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# The Prevalence, Predictive Factors, and Classification of Intrapulpal Cracks in Maxillary Molars Requiring Endodontic Treatment

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A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Dentistry at Virginia Commonwealth University

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# Abstract

**The prevalence, predictive factors, and classification of intrapulpal cracks in maxillary molars requiring endodontic treatment**

By Husain Karashi, DDS

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Diagnosis and treatment of teeth with longitudinal fractures is challenging. Cracks are usually not visible radiographically; they require a thorough evaluation to aid in diagnosis. Patients may be asymptomatic, demanding the dentist rely on clinical findings to make a diagnosis. Early diagnosis of the presence and extent of a crack is essential for the successful management of a cracked tooth. There is limited information in the literature regarding the prevalence or predictive factors of cracks extending into the pulp chamber of teeth. The purpose of this study was to determine the prevalence of intrapulpal cracks in maxillary molars and to identify factors that may aid in diagnosing the existence of a crack. All maxillary molar teeth requiring non-surgical root canal therapy or retreatment at the Virginia Commonwealth University graduate endodontic clinic from June 2016 through December 2016 were included in the study after obtaining patient consent. Teeth were examined visually, transilluminated, stained, and examined microscopically for the presence of an intrapulpal crack. Demographic information, subjective data associated with the chief complaint, objective results of diagnostic testing (percussion, palpation, bite stick test, transillumination, probing depths, existing restorations, and diagnosis) were analyzed using chi-square and logistic regression ($p<0.05$) to identify associations of these findings with the existence of a crack. A total of 18% (15/82 teeth) of maxillary molars that were

evaluated and had endodontic treatment initiated were cracked. There was a significant association between cracked teeth and pain on biting ($P<.0001$) and with probing depths greater than 4 millimeters (mm) ($P < 0.003$). Those positive on a tooth slooth test were more likely to have an intrapulpal crack ($P<.001$) and teeth with a positive transillumination test were also found to be associated with the presence of a crack($P < .001$).

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# Introduction

Diagnosis of cracked teeth is challenging. Ritchey first described symptoms associated with cracks as pain on release of biting and unexplained cold sensitivity (1). Abou-Rass proposed masticatory pain and thermal sensitivity as symptoms associated with cracks (2). He also mentioned the possibility of the patient reporting a history of examination and/or treatment of the tooth without resolution of pain. Later, Ehrmann reported the same association between sensitivity to mastication and thermal stimulation (3). Cameron proposed the term "cracked-tooth syndrome" in 1964 describing signs and symptoms of cracked teeth (4).

Cracks are generally not visible radiographically; they require a thorough evaluation to aid in diagnosis (4). Patients may be asymptomatic, demanding the dentist rely on clinical findings to make a diagnosis. Early diagnosis of the presence and extent of a crack is essential for the appropriate management of a cracked tooth (5, 6).

It is difficult to determine the appropriate treatment options for cracks of unknown depth. Full cuspal coverage with a crown or bonded restoration has been recommended for cracked teeth with vital asymptomatic pulps (7, 8). The pulp may become symptomatic or necrotic if a fracture progresses deep into the tooth (9). If the crack extends to the pulp and/or to the radicular surface of a tooth, the treatment options might involve endodontic, periodontic, orthodontic, and/or surgical intervention. If pulpal pathosis develops, non-surgical root canal therapy may be indicated. Therefore, early diagnosis is critical for the correct management of cracked teeth (5).

In 2008 The American Association of Endodontists established a categorization and description of terms used to define cracks and fractures in teeth and suggested potential treatment guidelines (10). Cracked teeth were described as a longitudinal fracture located on the crown of a

tooth that may propagate into the root. These may arise from weakened tooth structure or destructive occlusal forces and may have variable signs and symptoms (10). The AAE system classifies cracks based on external coronal features and symptoms, and puts them into five categories.

Craze lines are the first type, which affect only the enamel surface and are common in most adult teeth. They usually cross the marginal ridge and extend along the buccal and lingual surfaces. They have no associated pain and cause no concern other than an aesthetic one. The second type is designated for teeth with fractured cusps. They might be either complete or incomplete fractures, which start from the crown of the tooth and extend apically. These fractures usually extend down into a buccal or lingual groove and include a marginal ridge. Cracked teeth are the third and most challenging type to diagnose and determine an accurate and reliable prognosis of treatment. This type of longitudinal fracture presents with either complete or incomplete extension. The fourth type of longitudinal fractures are split teeth. These are teeth with a complete fracture that starts from the crown and extends to the subgingival area and is usually directed in a mesial-distal direction including both the marginal ridges. The fifth, and last, type of longitudinal fracture classified by The American Association of Endodontists are teeth with vertical root fractures. These fractures are the only type where the fracture propagates from the root apex rather than from the crown of the tooth and most of the time these fractures have a hopeless prognosis.

The AAE system classifies cracks based on external coronal features and symptoms, without describing the internal features of cracks and involvement of the pulp when root canal therapy is necessary for the treatment of pulp pathosis that develops as a result of the cracked tooth.

Detar in 2014 proposed The Intrapulpal Crack Classification system for use when evaluating a tooth that has a crack and requires non-surgical root canal therapy. This system characterized intrapulpal cracks based on their extension on walls, orifices, and the floor of the chamber (11). The term intrapulpal suggests a direct communication from the external environment to the pulp chamber via a propagated coronal fracture.

Prevalence studies by Hiatt and Cameron discovered that the most frequently cracked teeth were mandibular molars followed by maxillary premolars and then maxillary first molars (5, 12). Teeth with restorations were more likely to have a crack (12). Lawson, in 2014, evaluated the prevalence and predictive factors of intrapulpal cracks in mandibular molars (13). His study results showed prevalence of intrapulpal cracks in mandibular molars to be 9%. Age, probing depth greater than 4mm, positive transillumination, and biting sensitivity were predictive factors for an intrapulpal crack (13). Krygowski, in 2015, reported the overall prevalence of cracks in maxillary premolars to be 20% with predictive factors being probe depths greater than 4mm and positive transillumination (14). This study was based on a similar design where information of the predictive factors and classification of intrapulpal cracks might offer a more objective determination for diagnosis, classification and treatment of cracked maxillary molars.

There is limited information in the literature regarding the prevalence or predictive factors of cracks extending into the pulp chamber of teeth. The purpose of this study was to determine the prevalence of intrapulpal cracks in maxillary molars presenting for NSRCT or ReTx at the VCU Graduate Endodontic Clinic and to identify factors that may aid in diagnosing the existence of a crack and classify these cracks using the Intrapulpal Crack Classification System.

## Materials and Methods

This study replicated the research design and methodology of the study performed by Dr. Sarah Krygowski in 2015. The only difference in the design was the study of maxillary molars rather than maxillary premolars.

This study utilized a prospective dental chart review to determine the prevalence and location of intrapulpal cracks documented during routine evaluation and endodontic treatment at the VCU School of Dentistry's Graduate Endodontic Practice. The Institutional Review Board approved the study (IRB #HM200006713). Patients referred to the practice for evaluation and treatment (NSRCT or RETX) of maxillary molars from June 2016 through December 2016 were included in the study. Patients were referred from VCU's predoctoral clinic, advanced education practice, faculty practice, or private practice. No clinical protocol was altered for this study.

The clinical protocol for treating patients with intrapulpal cracks includes gathering subjective data regarding the patient's chief complaint, symptoms, dental history, and reason for referral. The clinical diagnostic testing for all molars referred for treatment involved the following: cold test, bite test, percussion test, palpation, mobility, probing, and transillumination. All diagnostic information was recorded in the electronic dental record (axiUm Dental Software, BC Canada) along with radiographs and clinical photographs (MiPACS Dental Enterprise Solution, Medicor Imaging, North Carolina). Prior to initiating treatment, a pulpal and periapical diagnosis were made. If non-surgical root canal therapy was indicated, the treating endodontic resident explained the aims of the study and presented the patient with a consent form. Once all of the patient's questions were answered regarding the study and the patient decided to be part of

the study, the patient and resident signed the consent. All residents were calibrated to present the study and obtain consent in the same manner. If the patient declined to participate in the study, the same clinical protocol was followed but the patient's information was not included in the data analysis. If the tooth was deemed restorable by the resident, the patient was anesthetized and the tooth was isolated. The tooth was visually inspected without magnification for a crack and transilluminated. If a crack was present, the resident took a clinical photograph of the crown of the tooth at a magnification of 1.0 using an OPMI pico dental microscope (Carl Zeiss Meditec, Jena, Germany). Next, the resident accessed the tooth and inspected the pulp chamber walls and floor for a crack using the same microscope at a magnification of 1.6. (The OPMI pico microscope provides 5 magnification settings: 0.4, 0.6, 1.0, 1.6, and 2.5, which correspond to the following magnifications, depending on the focal length of the objective: 250 nm: 3.40x, 5.10x, 8.50x, 13.60x, 21.25x; 300 nm: 2.83x, 4.25x, 7.08x, 11.33x, 17.71x). The pulp chamber walls and floor were stained, using methylene blue dye, and microscopically examined for a crack. If an intrapulpal crack was present, VCU's Intrapulpal Crack Classification System was used to document the location and extent of the crack. The information gathered regarding a cracked tooth was recorded on a data sheet (Appendix) and included in the patient's electronic health record.

At the end of the study period, the information was analyzed to determine the prevalence and classification of cracks present in maxillary molars presenting to the Graduate Endodontic Practice for root canal therapy as well as any predictive clinical factors. Data was summarized using percentages, means, and standard deviations as appropriate. Comparisons were done using chi-square test or multiple logistic regressions. Significance was declared at alpha less than 0.05.

The aim of this study was to look prospectively at the prevalence and predictive factors of intrapulpal cracks in maxillary molars requiring nonsurgical endodontic treatment at the Virginia Commonwealth University Graduate Endodontic Practice and to classify these cracks using the Intrapulpal Crack Classification System.

# Results

The first section of results describes the 82 cases and the values of the variables recorded. In the second section, the associations between individual characteristics and cracked teeth are explored. In the third section, the significant associations between individual predictors for intrapulpal cracks were combined in a logistic regression to determine their joint association.

## Description of cases

Between June 13, 2016 and December 12, 2016, 78 individuals (82 cases) met the selection criteria (Table 1). Nearly 59% of the individuals were females (46 females and 32 males) and 67% of all cases were first molars (55 first molars and 27 second molars). The average age of patients was 42.0 years (SD = 18.1, range = 13 to 80 years). 40% (33) of the teeth were the most distal tooth. Teeth with no restorations comprised 15% (12/82) of the total, and the remaining 85% (70/82) exhibited a variety of restorations. Restorations included one, two, three, or four surface fillings. Full coverage crowns were seen in 21% of the teeth (17/82).

**Table 1. Description of Cases**

| Characteristic | N | Percent |
|---|---|---|
| **Tooth #** | | |
| 2 | 15 | 18 |
| 3 | 27 | 33 |
| 14 | 28 | 34 |
| 15 | 12 | 15 |
| **Most distal tooth** | | |
| N | 49 | 60 |
| Y | 33 | 40 |
| **Type of restoration** | | |
| none | 12 | 15 |
| 1 surface | 15 | 18 |
| 2 surfaces | 22 | 27 |
| 3 surfaces | 15 | 18 |
| 4 surfaces | 1 | 1 |
| crown | 17 | 21 |

Note: Percentages may not add to 100 due to rounding.

Subjective questions recorded at the initial patient evaluation are described in Table 2 along with probing depths and the provider's ability to visualize a crack at the initial visit. Only 3 cases (4%) were referred for the evaluation of a suspected crack. In 30 cases (37%) patients reported a history of pain provoked by chewing or biting.

**Table 2. Referral and Patient History**

| Characteristic | N | Percent |
|---|---|---|
| **Is this tooth being referred to you for an evaluation of a suspected crack?** | | |
| N | 79 | 96 |
| Y | 3 | 4 |
| **Does the patient report a history of pain provoked by chewing/biting?** | | |
| N | 52 | 63 |
| Y | 30 | 37 |
| **Does the resident expect to find a crack in the tooth?** | | |
| N | 65 | 79 |
| Y | 17 | 21 |
| **Are there any probing depths greater than 4 mm around the tooth?** | | |
| N | 68 | 83 |
| Y | 14 | 17 |
| **Tooth slooth positive?** | | |
| N | 62 | 76 |
| Y | 20 | 24 |
| **Can you visualize a crack, or confirm presence of an apparent crack, with transillumination?** | | |
| N | 51 | 62 |
| Y | 14 | 17 |
| NA | 17 | 21 |

Notes: Percentages may not add to 100 due to rounding. Transillumination is not applicable (NA) in teeth with crowns.

There were 26 teeth found to have necrotic pulps (32%), 42 teeth had vital pulps (51%), and 14 teeth were previously treated (17%). The apical diagnoses varied, with the majority of teeth (51%) presenting with symptomatic apical periodontitis. This clinical history is recorded in Table 3.

**Table 3. Clinical History**

| Characteristic | N | Percent |
|---|---|---|
| **Pulpal Diagnosis** | | |
| Normal | 1 | 1 |
| Asymptomatic Irreversible Pulpitis | 11 | 13 |
| Symptomatic Irreversible Pulpitis | 30 | 37 |
| Pulp Necrosis | 26 | 32 |
| Previously Treated | 14 | 17 |
| **Apical Diagnosis** | | |
| Normal | 25 | 30 |
| Symptomatic Apical Periodontitis | 42 | 51 |
| Asymptomatic Apical Periodontitis | 9 | 11 |
| Acute Apical Abscess | 1 | 1 |
| Chronic Apical Abscess | 5 | 6 |
| **Etiology** | | |
| Caries | 69 | 84 |
| Crack | 13 | 16 |

Note: Percentages may not add to 100 due to rounding.

The primary outcome of interest was the presence or absence of a cracked tooth. There were 13 teeth with intrapulpal cracks visible before staining and 15 identified by staining (18%, 95% CI = 11.4 to 28.0%).

Using the Intrapulpal Crack Classification System (Table 4), the intrapulpal cracks were categorized based on their location relative to walls and orifices. Eight teeth had a crack extending down one wall (Type Is), and seven teeth had cracks extending down two walls (Type IIs).

**Table 4. Intrapulpal Crack Classification Counts**

| | Wall(s) only | Wall(s) and orifice | Wall(s) and partially across floor | Wall(s) and across entire floor |
|---|---|---|---|---|
| 1 Wall | IA<br>N=4 | IB<br>N=1 | IC<br>N=2 | ID<br>N=1 |
| 2 Walls | IIA<br>N=2 | IIB<br>N=1 | IIC<br>N=2 | IID<br>N=2 |

Association between Clinical Predictors and Cracked Teeth

In order to test for characteristics that may be associated with a cracked tooth, the analysis proceeded in two stages. The first stage of preliminary analysis looked at the association between the outcome and each characteristic, ignoring all of the other characteristics. This preliminary analysis screened each characteristic to determine which characteristics may be included in the final analysis. In the final analysis, a multiple logistic regression was used to determine which of the successfully screened variables remain statistically significant when all the other characteristics are adjusted for.

There was no association between a tooth's cracked status and sex ($P>0.2$, Table 5) nor was there an association with tooth type ($P>0.9$). Age was related to cracked status ($P<0.03$), with older individuals being more likely to have intrapulpal cracks. There was no evidence for an association with the size of the restoration ($P>0.9$). There was an apparent association with pain on biting ($P<.0001$) and with probing depths greater than 4 millimeters (mm) ($P < 0.003$). Those teeth positive on a tooth slooth test were more likely to have intrapulpal crack ($P<.001$) and a transillumination positive test was associated with the presence of a crack ($P < .001$).

**Table 5. Screening predictive characteristics**

| | Cracked status (n %) | | | | |
|---|---|---|---|---|---|
| Characteristic | Intrapulpal crack | | No crack | | Total |
| **Gender** | | | | | |
| F | 11 | 22.4% | 38 | 77.6% | 49 |
| M | 4 | 12.1% | 29 | 87.9% | 33 |
| Chi-square P = 0.2257 | | | | | |
| **Age** | | | | | |
| 10 - 19 | 0 | 0.0% | 9 | 100.0% | 9 |
| 20 - 29 | 0 | 0.0% | 14 | 100.0% | 14 |
| 30 - 39 | 2 | 9.5% | 19 | 90.5% | 21 |
| 40 - 49 | 3 | 30.0% | 7 | 70.0% | 10 |
| 50 - 59 | 4 | 30.8% | 9 | 69.2% | 13 |
| 60 - 69 | 5 | 45.5% | 6 | 54.5% | 11 |
| 70+ | 1 | 25.0% | 3 | 75.0% | 4 |
| Chi-square P = 0.0291 | | | | | |
| **Tooth Type** | | | | | |
| M1 | 10 | 18.2% | 45 | 81.8% | 55 |
| M2 | 5 | 18.5% | 22 | 81.5% | 27 |
| Chi-square P = 0.9705 | | | | | |
| **Restored Surfaces** | | | | | |
| none | 2 | 16.7% | 10 | 83.3% | 12 |
| 1 surface | 4 | 26.7% | 11 | 73.3% | 15 |
| 2 surfaces | 4 | 18.2% | 18 | 81.8% | 22 |
| 3 surfaces | 2 | 13.3% | 13 | 86.7% | 15 |
| 4 surfaces | 0 | 0.0% | 1 | 100.0% | 1 |
| crown | 3 | 17.6% | 14 | 82.4% | 17 |
| Chi-square P = 0.9448 | | | | | |
| **Pain on Biting?** | | | | | |
| N | 2 | 3.8% | 50 | 96.2% | 52 |
| Y | 13 | 43.3% | 17 | 56.7% | 30 |
| Chi-square P = <.0001 | | | | | |
| **Probing > 4mm** | | | | | |
| N | 8 | 11.8% | 60 | 88.2% | 68 |
| Y | 7 | 50.0% | 7 | 50.0% | 14 |
| Chi-square P = 0.0022 | | | | | |
| **Tooth slooth Pos** | | | | | |
| N | 3 | 4.8% | 59 | 95.2% | 62 |
| Y | 12 | 60.0% | 8 | 40.0% | 20 |
| Chi-square P = <.0001 | | | | | |
| **Transillumination** | | | | | |
| N | 1 | 2.0% | 50 | 98.0% | 51 |
| Y | 11 | 78.6% | 3 | 21.4% | 14 |
| NA | 3 | 17.6% | 14 | 82.4% | 17 |
| Chi-square P = <.0001 | | | | | |

Adjusted Analyses

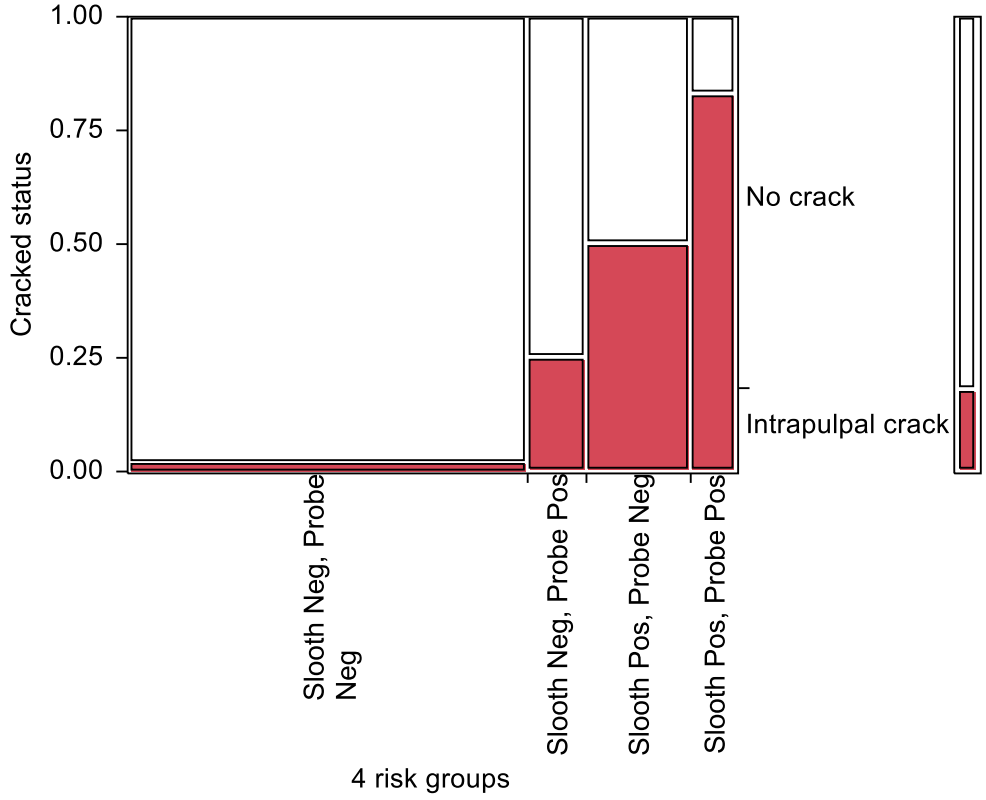
All of the previous analyses looked at the relationship of a single predictor to the outcome of interest. The following characteristics were found to be related to cracked teeth when all other characteristics were ignored: age, pain on biting, probing depth, tooth slooth positive, and transillumination. Since transillumination was thought to be an outcome essentially similar to cracked status, it was not included in the multiple logistic regressions. A logistic regression analysis indicated that, after accounting for the other factors, age (P=0.186) and pain on biting (P=0.3668) were not significantly related to cracked status. Two factors remained statistically significant when considered together, tooth slooth positive (P<.0001) and pocket depths greater than 4mm (P=0.0154, Table 6). Note that in 85% of cases, the tooth slooth test and pain on biting were the same (70/82) but the tooth slooth test proved to be more associated with a cracked status.

The bar on the right of Figure 1 shows the prevalence of cracks overall. The largest proportion is no crack (the white area, approximately 82%). These proportions vary by the results of the tooth slooth test and probing depth. Moving from left to right, one of the 54 teeth who were negative on both clinical indicators had a crack (wholly white area). Moving from left to right, there is an increasing proportion of cracks. In the 8 molars with tooth slooth negative and probing depths larger than 4mm, 25% had an intrapulpal crack. In the 14 molars with tooth slooth positive and probing depths less than 4mm, 50% had an intrapulpal crack. In the 6 molars positive on both indicators, 83% had an intrapulpal crack.

**Table 6. Risk groups**

| Tooth slooth Pos | Probing > 4mm | Cracked status (n %) Intrapulpal crack | | 95% CI | No crack | | Total |
|---|---|---|---|---|---|---|---|
| N | N | 1 | 2% | (0.3 to 9.8%) | 53 | 98% | 54 |
| N | Y | 2 | 25% | (7.1 to 59.1%) | 6 | 75% | 8 |
| Y | N | 7 | 50% | (26.8 to 73.2%) | 7 | 50% | 14 |
| Y | Y | 5 | 83% | (43.6 to 97%) | 1 | 17% | 6 |
| Chi-square = 36.4, df=3, P<.0001 | | | | | | | |

**Figure 1. Logistic regression depicting relationship between tooth slooth, probing depth, and crack status**



# Discussion

A total of 82 maxillary molars that were evaluated for endodontic treatment were included in this study. 67% of all cases were first molars (55 first molars and 27 second molars). Out of the 82 cases, 18% (15) had intrapulpal cracks. There was an apparent association with pain on biting and with probing depths greater than 4 millimeters. Teeth that were positive on a tooth slooth test were more likely to have an intrapulpal crack. A positive transillumination test was also associated with the presence of a crack.

The demographic results indicated that there were a relatively even number of males and females. This did not match previous studies by Cameron (12), Abbott (15), and Homewood (16) who all suggested that cracks or Cracked Tooth Syndrome might be more common in females. This could be attributed to the fact that those studies included all types of teeth, not just maxillary molars.

Lubisich (17) in a literature review of 12 clinical studies found that the proportion of cracked maxillary molars in relation to other cracked teeth accounted for 28%. Krygowski (14) in 2015 reported the overall prevalence of cracks in maxillary premolars to be 20%. Lawson (13) in 2014 found the prevalence of intrapulpal cracks in mandibular molars to be 9%. Krell (18) in his study of 8175 teeth showed that out of the 2633 maxillary first and second molars, 8% (213) had cracks. This seems to be lower than the incidence of 18% shown in our study. Krell's (18) inclusion criteria accounted for teeth that had cracks identified by transillumination and visualization with or without magnification before accessing the tooth, which represents only superficial cracks. In our study, teeth were accessed and stained then examined for cracks

intrapulpally, which might contribute to the higher incidence of cracks. Another contributing factor might be due to selection bias. Some cases that fit the criteria of the study might have been undocumented, especially in the absence of a crack. This could have led to a higher prevalence of cracked teeth in this study. Resident compliance with documenting all cases could be improved in future studies.

Our predictive factors are in agreement with the findings of Krygowski (14) and Lawson (13). They both found cracked teeth were associated with probing depths greater than 4 mm, a tooth slooth positive test and a transillumination positive test. In this study there was a statistically significant association of pain on biting and probing depths of 5 millimeters or more and the presence of intrapulpal cracks. Also teeth that tested positive with the tooth slooth were more likely to have an intrapulpal crack. Lawson (13) in his study also found an association of intrapulpal cracks in mandibular molars with positive tooth slooth test, probing depths greater than 4mm and transillumination positive teeth. Tan (19) in his study found 34% of cracked teeth had probing depths greater than 3 mms. This is attributed to the fact that cracked teeth could have an extension of the intrapulpal crack to the PDL and further down apically into the radicular structures. This causes inflammation in the area and loss of crestal epithelial attachment and periodontal ligament attachment and thus results in deeper probing depths. Patients might experience severe pain to chewing and soreness caused by inflammation of the gingival tissue.

Lawson (13) found that patients 40 years or older were more common to have cracks. Other studies suggested that the initiation of a coronal fracture might depend on carious lesions, existing restorations and occlusal forces, which lead to weakening of the tooth structure, and might cause the initiation of a crack (20, 21). In this study, a logistic regression analysis indicated that, after accounting for the other factors, there was no significant association between

age and the presence of a crack. This might be contributed to the small sample size of this study. A larger sample size might be needed to confirm the association between cracks and age.

Studies done by Cameron (12) and Seo (22) found that large restorations might cause the initiation and progression of cracks (3,12). However, Krygowski (14) in her study showed that maxillary premolars with fewer than 3 restored surfaces were more often associated with an intrapulpal crack than teeth with more than 2 restored surfaces. This was also shown by Roh (20) in his analysis of 154 cases of teeth with cracks in which he found that cracks were more associated and extensive in teeth with no restorations or small restorations. Beavers (23) evaluated the association of restoration volume and the presence of cracks. He also found that teeth with small restorations were more often associated with cracks than teeth with larger restorations. However, in our study there was no statistically significant association between the number of restored surfaces and the presence of a crack. This might be contributed to the small sample size of our study. Further investigation with larger sample size might be needed in the future to validate the results of this study.

Previous studies have suggested that staining teeth with methylene blue dye or iodine may help in identifying external cracks (2, 24). In contrast, Ratcliff (25) and Despain (26) showed that staining wasn't necessary for the identification of a crack. In this study there was no significant diagnostic value for the use of the methylene blue dye in detecting intrapulpal cracks. Only 2 of the 15 teeth that had intrapulpal cracks were identified after staining. The rest of cracks were detected by microscopic inspection only. This might be attributed to the fact that these teeth were accessed and the crack might have reached a point were some of the tissue and debris created during the access preparation could stain the crack from the inside and makes it easier to detect. Also the microscopic magnification in this study was 17.72x power, which appeared to be

efficient in detecting intrapulpal cracks. However most of the cracks that were identifiable visually with the microscope, were not clearly detectible in the digital images taken by the microscope. This might be caused by limitations of the microscope system, digital image capturing device or the illumination. Further studies might prove to be helpful in comparing different microscopes and capturing devices in the ability to identify cracks in the images captured.

Tooth slooth test was the best single predictor identifying cracks. In the 14 molars with tooth slooth positive test and probing depths less than 4mm, 50% had an intrapulpal crack. This was also shown by Seo (22) who found that the tooth slooth is the most reliable diagnostic indicator of teeth that are cracked. In the 8 molars with tooth slooth negative and probing depths greater than 4mm, 25% had an intrapulpal crack. In the 6 molars positive on both tooth slooth and probing depth greater than 4mm, 83% had an intrapulpal crack. Percussion test wasn't of diagnostic importance in detecting cracks. Early stages will have cracks that are invisible to the naked eye and hard to identify with staining. Severe sensitivity to cold and biting might be the only indicators. Deep probing depths as a result of periodontal involvement are associated with cracked teeth. Most of the time this happens at a later stage of the crack progression where prognosis might be questionable. Further studies focusing on the importance of the tooth slooth test in detecting cracks at an early stage are recommended.

In conclusion, 82 maxillary molars requiring non-surgical root canal therapy or retreatment were evaluated for the existence of intrapulpal cracks. Teeth were examined visually, transilluminated, stained, and examined microscopically. The prevalence of intrapulpal cracks in maxillary molars was found to be 18%. Tooth Slooth positive and probing depths greater than 4mm were important predictors of intrapulpal cracks. Tooth Slooth test was the single best

predictor identifying 50% of intrapulpally-cracked maxillary molars. No relationship between tooth number, gender, type of existing restorations, pulpal and periapical diagnosis was found with the presence of an intrapulpal crack. Future studies with larger sample sizes are needed to investigate the validity of the results shown in this study. More accurate diagnostic tools and predictive factors will help to diagnose cracked teeth at an earlier stage and help to determine the prognosis and best treatment options for restoring these teeth.

# References


1. Ritchey B, Mendenhall R, Orban B. Pulpitis resulting from incomplete root fracture. Oral Surg Oral Med Oral Pathol 1957;10:665-70.

2. Abou-Rass M. Crack lines: The precursors of tooth fractures - their diagnosis and treatment. Quintessence Int Dent Dig. 1983 Apr;14(4):437-47.

3. Ehrmann E.H. Tyas M.J. Cracked-tooth syndrome: diagnosis, treatment and correlation between symptoms and post-extraction findings. Aust Dent J 1990;35:105-12

4. Turp JC, Gobetti JP. The cracked tooth syndrome: an elusive diagnosis. J Am Dent Assoc 1996;127:1502-1507.

5. Hiatt WH. Incomplete crown-root fracture in pulpal-periodontal disease. J Periodontol. 1973 Jun;44(6):369-79

6. Rivera EM, Williamson A. Diagnosis and treatment planning: Cracked tooth. Tex Dent J. 2003 Mar;120(3):278-83.

7. Gibbs J. Cuspal fracture odontalgia. Dent Dig. 1954(60):158-60.

8. Opdam NJM , Roeters JJM, Loomans BAC,etal. Seven year clinical evaluation of painful cracked teeth restored with a direct composite restoration. J Endod 2008;34:808–11.

9. Cohen S, Blanco L, Berman L. Vertical root fractures: clinical and radiographic diagnosis. J Am Dent Assoc 2003;134:434–41.

10. Cracking the cracked tooth code. Endodontics: Colleagues for Excellence. 2008(Summer):1-7.

11. Detar MS. Evaluation of the Prevalence and Clinical Characteristics of Intrapulpal Cracks Utilizing a Novel Classification System. VCU Scholars Compass. 2014.

12. Cameron CE. The cracked tooth syndrome: additional findings. J Am Dent Assoc 1976;93:971-5.

13. Lawson SO. The prevalence of intrapulpal cracks in 1st and 2nd mandibular molars requiring non-surgical root canal treatment. VCU Scholars Compass. 2014.

14. Krygowski SE. The prevalence, predictive factors, and classification of intrapulpal cracks in maxillary premolars requiring endodontic treatment. VCU Scholars Compass. 2015.

15. Abbott P, Leow N. Predictable management of cracked teeth with reversible pulpitis. Aust Dent J. 2009;54(4):306-15.

16. Homewood CI. Cracked tooth syndrome – incidence, clinical findings, and treatment. Aust Dent J. 1998; 43:217-22.

17. Lubisich EB. Cracked teeth: A review of the literature. Wiley Periodicals, Inc. 2010 22(3):158-167.

18. Krell KV, Rivera EM. A six-year evaluation of cracked teeth diagnosed with reversible pulpitis: treatment and prognosis. J Endod. 2007; 33:1405-7.

19. Tan L, Chen NN, Poon CY, Wong HB. Survival of root filled cracked teeth in a tertiary institution. Int Endod J. 2006; 39:886-889.

20. Roh. Roh BD, Lee YE. Analysis of 154 cases of teeth with cracks. Dent Traumatol. 2006 Jun;22(3):118-23.

21. Cameron CE. Cracked-tooth syndrome. J Am Dent Assoc. 1964 Mar;68:405-11.

22. Seo DG, Yi YA, Shin SJ, Park JW. Analysis of factors associated with cracked teeth. J Endod. 2012 Mar;38(3):288-92.

23. Beavers CM. Restorative characteristics of intrapulpally cracked teeth. VCU Scholars Compass. 2015.

24. Rosen H. Cracked tooth syndrome. J Prosthet Dent. 1982;47(1):36-43.

25. Ratcliff S, Becker IM, Quinn L. Type and incidence of cracks in posterior teeth. J Prosthet Dent. 2001; 86:168-72.

26. Despain RR, Lloyd BA, Brown WS. Scanning electron microscope investigation of cracks in teeth through replication. J Am Dent Assoc. 1974; 88:580-4.

# Appendices

## RESEARCH PARTICIPANT INFORMATION AND CONSENT FORM

**TITLE:** The prevalence and classification of intrapulpal cracks in maxillary molars requiring non-surgical root canal therapy
**VCU IRB PROTOCOL NUMBER:** HM20006713
**INVESTIGATOR:** Dr. Garry L. Myers

If any information contained in this consent form is not clear, please ask the study doctor to explain it to you. You may take home an unsigned copy of this form. In this consent, "you" always refers to the research participant.

**PURPOSE OF THE STUDY**
The purpose of this research study is to count the number of teeth with cracks treated in the Virginia Commonwealth University Graduate Endodontic Clinic. Only a certain kind of tooth will be included in the study – upper molar teeth. You are being asked to participate in this study because you have an upper molar tooth requiring a root canal.

**DESCRIPTION OF THE STUDY**
This study aims to identify the number of upper molar teeth with cracks requiring non-surgical root canal therapy or retreatment. The care provided to you in our clinic is the standard of care. Your dental care will be the same as it would have been without the research study. All of the information used for this research is normally recorded for your dental care. For this study, your information will be analyzed at the end of the study period to understand how many upper molar teeth treated in our clinic have cracks.

**PROCEDURES**

If you decide to be in this research study, you will be asked to sign this consent form after you have had all your questions answered. Treatment will not be altered due to this study.

Your tooth will be visually examined for a crack before initiating endodontic treatment using a blue dye. The dye stains cracks and makes them easier to see. The tooth will be examined for a crack again, using a microscope and dye, during treatment. Information regarding the presence of a crack, diagnosis, depth of pocket between gum tissue and tooth, and clinical findings will be recorded in your electronic dental health record and analyzed. This information is normally collected in our clinic for all teeth with cracks. The study will analyze the recorded measurements for a group of these teeth (upper molars).

**RISKS AND DISCOMFORTS**
Potential but unlikely risks associated with this study include loss of confidentiality and inadvertent disclosure of PHI.

**USE AND DISCLOSURE OF PROTECTED HEALTH INFORMATION (HIPAA AUTHORIZATION)**
Your privacy is important to us. We are asking you to share identifiable health information with us. This type of information is considered "Protected Health Information" that is protected by federal law.

You have the right to decide if you want to give your permission before your health information can be used or shared for certain purposes. We are asking you to authorize the use and release of specific Protected Health Information as part of our research.

**Authority to Request Protected Health Information**
The following people and/or groups may request your Protected Health Information:
- Principal Investigator and Research Staff
- Data Safety Monitoring Boards
- Institutional Review Boards
- Others as Required by Law

**Article I. Authority to Release Protected Health Information**
The VCU Health System (VCUHS) may release the information identified in this authorization from your medical records and provide this information to:
- Health Care Providers at the VCUHS
- Data Safety Monitoring Boards
- Principal Investigator and Research Staff
- Institutional Review Boards

Once your health information has been disclosed to anyone outside of this study, the information may no longer be protected under this authorization.

**Type of Information that may be Released**
The following types of information may be used for the conduct of this research:

| | | |
|---|---|---|
| ☒ Complete dental record (AxiUm Dental Record) | ☒ Diagnosis & treatment codes | ☒ Diagnostic Testing |
| ☒ Medical History and dental exam | ☒ Consultation reports | ☒ Progress notes (AxiUm Dental Record) |
| ☒ CBCT Scan | ☒ X-ray reports | ☒ X-ray films / images (MiPacs Images) |

**Expiration of This Authorization**
☒ This authorization will expire when the research study is closed, or there is no need to review, analyze and consider the data generated by the research project, whichever is later.

**Article II. Right to Revoke Authorization and Re-disclosure**
You may change your mind and revoke (take back) the right to use your protected health information at any time. Even if you revoke this Authorization, the researchers may still use or disclose health information they have already collected about you for this study. If you revoke this Authorization you may no longer be allowed to participate in the research study. To revoke this Authorization, you must write to the Principal Investigator

**BENEFITS TO YOU AND OTHERS**
Knowing how often cracks occur can help endodontists diagnose and make treatment decisions in the future. This information may offer the dental community a better understanding of the outcome for these teeth.

**COSTS**
There are no costs to the study subject for this research.

**PAYMENT FOR PARTICIPATION**
Participants will not be compensated for their participation in this study.

**CONFIDENTIALITY**
Data is being collected only for research purposes. Your data will be de-identified. A random code will be assigned to your information, and the key to this code will be kept in a locked research area. The key will be destroyed at the end of the study. Access to all data will be limited to study personnel. Although results of this research may be presented at meetings or in publications, identifiable personal information pertaining to participants will not be disclosed.

**VOLUNTARY PARTICIPATION AND WITHDRAWAL**
Your participation in this study is voluntary. You may decide to not participate in this study. Your decision not to take part will involve no penalty or loss of benefits to which you are otherwise entitled. Treatment will not be altered if you choose not to participate.
If you are pregnant or currently trying to become pregnant you may not participate in this study.

**ALTERNATIVES:**
There is no alternative research procedure; therefore your only alternative is not to participate in this study.

**QUESTIONS**
If you have any questions, complaints, or concerns about your participation in this research, contact:

Dr. Husain Karashi
Virginia Commonwealth University
School of Dentistry
Department of Endodontics
520 North 12th Street
Richmond, VA 23298-0566
Phone: (804) 628-1552 Fax: (804) 828-1373

Dr. Garry L. Myers
Virginia Commonwealth University
School of Dentistry
Department of Endodontics
520 North 12th Street
Richmond, VA 23298-0566
Phone: (804) 628-2903 Fax: (804) 828-1373

If you have general questions about your rights as a participant in this or any other research, you may contact:

Office of Research - Virginia Commonwealth University
800 East Leigh Street, Suite 3000
P.O. Box 980568
Richmond, VA 23298 Telephone: (804) 827-2157

Contact this number for general questions, concerns, or complaints about research. You may also call this number if you cannot reach the research team or if you wish to talk to someone else. General information about participation in research studies can also be found at http://www.research.vcu.edu/irb/volunteers.htm.

Do not sign this consent form unless you have had a chance to ask questions and have received satisfactory answers to all of your questions.

CONSENT
I have been provided with an opportunity to read this consent form carefully. All of the questions that I wish to raise concerning this study have been answered.

By signing this consent form, I agree that health information that identifies me may be used and disclosed for this research as described herein.

By signing this consent form, I have not waived any of the legal rights or benefits, to which I otherwise would be entitled. My signature indicates that I freely consent to participate in this research study. I will receive a copy of the consent form once I have agreed to participate.

_____
Participant Name, printed

_____ _____
Participant Signature Date

_____ _____
Person Obtaining Informed Consent/Witness Signature Date

_____ _____
Principal Investigator's Signature Date

# Maxillary Molars Requiring NSRCT or RETX

**Intrapulpal Crack Data Sheet**

**Resident Instructions: Fill out for every maxillary molar seen for evaluation or treatment in the Graduate Endodontic Practice. Return Sheet to the research folder located in the locked cabinet in the Graduate Endodontic Practice at the end of each day. Notify Dr. Karashi by axiUm message that you have treated a maxillary molar.**

Resident: _____ Date: _____
Pt Axium #: _____ Tooth #: _____

**SUBJECTIVE QUESTIONS**

Is this tooth being referred to you for evaluation of a suspected crack? **Yes No**
Does the patient report a history of pain provoked by chewing/biting? **Yes No**
Has this patient ever been told there is a crack in the tooth? **Yes No**
Do you, as the resident, expect to find a crack in the tooth? **Yes No**

**CLINICAL EXAM**

Is this the last tooth in the arch? **Yes No**
Are there any probing depths greater than 4 mm around the tooth? **Yes No**
Can you visualize a crack? **Yes No**
Can you visualize a crack, or confirm presence of an apparent crack, with transillumination? **Yes No**

**MICROSCOPE AND STAINING**

After rubber dam placement and prior to access, take clinical photograph of occlusal surface of tooth at magnification of 0.6.
After cleaning and shaping the root canal system, inspect the chamber for an intrapulpal crack under magnification of 1.0. Is one present? **Yes No**
Stain pulp chamber with methylene blue for 1 minute. Rinse with NaOCl, dry, and inspect chamber for crack under magnification of 1.0. Did staining reveal or confirm presence of crack? **Yes No**
Do you think staining helped identify a crack? **Yes No**
If a crack is present, please classify according to chart below: _____

## Intrapulpal Crack Classification

| | Wall(s) only | Wall(s) and orifice | Wall(s) and partially across floor | Wall(s) and across entire floor |
|---|---|---|---|---|
| 1 Wall | IA | IB | IC | ID |
| 2 Walls | IIA | IIB | IIC | IID |

# Data Listing

| # | Tooth # | Gender | Age | Suspect crack? | Pain on Biting? | Pt told a crack present? | Probing > 4mm | Did trans reveal crack? | # OF RESTORATION SURFACES | Pulpal Diag | Apical diag | Crack before staining? | Crack after staining? | most distal tooth |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 14 | F | 59 | Y | Y | N | Y | Y | 2 | NECROTIC | SAP | Y | Y (IIB) | N |
| 2 | 14 | F | 27 | N | N | N | N | N | 2 | AIP | AAP | N | N | N |
| 3 | 14 | M | 69 | Y | Y | N | Y | Y | 1 | NECROTIC | SAP | Y | Y(IID) | N |
| 4 | 14 | F | 26 | N | N | N | N | N | 1 | SIP | NORMAL | N | N | N |
| 5 | 3 | F | 22 | N | N | N | N | N | 2 | NECROTIC | SAP | N | N | N |
| 6 | 14 | F | 63 | N | Y | N | Y | NA | NA | PREVIOUSLY TREATED | SAP | N | Y(ID) | N |
| 7 | 14 | F | 37 | N | N | N | Y | N | 3 | NECROTIC | NORMAL | N | N | N |
| 8 | 15 | F | 37 | N | N | N | Y | N | 2 | NECROTIC | NORMAL | N | N | Y |
| 9 | 14 | F | 33 | Y | Y | N | N | N | 1 | PREVIOUSLY TREATED | SAP | N | N | N |
| 10 | 2 | M | 43 | Y | Y | N | Y | Y | 1 | NORMAL | SAP | Y | Y(IB) | N |
| 11 | 3 | F | 13 | N | N | N | N | N | 0 | SIP | SAP | N | N | N |
| 12 | 14 | M | 48 | N | N | N | N | NA | NA | SIP | SAP | N | N | Y |
| 13 | 2 | M | 55 | N | Y | N | N | N | 2 | SIP | SAP | N | N | Y |
| 14 | 15 | M | 35 | N | N | N | N | N | 2 | AIP | NORMAL | N | N | Y |
| 15 | 2 | F | 19 | N | N | N | N | N | 1 | SIP | SAP | N | N | Y |
| 16 | 14 | M | 33 | N | N | N | Y | N | 3 | SIP | SAP | N | N | Y |
| 17 | 15 | M | 73 | Y | Y | N | Y | Y | 2 | AIP | NORMAL | Y | Y(IA) | Y |
| 18 | 2 | M | 57 | N | Y | N | N | N | NA | SIP | SAP | N | N | Y |
| 19 | 2 | M | 57 | N | N | N | Y | N | 2 | NECROTIC | CAA | N | N | Y |
| 20 | 14 | M | 38 | N | N | N | N | N | 3 | SIP | SAP | N | N | N |
| 21 | 3 | M | 20 | N | N | N | N | N | 2 | AIP | NORMAL | N | N | N |
| 22 | 3 | F | 33 | N | N | N | N | N | 0 | AIP | NORMAL | N | N | N |

| # | Tooth # | Gender | Age | Suspect crack? | Pain on Biting? | Pt told a crack present? | Probing > 4mm | Did trans reveal crack? | # OF RESTORATION SURFACES | Pulpal Diag | Apical diag | Crack before staining? | Crack after staining? | most distal tooth |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 23 | 3 | F | 35 | N | N | N | Y | N | 3 | NECROTIC | CAA | N | N | N |
| 24 | 3 | F | 50 | Y | Y | N | N | Y | 3 | NECROTIC | CAA | N | N | N |
| 25 | 14 | F | 66 | N | Y | N | N | N | 2 | SIP | SAP | Y | Y(IID) | N |
| 26 | 2 | M | 67 | N | N | N | N | N | NA | NECROTIC | SAP | N | N | Y |
| 27 | 2 | M | 28 | N | N | N | N | N | 2 | AIP | NORMAL | N | N | Y |
| 28 | 14 | M | 19 | N | Y | N | N | NA | NA | PREVIOUSLY TREATED | SAP | N | N | N |
| 29 | 15 | F | 34 | N | N | N | N | N | NA | PREVIOUSLY TREATED | AAP | N | N | Y |
| 30 | 2 | F | 27 | N | N | N | N | NA | NA | PREVIOUSLY TREATED | SAP | N | N | Y |
| 31 | 14 | F | 36 | Y | N | Y | N | Y | 3 | PREVIOUSLY TREATED | NORMAL | N | N | N |
| 32 | 14 | F | 17 | N | N | N | N | N | 0 | SIP | NORMAL | N | N | N |
| 33 | 14 | M | 26 | N | N | N | N | N | 0 | AIP | NORMAL | N | N | N |
| 34 | 15 | F | 54 | Y | Y | N | N | Y | 1 | SIP | SAP | N | N | Y |
| 35 | 14 | F | 32 | Y | Y | N | N | Y | 2 | SIP | SAP | N | Y(IIA) | N |
| 36 | 2 | F | 43 | N | N | N | Y | N | 3 | NECROTIC | NORMAL | N | N | Y |
| 37 | 2 | M | 29 | N | N | N | N | N | 2 | AIP | NORMAL | N | N | Y |
| 38 | 3 | M | 20 | N | N | N | N | NA | NA | PREVIOUSLY TREATED | AAP | N | N | N |
| 39 | 3 | F | 21 | N | Y | N | N | N | 0 | SIP | SAP | N | N | N |
| 40 | 3 | F | 31 | N | Y | N | N | N | 1 | SIP | SAP | N | N | Y |
| 41 | 3 | M | 80 | N | Y | N | N | NA | NA | NECROTIC | SAP | N | N | N |
| 42 | 14 | F | 78 | N | N | N | N | NA | NA | NECROTIC | AAP | N | N | Y |
| 43 | 3 | F | 60 | N | N | N | N | N | NA | NECROTIC | SAP | N | N | N |
| 44 | 15 | M | 69 | N | Y | N | N | N | 1 | NECROTIC | SAP | N | N | N |
| 45 | 14 | M | 31 | N | N | N | N | N | 3 | PREVIOUSLY TREATED | AAP | N | N | Y |
| 46 | 3 | F | 26 | N | N | N | N | N | 3 | NECROTIC | CAA | N | N | N |
| 47 | 3 | F | 58 | N | N | N | N | N | 0 | NECROTIC | CAA | N | N | N |

| # | Tooth # | Gender | Age | Suspect crack? | Pain on Biting? | Pt told a crack present? | Probing > 4mm | Did trans reveal crack? | # OF RESTORATION SURFACES | Pulpal Diag | Apical diag | Crack before staining? | Crack after staining? | most distal tooth |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 48 | 2 | F | 46 | N | N | N | N | N | 2 | NECROTIC | AAP | N | N | Y |
| 49 | 14 | M | 78 | N | Y | N | N | N | NA | SIP | NORMAL | N | N | N |
| 50 | 3 | F | 38 | N | Y | N | N | N | 3 | SIP | SAP | N | N | N |
| 51 | 14 | F | 31 | N | N | N | N | N | 1 | NECROTIC | AAP | N | N | N |
| 52 | 3 | F | 44 | N | Y | N | N | N | 2 | SIP | SAP | N | N | Y |
| 53 | 3 | F | 15 | N | N | N | N | N | 3 | PREVIOUSLY TREATED | SAP | N | N | N |
| 54 | 2 | F | 46 | N | N | N | N | N | 2 | NECROTIC | AAP | N | N | Y |
| 55 | 14 | F | 67 | Y | Y | Y | N | NA | NA | PREVIOUSLY TREATED | SAP | Y | Y(IC) | N |
| 56 | 15 | M | 43 | Y | Y | N | N | Y | 0 | SIP | SAP | Y | Y(IID) | Y |
| 57 | 15 | F | 35 | N | N | N | N | N | 2 | SIP | SAP | N | N | Y |
| 58 | 3 | F | 68 | N | N | N | Y | NA | NA | PREVIOUSLY TREATED | NORMAL | Y | Y(IID) | N |
| 59 | 3 | F | 44 | Y | N | Y | N | N | 2 | SIP | NORMAL | N | N | N |
| 60 | 3 | M | 31 | N | N | N | N | N | 2 | SIP | SAP | N | N | N |
| 61 | 14 | M | 31 | N | N | N | N | N | 0 | NECROTIC | NORMAL | N | N | N |
| 62 | 14 | M | 13 | N | N | N | N | N | 0 | SIP | NORMAL | N | N | N |
| 63 | 14 | F | 36 | N | Y | N | N | N | 2 | NECROTIC | SAP | N | N | N |
| 64 | 3 | M | 55 | N | N | N | N | N | 2 | SIP | SAP | N | N | N |
| 65 | 14 | F | 44 | Y | Y | N | N | Y | 1 | SIP | NORMAL | Y | Y(IA) | N |
| 66 | 3 | F | 59 | N | N | N | N | N | 1 | SIP | NORMAL | N | N | Y |
| 67 | 3 | M | 50 | N | N | N | N | N | NA | SIP | NORMAL | N | N | N |
| 68 | 3 | M | 49 | N | Y | N | N | NA | NA | PREVIOUSLY TREATED | SAP | N | N | N |
| 69 | 3 | F | 58 | Y | Y | N | N | Y | 3 | SIP | SAP | Y | Y(IIA) | N |
| 70 | 14 | M | 13 | N | N | N | N | N | 0 | AIP | NORMAL | N | N | N |
| 71 | 2 | F | 37 | Y | Y | N | N | Y | 1 | NECROTIC | SAP | Y | Y(IA) | Y |
| 72 | 14 | M | 18 | N | N | N | N | N | 0 | NECROTIC | NORMAL | N | N | N |

| # | Tooth # | Gender | Age | Suspect crack? | Pain on Biting? | Pt told a crack present? | Probing > 4mm | Did trans reveal crack? | # OF RESTORATION SURFACES | Pulpal Diag | Apical diag | Crack before staining? | Crack after staining? | most distal tooth |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 73 | 15 | M | 16 | N | N | N | N | N | 1 | SIP | SAP | N | N | Y |
| 74 | 15 | F | 28 | N | N | N | N | N | 2 | SIP | SAP | N | N | Y |
| 75 | 2 | F | 28 | N | N | N | N | N | 2 | NECROTIC | SAP | N | N | Y |
| 76 | 15 | F | 52 | Y | N | N | N | Y | 0 | PREVIOUSLY TREATED | NORMAL | Y | Y(IC) | Y |
| 77 | 3 | M | 29 | N | N | N | N | N | 3 | PREVIOUSLY TREATED | AAP | N | N | N |
| 78 | 3 | F | 60 | N | N | N | N | N | NA | NECROTIC | SAP | N | N | N |
| 79 | 15 | F | 30 | N | N | N | N | N | 3 | SIP | NORMAL | N | N | Y |
| 80 | 3 | F | 55 | Y | Y | N | Y | Y | 3 | NECROTIC | AAA | Y | Y(IA) | N |
| 81 | 14 | M | 69 | N | Y | N | Y | N | 1 | AIP | SAP | N | N | Y |
| 82 | 2 | F | 67 | N | Y | N | N | N | 1 | AIP | SAP | N | N | Y |

# Vita

Dr. Husain Karashi was born on November 14, 1987 in Kuwait and is a Kuwaiti citizen. Dr. Karashi did his Pre-dental program at Creighton University in 2009. He received his Doctor of Dental Surgery in 2013 from Creighton University. Dr. Karashi practiced general dentistry for 2 years back in kuwait before enrolling in the Advanced Specialty Program in Endodontics at Virginia Commonwealth University. Dr. Karashi is a member of the ADA and AAE and will go back to Kuwait to practice Endodontics. He will graduate from Virginia Commonwealth University with a Master of Science in Dentistry and a Certificate in Endodontics.