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The Use of NaI As A Novel Radiographic Contrast Material For Differentiating
Between Cavitated and Non-cavitated Interproximal Carious Lesions

By
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A THESIS
Submitted to the Faculty of the Graduate School in partial fulfillment of the
requirements for the Degree of Master of Oral Biology in the Department of Oral
Biology.

Omaha, Nebraska
March 29th 2012
Abstract

In managing dental caries, the ability to distinguish between non-cavitated and cavitated lesions is crucial since the former can be treated by non-surgical methods. Interproximal caries relies mostly on radiographic assessment and current methods are unable to distinguish between non-cavitated and cavitated lesions. The goal of this research was to determine by an in vitro pilot study if a concentrated aqueous solution of sodium iodide applied topically to the interproximal surfaces of extracted teeth can discriminate radiographically between non-cavitated and cavitated natural carious lesions. Human pre-molar extracted teeth stored in thymol were collected in the Omaha area. 12 sound, cavitated, and non-cavitated white spot lesion surfaces were used for the experiment. Control exposures were made using Gendex Gx-770, 70 kVp, 0.1 secs, 7 mA with the digital intraoral sensor, XDR radiology (Cyber Medical Imaging, Los Angeles, CA), 8 cm source to digital sensor, 6 mm center of tooth to sensor. A 9 molar solution of sodium iodide (NaI) in distilled water was made and placed on the interproximal surfaces of the test teeth. Teeth were radiographed and two authors read the images for the presence or absence of opaque regions after NaI application compared to controls. The non-decalcified teeth were sectioned using a diamond saw (Scientific Fabrications, Littleton, CO, USA) and photographed dry (Olympus DP71, 12.5 megapixel camera) mounted on a stereomicroscope. Presence of caries determined visually. It was determined that 11 of 12 cavitated lesions had radiopacities but not the non-cavitated or sound surfaces. The results indicated that a concentrated solution of NaI quickly produces a radiopaque region in cavitated but not in non-cavitated or sound teeth.
Acknowledgements

I would like to thank my advisor, Dr. Sonia Sanchez for her invaluable support and advice throughout the course of this research. Along with Laura Sheetz and Sabrina who helped me navigate the lab. I would also like to thank my mentor, Dr. Douglass Benn for his time and guidance by which I learned a great deal. I would like to thank Dr. James O’Meara for his instruction on sectioning teeth as well as Dr. Laura Barritt for her advice on the histology of caries. Also, Dr. Wayne Barkmeier for his help with electron microscopy. I am also grateful to the surgeons and staff at Premier Oral Surgery, and the Oral Surgery Associates of Omaha for the extracted teeth necessary for this research.

The Department of Oral Biology at Creighton University School of Dentistry generously provided me with the resources and knowledge necessary to complete this research. Their support put a lasting impression on my education that I will benefit from throughout my career.

I must also thank my wife, Katie, for the unwavering love and encouragement that keeps me going every day. Additionally, I thank my parents for their support and inspiration that has allowed me to achieve my goals.
Table of Contents

I. INTRODUCTION .................................................................................................................1
   A. HYPOTHESIS ..................................................................................................................1
   B. DEFINITION OF DENTAL CARIES & STAGES OF PROGRESSION..............................2
   C. TRADITIONAL DIAGNOSTIC TECHNIQUES ..................................................................4
   D. SUMMARY .....................................................................................................................8

II. MATERIALS & METHODS .................................................................................................9
   A. TOOTH SELECTION .......................................................................................................9
   B. X-RAY SENSOR AND SPECIMEN HOLDER DEVICE ....................................................9
   C. SODIUM IODIDE (NAI) ...............................................................................................10
   D. NAI APPLICATION AND X-RAY PROCEDURE ...........................................................11
   E. TOOTH SECTIONING .....................................................................................................11

III. RESULTS & DISCUSSION ...............................................................................................12
   A. TOOTH ANATOMY ........................................................................................................12
   B. NAI CONCENTRATION TEST ......................................................................................13
   C. SOUND SURFACES .....................................................................................................15
   D. NON-CAVITATED CARIOUS SURFACES ....................................................................18
   F. NAI ALLOWS FOR DIFFERENTIATION BETWEEN CAVITATED & NON-CAVITATED
      LESIONS .......................................................................................................................24

IV. CONCLUSION ..................................................................................................................29

V. CITATIONS .......................................................................................................................30
LIST OF FIGURES AND TABLES

FIGURE 1: Radiolucency scores used to classify interproximal caries ............ 17

FIGURE 2: Representative specimens for sound, non-cavitated white spot lesion, and cavitated teeth ................................................................. 19

FIGURE 3: Tooth holder device .................................................................... 20

FIGURE 4: A radiographic tooth anatomy .................................................... 22

FIGURE 5: NAI concentration test ................................................................. 24

FIGURE 6: Sound tooth specimen #1 .......................................................... 26

FIGURE 7: Sound tooth specimen #2 .......................................................... 27

FIGURE 8: Non-cavitated carious specimen #1 .......................................... 29

FIGURE 9: Non-cavitated carious specimen #2 .......................................... 30

FIGURE 10: Cavitated specimen #1 ............................................................. 32

FIGURE 11: Cavitated specimen #2 & Non-cavitated carious specimen #3 ......... 33

FIGURE 12: Cavitated specimen #3 (0.3 mm cavity depth) ................................ 35

FIGURE 13: Electron micrograph image of 0.3 mm cavitation ...................... 36

FIGURE 14: Cavitated specimen #4 (50 micron cavitation) .......................... 37

TABLE 1: Results of NAI radiographic assessment .................................. 38
I. Introduction

A. Hypothesis

Dental caries is a significant oral health problem that affects 60-90% of school children and a majority of adults in most industrialized countries (World Oral Health Report, 2003). The prevalence of caries, however, does not exhibit a uniform distribution; it is affected by socio-economic status, race-ethnicity, and age of the population. For instance, 15 year-old adolescents in the United States, who have a lower socioeconomic status, exhibit higher caries scores than do their wealthier counterparts (Fejerskov & Kidd, 2008). Moreover, the mean Decayed Missing Filled (DMF) scores, particularly in a lower socioeconomic population, increases with age (Fejerskov & Kidd, 2008). Consistent with an irregular distribution of caries prevalence among different population groups, it has been shown that the disease is becoming less common in certain areas of the world. In industrialized countries, a steady decline in caries prevalence has been observed since the 1960’s (Fejerskov & Kidd, 2008). Although this decline in caries prevalence among wealthier countries is a positive sign, it also brings some unique challenges for General Dental Practitioners (GDPs) working in underprivileged areas worldwide. These challenges are directly related to the skewed distribution of caries within a population. For example, in data obtained from a national Scottish sample of 14 year olds it was found that nine percent of individuals sampled carried the greatest burden of 30 percent of the DMF surfaces for the entire country (Pitts & Kidd, 1992). In spite of its decline among wealthy populations, the high incidence of caries in low-income groups and
underdeveloped countries supports the need for the development of inexpensive and accessible diagnostic methods to supplement the work of GDPs around the world. The current tools at the GDPs disposal are inadequate to make the choice between surgical intervention and non-surgical method of caries treatment. Dental radiography has a great degree of specificity, but lower sensitivity. This affects caries diagnosis resulting in more false negative than false positive diagnoses, potentially causing irreversible damage to a healthy tooth (Dove, 2001). The application of a radio-contrast material, such as sodium iodide, between the interproximal surfaces of the teeth before taking x-rays could give the GDP the necessary diagnostic tool in order to make the critical decision for surgical or non-surgical treatment of a tooth by giving them the ability to determine between cavitated and non-cavitated surfaces conclusively.

Here, we present for the first time the preliminary studies that could lead to the development of a novel method to diagnose caries in cavitated and non-cavitated interproximal carious lesions. This work was based on the hypothesis that application of sodium iodide to interproximal tooth surfaces will produce radio-opacity in cavitated specimens, but not in non-cavitated lesions and sound surfaces on x-ray assessments. We have designed specific experiments and gathered a substantial amount of data supporting this hypothesis, which will be presented in this thesis.

B. Definition of Dental Caries & Stages of Progression

Dental caries are defined as the “signs and symptoms of a localized chemical dissolution of the tooth surface caused by metabolic events taking place in the biofilm
(dental plaque) covering the affected area” (Fejerskov & Kidd, 2008). As oral bacteria develop a biofilm on a tooth surface, acids are produced that dissolve the inorganic hydroxyapatite crystals that form the outermost surface of the tooth called enamel. The tooth surface maintains a dynamic equilibrium with the saliva and intraoral fluids that changes the pH within the oral cavity (Featherstone, 2008). Thus, the fluctuation between a basic and acidic environment will influence the dissolution and redeposition of minerals and therefore caries progression may be stopped or continued at any stage of development (Nyvad & Fejerskov, 1997). The first stage of caries is the white-spot lesion, which is defined as an early or incipient stage of caries (Featherstone, 2008). These lesions are further classified as active (continuing loss of mineral) or arrested (cessation of mineral loss with possible remineralization) depending on the stage of carious development. On the interproximal surface (the contacting surfaces between two adjacent teeth), white-spot lesions usually appear as white kidney-shaped defects directly below the interdental facet (or the contact point between two neighboring teeth) (Silverstone, 1982). Histologically, the white-spot lesion is a conical defect with its base at the surface of the tooth (Spouge, 1973). The particular histological shape of the lesion is explained by the arrangement of rod and interrod enamel. When caries progresses through the enamel it will travel along the direction of the rods and form four distinct zones (Spouge, 1973). The zones attributed to the interproximal white-spot lesions are as follows: The relatively intact surface zone (zone 1), the body of the lesion (zone 2), the dark zone (zone 3), and the translucent zone (zone 4). The surface zone typically has a pore volume of 1% while the body of the lesion—which is deep to the surface layer and superficial to the dark
zone—exceeds 5% in porosity. The dark zone lies just superficial to the translucent zone and has a pore volume of 1-2%. The translucent zone, which is the deep advancing front of the lesion, exhibits slightly more than 1% pore volume (Hicks & Silverstone, 1985). These zones in the white-spot lesion appear without an actual surface cavitation (or hole). Mineral loss will occur during the progression of the caries to render the tooth porous, but enough mineral structure will still remain on the surface to consider it non-cavitated (Silverstone, 1982). However, after enough time has passed the surface enamel may break down due to attrition and form an actual cavitation in the surface of the tooth. One study found that it took an average of one and half years before an actual surface cavitation developed (Wenzel, 2004). Studies have shown that at any point of caries development the lesion can be arrested if the site of demineralization is kept clean to where the plaque-tooth interface favors redeposition of minerals (Nyvad & Fejerskov, 1997). Indeed, the fact that a lesion can be stopped during its progression should play an important role in the treatment decisions made by GDPs.

C. Traditional Diagnostic Techniques

Currently, caries diagnosis in the clinic has been traditionally limited to visual/tactile examination in combination with radiographic assessment (Wenzel, 2004). Clinical examination is commonly performed using a dental mirror to hold the cheek away from the patient’s teeth and involves the use of a sharp probe to remove plaque—and to detect demineralization by minute vibrations felt by the examiner’s fingers (Hamilton & Stooky, 2005). The use of a probe does not directly detect the
presence of caries but the friction of withdrawal from a pit or fissure; therefore it is an invalid test for caries. In contrast, radiographic diagnosis is a valid method and provides a direct measure of the relative densities of sound and demineralized enamel and dentin. Caries is detected because there is a decrease in mineral content as the lesion progresses, which allows more of the x-ray photons to pass through to the sensor, thereby resulting in a radiodensity on the x-ray sensor (Dove, 2001). While visual examination may provide the practitioner with a quick and inexpensive method of caries detection, its use as a standalone method is known to be unreliable due to its low diagnostic accuracy when compared to radiography (Selwitz et al, 2007). In a recent study, 3,162 teeth from 200 college students were examined visually as well as radiographically. About fifty percent of all the carious lesions went undetected using clinical examination. On another hand, the extra diagnostic yield of bitewing radiographs was 105%, as determined by dividing the number of additional carious surfaces detected with bitewings by the number of carious teeth found by clinical examination alone (Chu, 2008). Some extra diagnostic yields that have been reported by other researchers can be as high as 324% (Hopcraft, 2005). In addition to the low diagnostic yields of clinical examination alone, the use of a probe can cause irreversible damage to the surface layer of an incipient (non-cavitated) lesion and may cause it to progress more rapidly (Fejerskov & Kidd, 2008), (Kühnisch, 2007). Furthermore, the use of the dental probe as well as direct visual examination is challenging for interproximal caries diagnosis simply because of its inaccessible location. To overcome this difficulty, temporary tooth separation has been suggested as an inexpensive and reliable way of examining the interproximal tooth surfaces. In
this method, orthodontic elastomeric separators are applied between the contact points of teeth and left in for one week until the space is sufficient for visual inspection and probing (Seddon, 1989). Temporary tooth separation has been found to be as reliable as bitewing radiography (Pitts & Kidd, 1991), (Mariath, 2007), (Seddon, 1989). The small space between the teeth does not allow complete visualization of the surfaces so that unlike histological examination, which is the gold standard, tooth separation is considered a silver standard as it is less accurate (Mariath, 2007). Tooth separation also gives some discomfort to the patient and requires an inconvenient second visit to the dentist. Hence, temporary tooth separation is not recommended for routine use in general practice (Wenzel, 2004).

Radiography poses no threat to the integrity of the tooth surfaces and radiographs can be taken quickly within a dental visit. It is agreed that radiography is a more sensitive diagnostic tool than clinical inspection for interproximal caries into the dentin (Wenzel, 2004). Bitewing radiography also has a high specificity for interproximal cavitated lesions reaching into dentin ranging from 92% to 99% (Bader, 2002). Specificity is defined as the percentage of sound teeth that are correctly diagnosed as not exhibiting a disease. On the other hand, sensitivity is defined as the actual percentage of lesions that are correctly diagnosed as such. Although there is a high specificity associated with bitewing radiography its sensitivity is quite low. The sensitivity of radiographs depends in part on the depth of the lesion. As shown in a number of studies, (Nielsen et al., 1996) (Bille & Thylstrup, 1982), bitewing radiography partially determines the extent of mineral loss and not the presence or absence of cavitation. The radiographic sensitivity to assess cavitated lesions reaching
into the dentin ranged from 16-63% (Bader, 2002). For interproximal enamel only lesions the sensitivity of non-cavitated lesions was about 15% and cavitated about 25% (Bottenberg, 2011).

The probability associated with radiographic depth for finding cavitation is measured in scores, which varies from 1% to nearly 100% depending on the radiolucency score (R), see figure 1 (Mejàre et al., 1985). An R0 score has a 1% chance of having cavitation whereas an R1 and R2 would have 11% and 31% chances of exhibiting cavitation respectively. It has been shown that teeth exhibiting R3 and R4 radiolucencies are nearly 100% certain to have a cavitation (Mejàre et al., 1985). Nevertheless, shadow depth can provide an unreliable threshold for diagnosis particularly because the depth of radiographic shadows can be altered by small changes in the irradiation geometry (Benn, 1989). Since cavitation is generally the diagnostic threshold that determines if a tooth needs surgical treatment, it is of utmost importance that the GDP is able to distinguish between cavitated and non-cavitated caries with a high degree of accuracy.

Figure 1: Radiolucency scores used to classify interproximal caries (Stenlund et al., 2003).
D. Summary

Current diagnostic techniques for caries at the GDPs disposal are inadequate and to some extent invalid. The sensitivity of bitewing radiography for detecting cavitated lesions is only 25% (Bottenburg et al., 2011). It is the aim of this research to improve the sensitivity of bitewing radiography by using NaI as a contrast agent. This research will provide the groundwork for clinical trials in the near future.
II. Materials & Methods

A. Tooth Selection

Teeth were collected from oral surgeons around the Omaha, Nebraska area. Twelve non-cavitated, twelve cavitated, and twelve sound interproximal surfaces of mostly premolars, some molars, and one canine were selected for the experiment (see figure 2 for representative teeth specimens). The teeth were stored in 1g/L thymol solution (Cat No. T0501, Sigma-Aldrich, St. Louis, MO). Photomicrographs were taken of the mesial, distal, buccal, lingual, and occlusal surfaces of each specimen with a camera (Olympus DP71, 12.5 megapixel cooled CCD camera) mounted on a stereomicroscope (Leica S8APO).

Figure 2: Representative specimens for sound, non-cavitated white spot lesion, and cavitated teeth respectively.

B. X-ray Sensor and specimen holder device

In order to create reproducible x-ray images, a sensor and tooth holder were fashioned. The system consisted of a rubber tooth mold and a water filled plastic cassette with a 1 cm depth, in order to simulate the x-ray scattering effect of a
patient’s cheek. A plastic x-ray aiming ring was also attached to the holder device to achieve a reproducible distance from the end of the collimator in the x-ray machine. Rubber molds for each tooth specimen was made by filling the designated tooth slot in the specimen holder device with Permadyne Garant 2:1 impression paste. The desired specimen was placed in the paste as well as two flanking non-experimental teeth and allowed to harden after 5 ½ minutes (see figure 3).

![Figure 3: Bird's eye view of tooth holder device inside the x-ray machine](image)

C. **Sodium Iodide (NaI)**

Iodine is an essential trace mineral found in fish and iodized salt and is necessary for the synthesis of thyroid hormones (Coakley & Panicek, 1997). Sodium iodide was first introduced as a radiographic contrast agent in the 20th century by Egas Moniz to develop angiography (Ligon, 2003). NaI solutions at 3 Molar (M), 6M, and 9M were tested (Cat No. 409286, Sigma-Aldrich, St. Louis, MO). NaI solutions at different concentrations were applied topically to cavitated, non-cavitated, and sound tooth surfaces with flocked applicator tips (DENTSPLY DeTrev
GmbH, Konstanz, Germany). Radiographs were taken 10 seconds after application. See figure 3 for representative tooth specimens.

D. **NaI application and x-ray procedure**

For every specimen the tooth was dried for 5 minutes and a control x-ray was taken by placing the tooth in the premade mold with the mesial and distal surfaces parallel to the x-ray beams and placed into the x-ray machine (Gendex Gx-770, 70 kVp, 0.1 secs, 7 mA) with the digital intraoral sensor #1, XDR radiology (Cyber Medical Imaging, Los Angeles, CA) 8 cm away from the end of the collimator. The specimen was then irradiated while the tooth itself was 7 cm away from the end of the collimator and 6 mm away from the digital sensor. After the control x-ray was taken a flocked applicator tip was dipped in 9 M NaI solution and applied lightly by touching the tip of the applicator directly on the lesion. For sound surfaces, the NaI was applied right below the interdental facet. The tooth was then quickly placed in the pre-made mold in the holder device and x-rayed at 10 seconds and again at 2 minutes after NaI application. The tooth was then rinsed under running tap water and placed back in its thymol container. The tooth x-ray was viewed with the XDR digital systems software (Cyber Medical Imaging, Los Angeles, CA).

E. **Tooth Sectioning**

Experimental and control (sound) teeth were sectioned through the mesial-distal plane perpendicular to the lesion or interdental facet, respectively using a SCIFAB Series 1000 Deluxe Hard Tissue Microtome (Scientific Fabrications, Littleton, CO, USA). For specimens with areas of interest on both the mesial and
distal surface the tooth was sectioned first through the buccal-lingual plane and then through the mesial-distal plane of both halves. Care was taken to cut just to one side of the lesion so as not to destroy the lesion surface. Sectioned teeth were photomicrographed. Histological assessment of photomicrographs allowed for evaluation and confirmation of tooth classification (i.e., cavitated, non-cavitated, or sound).

III. Results & Discussion

A. Tooth Anatomy

On a radiographic image several anatomical regions of the tooth are visible. Regions of enamel, dentin, and the pulp chamber are visible in figure 4.

Figure 4: A radiographic image of a pre-molar tooth showing regions of enamel, dentin, and the pulp chamber.
B. NaI Concentration Test

To determine the concentration of NaI to be used, 3 different concentrations were tested: 3, 6, and 9M. Contrasting with the 9M, 3M and 6M NaI subsurface radio-opacities were less dense and did not give sharp images (figure 5). Therefore, the 9M NaI was chosen for the remaining experiments.
Figure 5: A) A control radiograph (without application of NaI). B) As indicated by the circle on the interproximal surface 3M NaI was applied to the cavitation before the radiograph was taken. A slight radio-opacity was visible. C) An increase in radio-opacity was observed when 6M NaI was applied to the interproximal surface indicated by the circle. D) 9M NaI resulted in a more obvious radio-opacity than the 3M and 6M NaI concentrations. The arrow in A indicates a metal filling present in images A-D that shows as a large radio-opacity.
C. **Sound Surfaces**

Sound tooth surfaces do not uptake NaI and as such do not produce a subsurface radio-opacity after application of NaI to the interproximal surface (Figures 6 and 7).
Figure 6: A) Photomicrograph showing the sound mesial surface of a pre-molar tooth.  B) Histology of the same pre-molar that confirmed the sound condition of the tooth surface (dotted arrow)  C) Control radiograph of the pre-molar (dashed arrow).  D) Radiographic test of the pre-molar after application of the NaI.  Indicated by the solid arrow, there is pooling of NaI due to excess resting on the tooth surface.  This resulted in a supra-surface radio-opacity.  There was, however, no subsurface opacity visible in the radiograph.  This provided evidence that NaI does not soak into the surface of a sound tooth specimen and confirmed the tooth to be non-cavitated.  Bar= 3mm.
Figure 7: A) Photomicrograph of the mesial surface of a sound molar. The area of interest is indicated by the oval shape (A) and distal (B). White highlights indicated by the dashed arrows are caused by the light reflecting off the tooth surface during photography and are not carious lesions. C) Histology of the molar cut through the buccal-lingual plane shows the distal surface on the left side and the mesial surface on the right side. D) Control radiograph with the arrows indicating the areas of interest. E) Experimental radiograph after application of the NaI to the areas of interest. Pooling of NaI occurred on the mesial (thick arrow) and distal (thin arrow) surfaces resulting in suprasurface radio-opacities. This provided further evidence that NaI will not produce a subsurface opacity in sound surfaces thereby confirming that NaI allows for differentiation between cavitated and non-cavitated surfaces.
D. Non-cavitated Carious Surfaces

Non-cavitated carious teeth have begun the destructive process of demineralization but are without an actual cavitation in the surface of the tooth (Spouge, 1973). Traditionally, Dentists diagnose the stage of caries by using Radiography. However, radiography detects loss of mineral content and not the presence or absence of a cavitation in the tooth surface. Therefore, a radiolucency on an x-ray image is not necessarily indicative of a cavitation but may be a radiolucent “scar” left from the demineralized area of an arrested lesion (Wenzel, 2004). For example, in Figure 9C, a radiolucent scar is visible in the control radiograph. It was confirmed to be non-cavitated because there was no subsurface radio-opacity after application of NaI (Figure 9D). Traditional radiography is not a sufficient diagnostic tool for distinguishing between cavitated and non-cavitated surfaces.
**Figure 8:** A) Photomicrograph of the mesial surface. The circle indicates the non-cavitated carious lesion of interest. B) A photomicrograph of histological section through the buccal-lingual plane. The arrow points to the non-cavitated carious lesion on the mesial side. The histology confirms the non-cavitated nature of the lesion shown in A. C) Control radiograph before NaI was applied to the non-cavitated lesion. The arrow points to the region of the lesion. D) The experimental radiograph taken after application of NaI to the non-cavitated lesion. Pooling occurred (as shown by the arrow) resulting in a convex opacity above the surface. This indicates that there is no cavitation present. Bar= 3 mm.
Figure 9: A) Photomicrograph of the mesial surface of a pre-molar. A non-cavitated lesion is present shown by the circle. B) Photomicrograph of the histology cut through the buccal-lingual plane. The white arrow shows a non-cavitated carious lesion. C) Control radiograph. The arrow points to a radiolucency on the mesial surface. D) The experimental radiograph after application of NaI. The solid arrow shows a suprasurface radio-opacity indicative of a non-cavitated surface. The dashed arrows point to small bubbles of NaI that were unintentionally on the tooth at the time of exposure. Bar= 3mm.
E. Cavitated Carious Surfaces

In order to establish NaI as an effective diagnostic tool we needed to confirm that it would give a subsurface radio-opacity to differentiate the cavitated surfaces from non-cavitated surfaces. Application of NaI to the cavitated surfaces demonstrated that it is able to soak into the cavity to give subsurface radio-opacities on the experimental radiographs (figures 10D & 11F).
Figure 10: A) Photomicrograph of the mesial surface of a cavitated pre-molar. The cavitation of interest is indicated by the circle. B) Histological section of the pre-molar with the cavitation indicated by the arrow. C) The control radiograph of the tooth with a radiolucency corresponding to the cavitation as indicated by the arrow. D) The test radiograph after application of NaI showing a subsurface radio-opacity shown by the arrow. Bar= 3mm.
Figure 11: A) Photomicrograph of a cavitated lesion on the mesial surface of a pre-molar. The cavitation is shown in the circle. B) Photomicrograph of a non-cavitated lesion of the distal surface of the same pre-molar. The non-cavitated lesion is indicated by the circle. C) The histology of the cavitation on the mesial surface indicated by the arrow. Although cavitated, the plane of section does not show the cavity, which was lost in the process of sectioning. The arrow indicates the area of the cavitation. D) The histology of the non-cavitated lesion on the distal surface of the tooth. The non-cavitated lesion is indicated by the dashed arrow. E) The control radiograph with a radiolucency corresponding to the cavitated lesion indicated by the solid arrow (mesial surface). The control radiograph also shows a radiolucency corresponding to the non-cavitated lesion indicated by the dashed arrow (distal surface). F) The test radiograph after application of NaI. The solid arrow shows a subsurface opacity on the mesial surface corresponding to the cavitation. The dashed arrow shows a suprasurface radio-opacity corresponding to the non-cavitated lesion on the distal surface. Bar= 3mm.
F. **NaI Allows For Differentiation Between Cavitated & Non-Cavitated Lesions**

The specimen in figure 11 was histologically confirmed to have one interproximal surface cavitated and the other non-cavitated. Radio-lucencies on both the mesial (solid arrow) and distal surfaces (dashed arrow) of the tooth in the control radiograph is indicative of cavitation on both surfaces. After application of NaI, however, only the mesial surface showed a subsurface radio-opacity while the distal surface did not (figure 11F). This provides evidence for the potential use of NaI as a diagnostic tool for caries. The sensitivity, specificity, and accuracy of caries diagnosis should be increased with the use of NaI. Previous data have shown that the sensitivity for non-cavitated caries confined to the enamel was only 15% and the specificity was 90% using traditional x-ray techniques (Bottenburg et al., 2011). Moreover, for cavitated caries confined to the enamel, the sensitivity increased to only 25% and the specificity remained the same at 90% (Bottenburg et al., 2011). Taken into consideration, it is fair to say that the accuracy for distinguishing between cavitated and non-cavitated lesions using traditional bitewing radiography is 58% and 53% respectively, which is only slightly better than tossing a coin. In this research we found that the 12 sound surfaces and 12 non-cavitated surfaces exhibited subsurface opacities (table 1). Furthermore, 11 of the 12 cavitated lesions did show subsurface radio-opacities (table 1). Small cavitations of 0.3 mm in depth or greater displayed visible subsurface opacities (figure 12 & 13). Nevertheless, no subsurface opacity was observed in cavitations of approximately 50 microns in diameter or smaller (figure 14). Contrasting with traditional methods, the use of NaI as a radio-contrast
material provides a sensitivity of 92%, and a specificity of 100%, which corresponds to an accuracy of 97%. In clinical practice this could mean less false negative or false positive diagnoses. Therefore, dentists could use surgical or non-surgical methods when appropriate.

**Figure 12:** A) Photomicrograph of the mesial surface of a tooth exhibiting a cavitation (circle region). B) High magnification of cavitated region. C) Control radiograph with cavitated region (arrow). D) Experimental radiograph with a subsurface radiopacity (arrow). An electron micrograph image of the small cavitation is shown in Figure 13.
Figure 13: Electron micrograph image with the cavity (circled area).

The cavitation is shown to be 0.3 mm in depth.
Figure 14: A) Photomicrograph of the mesial surface with 50 µm cavitation (circle). B) Arrow points to cavitation in sectioned tooth. C) Control radiograph of the tooth with cavity (arrow). No radiolucency is visible. D) Test radiograph of the cavitated tooth after application of NaI to the 50 µm. Arrow points to cavitated region. No radio-opacity is visible. Bar= 3 mm.
Table 1: Results of NaI radiographic assessment

<table>
<thead>
<tr>
<th>Non Cavitated Surfaces (spec#)</th>
<th>Control Lucency</th>
<th>NaI Opacity</th>
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<td>No</td>
</tr>
<tr>
<td>2 (64M)</td>
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<th>Cavitated Surfaces (spec#)</th>
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<th>NaI Opacity</th>
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IV. Conclusion

This study demonstrated a novel method for caries diagnosis. We have shown that NaI is able to distinguish between cavitated and non-cavitated teeth with 97% accuracy \textit{in vitro}. This groundbreaking research has implications for use in the dental clinic. Firstly, one could be able to detect small-cavitated caries down to 0.3 mm in depth (figure 12). Secondly, this method could be used to monitor caries progression by applying NaI at several points in time. This would allow the dentist a better understanding of their particular patient’s caries to determine if he or she should intervene surgically or not. Moreover, this diagnostic method could keep the dentist from permanently damaging the tooth surface since NaI allows for identification of non-cavitated teeth even if a radio-lucency is present in the control radiograph. On the other hand, this method allows for earlier detection of small cavities and early intervention to arrest its progression, thereby protecting the tooth from further damage.

Overall, this study provides the groundwork for \textit{in vivo} trials in the dental clinic. How the NaI will be delivered to the patient’s interproximal tooth surfaces and how the NaI will perform in the wet environment of the oral cavity are questions that remain to be answered and are beyond the scope of this thesis.
V. Citations


US Department of Health and Human Services, National Center for Health Statistics.  
