits. The consent form may contain words or language you do not understand. Please ask the study doctor or the study staff to explain any words or information you do not clearly understand.

PURPOSE OF THE STUDY The purpose of this study is to evaluate the efficacy and the clinical success of adhesives used to bond tooth colored fillings placed in notched out areas on the sides of your teeth. This study will compare three adhesives used to hold white tooth colored filling materials on teeth.

DESCRIPTION OF THE STUDY AND PROCEDURES This study will recruit 45 patients to place 135 dental restorations using signs posted in the dental school and from newspaper advertisements. To be eligible for the study you must need a filling on the sides of three teeth. This study will place a filling on the side of your tooth next to the gum of your tooth. We will measure the biting force you can make on your teeth using a small piece of plastic which slips between your teeth. You will be instructed to bite on
this material and after making several jaw movements the plastic will be removed. The fillings will be placed like other fillings you may have had. You will be given a shot in the mouth to numb the teeth. The teeth to be filled will be isolated with a square piece of rubber, which slips around the tooth and is clamped to the tooth to prevent saliva from contacting the filling. Some drilling with a high-speed drill will be necessary to remove the decay and prepare the tooth. Then the tooth colored filling material will be placed into the cavity. The filling will then be polished. These filling appointments will last about two hours and normally one appointment will complete the fillings. Sometimes a second appointment may be necessary if the fillings are very large. You will be asked to return for an evaluation of these fillings about 1 week after placement and also at 6 months, 1 year, 2 years, and 3 years after placement. These recall appointments will last about 30 minutes and include making an impression (or mold) of your teeth, completing a data sheet, testing the filled teeth with an ice stick to see if restoration is sensitive and taking photographs and x-rays of the fillings.

**RISKS AND DISCOMFORTS**

You may have discomfort from these dental procedures since some drilling will be done, but the discomfort should not be greater than you would have with any filling. There is also a possibility that you may be allergic to a local anesthetic (the solution used in the numbing shot) given to you. Although a true allergy is very rare it is possible.

**NEW FINDINGS**

You will be told about any new information that might change your decision to be in this study.

**BENEFITS**

The new composite filling material is bonded in three ways. Two of these adhesives are new and use fewer steps than the older but very successful adhesive. The manufacturer wants to know if one of these adhesives materials provides a better more long lasting filling. It may be that they are the same. While these fillings will be placed into teeth needing a filling, there are no guarantees that any subject will benefit from these procedures.

**COSTS**

There will be no costs for the fillings placed in this study.

**PAYMENT FOR PARTICIPATION**

You will receive a dental exam and three dental fillings for participating in this study. In addition you will receive 30 dollars at each recall examination (6 months and 1, 2, and 3 years) for partial reimbursement of traveling and parking expenses. If you are injured as
a result of being in the study, medical care will be provided. You will be responsible for all charges and we will not be able to give you money if you are injured.

**ALTERNATIVE TREATMENT**
If you do not wish to take part in this study, you may seek treatment of defective teeth at your own cost through a private office or you can elect not to have your teeth filled. If you elect not to have your teeth filled, the lesion may get worse with time.

**AUTHORIZATION TO USE AND DISCLOSE INFORMATION FOR RESEARCH PURPOSES**
Federal regulations give you certain rights related to your health information. These include the right to know who will be able to get the information and why they may be able to get it. The study doctor must get your authorization (permission) to use or give out any health information that might identify you. If you choose to be in this study, the study doctor will get personal information about you. This may include information that might identify you. The study doctor may also get information about your health including:

- Past and present medical records
- Records about your study visits

Information about your health may be used and given to others by the study doctor and staff. The dental records related to this study are also available to the sponsoring agency (3M ESPE), the Food and Drug Administration, and the IRB.

- Information about you and your health, which might identify you, may be given to:
  - The U.S. Food and Drug Administration (FDA)
  - Department of Health and Human Services (DHHS) agencies
  - Governmental agencies to which certain diseases (reportable diseases) must be reported
  - The University of Alabama at Birmingham - The physicians, nurses and staff working on the research protocol (whether at UAB or elsewhere); other operating units of UAB, the UAB IRB and its staff.
  - The Western Institutional Review Board® (WIRB®)
  - The billing offices of UAB and UAB Health Systems affiliates

**Why will this information be used and/or given to others?**
Information about you and your health that might identify you may be given to others to carry out the research study. The sponsor will analyze and evaluate the results of the study. In addition, people from the sponsor and its consultants will be visiting the research site. They will follow how the study is done, and they will be reviewing your information for this purpose.
The results of this research may be published in scientific journals or presented at medical meetings, but your identity will not be disclosed.

The information may be reviewed by WIRB®. The WIRB is a group of people who perform independent review of research as required by regulations.

Information may be shared with the UAB or UAB Health System affiliates billing services. This would be done so that the sponsor or your insurance can be appropriately billed for certain study activities.

**What if I decide not to give permission to use and give out my health information?**
By signing this consent form, you are giving permission to use and give out the health information listed above for the purposes described above. If you refuse to give permission, you will not be able to be in this research.

**May I review or copy the information obtained from me or created about me?**
You have the right to review and copy your health information. However, if you decide to be in this study and sign this permission form, you will not be allowed to look at or copy your information until after the research is completed.

**May I withdraw or revoke (cancel) my permission?**
You may withdraw or take away your permission to use and disclose your health information at any time. You do this by sending written notice to the study doctor. If you withdraw your permission, you will not be able to continue in this study.

When you withdraw your permission, no new health information which might identify you will be gathered after that date. Information that has already been gathered may still be used and given to others. This would be done if it were necessary for the research to be reliable.

**Is my health information protected after it has been given to others?**
If you give permission to give your identifiable health information to a person or business, the information may no longer be protected. There is a risk that your information will be released to others without your permission.

**COMPENSATION FOR INJURY**
If you are injured as a result of a research procedure used in this study you will be treated. In the event of such injury, treatment is provided, but is not provided free of charge. You or your medical insurance will be billed for the cost of such treatment.

**VOLUNTARY PARTICIPATION AND WITHDRAWAL**
Participation is voluntary. Subjects may choose not to participate or may discontinue participation at any time without penalty or loss of benefits and without affecting your future medical care at this facility. The study doctor or the sponsor may, without your consent, terminate your participation in this study at any time. If significant new findings develop during the course of the research which may relate to the subject’s willingness to continue participation that information will be provided to the subject.

**SOURCE OF FUNDING FOR THE STUDY**
The study doctor (investigator) is being paid by 3M ESPE to conduct this research.

**QUESTIONS**
If you have any questions about this study or your participation in it, or if at any time you feel you have experienced a research-related injury contact Dr. John O. Burgess at 205-996-5795 or e mail at JBurgess@UAB.edu. Or you can contact Ms. Latara Rogers at 996-5747 or e mail mz.tara@uab.edu

If you have questions about your rights as a research subject, you may contact:

- Western Institutional Review Board® (WIRB®)
  3535 Seventh Avenue, SW
  Olympia, Washington 98502
  Telephone: 1-800-562-4789.

or

Ms. Sheila Moore, Director of the Office of the UAB Institutional Review Board for Human Use (IRB). Ms. Moore may be reached at (205) 934-3789 or 1-800-822-8816, press the option for operator/attendant and ask for extension 4-3789 between the hours of 8:00 a.m. and 5:00 p.m.CT, Monday through Friday.

If you agree to participate in this study, you will receive a signed and dated copy of this consent form for your records.

**CONSENT**
I have read the information in this consent form (or it has been read to me). All my questions about the study and my participation in it have been answered. I freely consent to participate in this research study.
I understand that by signing this form I am agreeing to participate in this dental fillings study and the required follow up visits at 6 months and 12 months after the first (baseline) appointment.

I authorize the use and disclosure of my health information to the parties listed in the authorization section of this consent for the purposes described above.

By signing this consent form I have not waived any of the legal rights that I otherwise would have as a subject in a research study.

______________________________
Subject Name

CONSENT SIGNATURE:

____________________________________
Signature of Subject                      Date

Signature of Legally Authorized Representative
(When applicable)                       Date

Authority of Subject’s legally Authorized Representative or Relationship to Subject (when applicable)

____________________________________
Signature of Person Conducting Informed Consent Discussion                      Date

____________________________________
Witness                                     Date
Use the following only if applicable

If this consent form is read to the subject because the subject is unable to read the form, an impartial witness not affiliated with the research or investigator must be present for the consent and sign the following statement:

I confirm that the information in the consent form and any other written information was accurately explained to, and apparently understood by, the subject. The subject freely consented to participate in the research study.

__________________________  _______________________
Signature of Impartial Witness  Date

Note: This signature block cannot be used for translations into another language. A translated consent form is necessary for enrolling subjects who do not speak English.
APPROVAL TO BE INCLUDED IN STUDY

From: Bailey Ramsdell [mailto:bramsdell@wirb.com]  
Sent: Thursday, July 21, 2011 4:23 PM  
To: Laura M Merrill  
Subject: RE: WIRB PRO NUM 20072058

Laura Merrill  
University of Alabama Birmingham  
Sponsor: 3M™ ESPE™  
Sponsor Pr #: CR-07-009  
WIRB Pr #: 20072058  
WIRB Study #: 1095223  
Investigator: Burgess, John O.

Dear Ms. Merrill;

Thank you for your inquiry. I can confirm that Dr. Shreya Shah has been included as a sub-investigator for Dr. Burgess’s above-referenced study since February 18, 2011.

If you have any questions, please e-mail, or contact WIRB at 800-562-4789 and a Client Services representative will be able to assist you.

Sincerely,

Bailey Ramsdell | Client Services Specialist  
Office: (800) 562-4789 | Fax: (360) 252-2498  
| www.wirb.com

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