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# Characteristics of Posterior Permanent Teeth with a Periradicular Diagnosis of Symptomatic Apical Periodontitis: A Retrospective Study

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**Characteristics of Posterior Permanent Teeth with a Periradicular Diagnosis of Symptomatic Apical Periodontitis: A Retrospective Study**

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

CHARACTERISTICS OF POSTERIOR PERMANENT TEETH WITH A PERIRADICULAR DIAGNOSIS OF SYMPTOMATIC APICAL PERIODONTITIS: A RETROSPECTIVE STUDY

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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.

Virginia Commonwealth University, May 2022

Thesis Advisor: Garry L. Myers, DDS

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The diagnosis of apical periodontitis is based on radiographic manifestations and the results of the various clinical tests that can be performed as part of a routine dental examination. Apical periodontitis producing clinical symptoms involving a painful response to biting and/or percussion or palpation is given the diagnosis of symptomatic apical periodontitis (SAP). This study aimed to determine associations of SAP with gender, age, radiographic findings, diagnostic testing, pulpal diagnosis, and location of the tooth in the arch. Data for this study were obtained from patients of record treated at Virginia Commonwealth University School of Dentistry in the Department of Endodontics by first- and second-year residents. Electronic dental charts obtained through axiUm™ were used to identify all patients diagnosed with SAP and these charts were used to determine clinical characteristics associated with the diagnosis. Radiographs of charts included in the initial data set were analyzed using the digital database, MiPACS™. The data showed SAP is associated with the presence of a periapical radiolucency or widened PDL in 63% of cases. A pulpal diagnosis of symptomatic irreversible pulpitis was given in 45% of cases, pulp necrosis in 30%, previous treatment in 19%, and other 6%. Of the posterior teeth included in this study, 73% were molars with mandibular molars representing 44%. Of pulps that responded to cold, 23% presented with radiographic deviations from normal. The study showed more than half of the patients were female (62%) with roughly equal distribution of age, which ranged from 18-94 years. This project was funded by the Foundation of Endodontics.

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## Introduction

Diagnosis in endodontics has been defined as the art and science of detecting and distinguishing deviations from health and the cause and nature thereof. (1) Establishing a proper pulpal and periapical diagnosis is important in determining appropriate clinical treatment. Historically, there have been a variety of diagnostic classification systems for determining endodontic disease often leading to confusion and incorrect diagnoses. (2) A simple and practical system which uses terms related to clinical findings is essential to help clinicians understand the progressive nature of pulpal and periapical disease, directing them to the most appropriate treatment for each condition. In 2008, the American Association of Endodontists (AAE) held a consensus conference to standardize diagnostic terms with goals to propose universal recommendations regarding endodontic diagnoses, to develop standardized definitions of endodontic terms, to resolve concerns about interpretation of test results, and to determine the radiographic criteria, objective test results, and clinical criteria needed to validate the diagnostic terms. These terms have now been accepted by the AAE and the American Board of Endodontists (ABE) with recommended usage among all health care professionals. (3) Although this standardized classification system has allowed for more consistency, an accurate diagnosis still cannot be made from a single, isolated piece of information. It is critical to recognize that diseases of the pulp and periapical tissues are dynamic and progressive meaning that signs and symptoms will vary depending on the stage of the disease. (4) Arriving at an endodontic diagnosis involves the culmination of subjective information, clinical and radiographic examination, and clinical testing. (2)

In a general sense, apical periodontitis is defined as inflammation of the periodontium. (5) As detailed in the most recent recommended diagnostic terminology, apical periodontitis is divided into two further classifications: asymptomatic apical periodontitis and symptomatic apical periodontitis. Asymptomatic apical periodontitis (AAP) is defined as "inflammation and destruction of the apical periodontium that is of pulpal origin. It appears as an apical radiolucency and does not present clinical symptoms (no pain on percussion or palpation.)" Symptomatic apical periodontitis (SAP) is defined as "inflammation usually of the apical periodontium, producing clinical symptoms including a painful response to biting and/or percussion or palpation. It might or might not be accompanied by radiographic changes (i.e depending upon the stage of the disease, there may be normal width of the periodontal ligament or there may be a periapical radiolucency). Severe pain to percussion and/or palpation is highly indicative of a degenerating pulp and root canal treatment is needed." (3)

Epidemiologic studies bring knowledge about trends in incidence and prevalence of diseases and their risk factors. In a 2020 systematic review and meta-analysis, Tibúrcio-Machado et al found the prevalence of apical periodontitis to be approximately 52% at the individual level and 5% at the tooth level. (6) These results led to the conclusion that half of the adult population worldwide have at least one tooth with apical periodontitis. Patients with symptomatic apical periodontitis often present with an intense, spontaneous, and localized pain. The presence of symptomatic apical periodontitis does not indicate that the pulp within the tooth is vital or non-vital but is rather an indication of inflammation of the periodontal ligament.

Apical periodontitis is an inflammatory disorder caused by persistent microbial infection within the root canal system of the affected tooth. (7). The process of apical periodontitis is initiated by bacterial invasion of the pulp via caries, cracks and fractures, attrition, abrasion, trauma, or congenital defects in the crown causing pulpal irritation. As bacteria approaches the pulp, the inflammation increases and eventually progresses through the affected pulp leading to pulpal degeneration. This process of inflammation followed by infection continues to the periapex and into the periapical tissues. (8) This process was verified histologically leading to the conclusion that apical periodontitis is a direct extension of pulpitis into the periapical tissues before total pulp necrosis. (9) Thus, periradicular changes and apical periodontitis can occur before total pulp necrosis is established at the apical foramen. If left untreated, the microbes and their byproducts in the root canal system can advance into the periapex eventually causing complete pulp necrosis and periapical inflammation and infection. (10) As there is no longer any blood supply to a necrotic pulp or into the root canal system in a pulpless tooth, the host's defense cells cannot reach the source of the irritation and therefore the body is unable to eliminate the infection. This leads to a chronic inflammatory response in the periapical region and the intra-canal bacteria survive with nutrients being obtained from tissue fluid and inflammatory exudate. (11) Periapical inflammation is generally a direct effect of bacterial infection of the root canal system. Healthy tissue endures injury or insult leading to inflammation, infection, necrosis, and finally tissue destruction which can eventually be seen radiographically. (12)

Radiographic examination is an essential part of the endodontic diagnostic process and has proven to be a valuable aid in determining the appropriate treatment for the tooth in question. Currently, the most commonly used method for radiological detection of apical periodontitis is periapical radiography. (13) The radiographic diagnosis of apical periodontitis is based on deviations from the normal periapical anatomy. The periodontal ligament, the lamina dura, cancellous and cortical bone, and the root itself may all be impacted by the biological activities of apical periodontitis. (14)

Clinically, periapical bone loss is usually visible radiographically when the pulp is necrotic although periapical inflammation is seen histologically in animal studies during the period of pulpal inflammation. (15) In 2001, the AAE published guidelines on the pulpal/periapical relationship. In this article it was stated that a limitation of the radiographic examination was that pathologic vital pulps are not visible on radiographs. It was also stated that if a radiolucency was seen in the periradicular region of a tooth with a vital pulp, it could not be of pulpal origin and would either be a normal structure or another type of pathosis. (16) These statements supported the belief that if a radiographic radiolucency existed at the apex of a tooth, the pulp must be non-vital or the radiolucency was not of odontogenic origin. Alternatively, in a histological study by Ricucci, vital tissue with varying degrees of inflammation was observed in the apical portion of the root canal system of teeth with periradicular radiolucencies. (17) These are just two examples, of many, exploring both sides of the controversial topic of the relationship between periapical radiolucencies and pulp vitality.

One possible explanation for this paradigm shift from periapical radiolucencies being associated with strictly necrotic pulps to radiolucencies being associated with both vital and necrotic pulps are the technological advances seen in endodontics. Periapical radiographs are used during endodontic treatment as well as after to evaluate treatment. Although periapical radiography has many benefits in endodontics, there are limitations to periapical radiographs. One limitation is that periapical imaging provides a two-dimensional view of a three-dimensional structure. (18) This means that the radiographic evaluation cannot encompass the region of interest in its entirety. Additionally, periapical films may not have the ability to detect apical periodontitis confined solely within cancellous bone. It has been demonstrated that although lesions of a certain size can be detected if covered by a thin cortex, the same size lesion cannot be detected in regions covered by a thicker cortex. (19) In a study comparing the prevalence of apical periodontitis in teeth reviewed with periapical radiographs and cone beam computed tomography, periapical radiographs proved to have low sensitivity and cone beam computed tomography was significantly more sensitive in detecting apical bony changes. (20) Therefore, the advances in technology have proven that the pulp does not have to be totally necrotic for periapical bone resorption to occur. It is a possibility that apical periodontitis can occur before its detection radiographically. Although periapical radiographs have a limited capacity to show small bone lesions, they have a high capacity to identify normal periapical conditions making them valuable to diagnosis in endodontics. (21)

The presentation of apical periodontitis has proven to encompass a variety of symptoms and appearances. The purpose of this study was to analyze the clinical presentation of symptomatic apical periodontitis. This study aimed to determine associations of symptomatic apical periodontitis with radiographic changes, diagnostic testing, pulpal diagnosis, location of the tooth in the arch, gender, and age.

## Methods

This study was a retrospective electronic dental chart and digital radiograph review of patients diagnosed with symptomatic apical periodontitis in the graduate endodontic department at the School of Dentistry at Virginia Commonwealth University. The Institutional Review Board of Virginia Commonwealth University, Richmond, Virginia, approved this study (IRB #HM20021627).

Data for this study was obtained from patients of record treated at the Virginia Commonwealth University School of Dentistry graduate endodontic clinic by first- and second-year residents from August 2019 through March 2020. Electronic dental charts obtained through axiUm™ were used to identify all patients diagnosed with symptomatic apical periodontitis during this time period. Virginia Commonwealth University School of Dentistry (VCU SoD) uses the dental software program axiUm™ for its electronic charting. Charts were obtained by searching diagnostic template notes used during evaluation appointments with the key words of 'symptomatic apical periodontitis' as the periapical diagnosis. This resulted in an initial data set from which information was retrieved. The patient chart number was recorded in a separate excel spreadsheet and given a non-identifying number from 2 to 320. This excel sheet was kept separately so as to comply with HIPPA standards. The de-identified spreadsheet included patient gender, patient age, tooth number, palpation response, percussion response, mobility, biting sensitivity, cold response, pulpal diagnosis, and lesion size as shown in Figure 2. A research assistant helped gather this information and record all findings in an excel spreadsheet stored on a VCU secured computer.

The inclusion criteria for this retrospective chart review included: teeth with a periapical diagnosis of symptomatic apical periodontitis verified in the template note with a positive percussion test and/or positive palpation test; permanent teeth in patients of eighteen years or older; and posterior teeth meaning all molars and premolars with the exception of third molars. All included patients had periapical radiographs taken on the day of evaluation that were of diagnostic quality. Excluded from this study were patients under the age of eighteen, anterior teeth, and primary teeth. Medically complex patients with compromised immune status including diabetics, smokers, and pregnant patients were also excluded from this study.

During initial data collection, the sample was refined and excluded subjects with (a) incomplete axiUm™ charts, (b) charts that were inaccessible, (c) inconsistencies present in the chart. An example of an inconsistency was if the recorded tooth number did not match the treatment code. Radiographic interpretation resulted in further refinement of the study population. Subjects were excluded if the tooth in question was not included in the periapical radiograph, if the tooth apex or the complete periapical radiolucency was not captured in the radiograph, and if the radiograph was not clear leading to difficult interpretation. If treatment was initiated or completed the same day as the evaluation and the pre-operative radiograph did not meet the standard to be included in this study, the post-operative image was used in its place if all other inclusion criteria were met.

The final population sample size was comprised of 305 teeth that had the periapical diagnosis of SAP.

Radiographs included in the data set were obtained from the digital database, MiPACS™. A Microsoft PowerPoint presentation was created which included the periapical radiograph taken during the evaluation for each subject. The title of each slide was labeled with the number assigned to the subject during the de-identification process as well as the number of the tooth being evaluated. Before individual interpretation, all examiners were calibrated. The calibration exercise was carried out by using 5 randomly selected subjects from the overall sample and evaluating them as a group to determine the correct radiographic interpretation. Examiners were instructed to determine if the tooth in question presented with or without a periapical lesion. If the examiner determined there to be a lesion, the approximate size of the lesion at its widest dimension was recorded as either a wide PDL, 0-2mm, 2.1-4mm, or >4mm. Andreasen and Rud found that if the periodontal membrane is more than doubled in width, moderate or severe inflammation is likely present. This study defined a widened PDL as presenting with twice its normal width. (22)

The radiographic evaluation was carried out by two board certified endodontists, two general dentists, and two second year graduate endodontic residents. Each examiner was responsible for interpreting their own set of radiographs that were compiled into a PowerPoint presentation and sent with instructions electronically. Of the 305 total subjects, 300 were randomly divided into six groups containing 50 subjects each. To test intra-rater reliability the 5 subjects used during calibration were randomly dispersed throughout each group of radiographs making each group contain 55 subjects each. To test inter-rater reliability, two subjects from each group were added to every other group. This made for a total of 65 samples in each of the six groups for the assigned examiner to interpret; 48 unique cases, the five calibration cases, and 12 cases that were included in all six groups. Once the examiner was finished with the interpretation of their assigned 65 radiographs, the results were recorded into the de-identified Excel spreadsheet.

Figure 1 shows one of the PowerPoint slides sent to one of the six examiners for interpretation.

*Figure 1: Radiographic Interpretation Example*

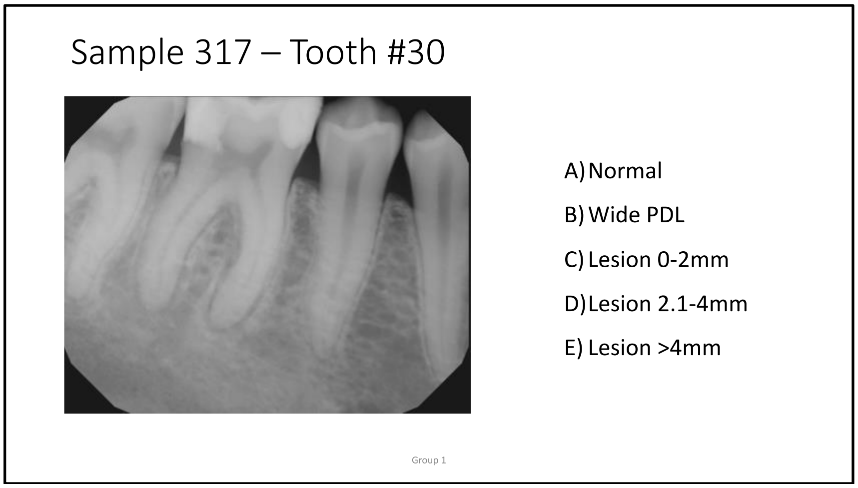


*Figure 2: Clip of the De-identified Spreadsheet with Radiographic Interpretation Results*

| | A | B | C | D | E | F | G | H | I | J | K |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Pt. Sex | Age | Tooth | Palp | Perc | Mobi | Biting | Cold | Pulpal | LESION | |
| 2 | Female | 48 | 3 | + | N | N | N | 0 | PT | D | |
| 3 | Female | 38 | 19 | N | + | N | N | +++ | SIP | B | KEY |
| 4 | Female | 38 | 20 | N | + | N | N | +++ | SIP | A | Calibration (intra) |
| 5 | Male | 54 | 20 | N | ++ | N | + | ++ | SIP | B | In all Groups (inter) |
| 6 | Male | 66 | 19 | + | ++ | N | ++ | 0 | PN | C | |
| 7 | Male | 34 | 3 | N | ++ | 0 | ++ | 0 | PN | A | |
| 8 | Male | 58 | 31 | N | + | N | N | 0 | PN | D | Lesion: |
| 9 | Male | 48 | 31 | N | ++ | N | N | +++ | SIP | BBBBBB | A) Normal |
| 10 | Female | 69 | 30 | + | + | N | + | 0 | PN | E | B) Wide PDL |
| 11 | Male | 24 | 30 | N | + | N | + | ++ | SIP | B | C) 0-2mm |
| 12 | Female | 51 | 15 | + | +++ | 0 | N | +++ | SIP | A | D) 2.1 - 4mm |
| 13 | Female | 26 | 3 | N | +++ | N | ++ | +++ | SIP | B | E) >4mm |
| 14 | Male | 54 | 30 | N | ++ | N | ++ | 0 | PN | D | |
| 15 | Female | 26 | 31 | N | + | N | N | +++ | SIP | A | **Group 1: 2-53** |
| 16 | Female | 18 | 30 | N | ++ | N | ++ | 0 | PT | E | **Group 2: 54-104** |
| 17 | Female | 31 | 20 | N | + | N | + | ++ | SIP | A | **Group 3: 105-156** |
| 18 | Male | 42 | 18 | N | ++ | N | ++ | ++ | SIP | B | **Group 4: 157-207** |
| 19 | Male | 20 | 3 | N | + | 2 | + | 0 | PT | B | **Group 5: 208-259** |
| 20 | Female | 39 | 3 | N | + | N | + | 0 | PIT | B | **Group 6: 260-311** |
| 21 | Male | 41 | 19 | N | N | N | ++ | + | N | A | |
| 22 | Female | 18 | 30 | N | + | N | + | +++ | SIP | B | |
| 23 | Female | 39 | 18 | ++ | +++ | N | +++ | 0 | PN | C | |
| 24 | Female | 64 | 4 | + | + | N | N | 0 | PN | D | |
| 25 | Female | 33 | 2 | N | ++ | N | ++ | +++ | SIP | A | |
| 26 | Female | 68 | 30 | N | + | N | + | ++ | SIP | A | |
| 27 | Male | 48 | 29 | N | + | N | + | ++ | SIP | A | |
| 28 | Female | 53 | 31 | N | + | N | N | + | AIP | A | |
| 29 | Male | 18 | 15 | N | ++ | N | + | ++ | SIP | B | |
| 30 | Female | 22 | 30 | N | + | N | N | 0 | PN | EEDEE | |
| 31 | Female | 19 | 20 | N | ++ | N | + | +++ | SIP | B | |
| 32 | Male | 48 | 30 | N | + | N | N | 0 | PT | E | |
| 33 | Female | 59 | 14 | + | N | N | N | 0 | PN | E | |

# Results

## Statistical Methods

Interrater reliability and intrarater reliability were assessed with Cohen's Kappa statistic for pairs of raters. Average Kappa was calculated based on the combination of raters. Median Kappa was calculated based on the agreement with calibration. Associations between clinical characteristics (biting, cold, mobility, palpation, percussion, pulpal diagnosis) and lesion size (normal, widened PDL, 0-2mm, 2.1-4mm, >4mm) with chi-squared tests. Association of patient age and lesion size was assessed with ANOVA. Significance level was set at 0.05. SAS EG v.8.2 (SAS Institute, Cary, NC) was used for analyses.

## Results

A total of 305 teeth were included in the analysis. More than half of the patients were female (62%) with roughly equal distribution of age which ranged from 18 to 94. The majority of teeth included were molars (73%) and the remaining were premolars (27%). There was a nearly equal split between the two arches. The largest category of teeth was the mandibular molar group (43%), followed by maxillary molars (29%), maxillary premolars (20%), and finally mandibular premolars (8%). The most common pulpal diagnoses were symptomatic irreversible pulpitis (45%), pulp necrosis (30%) and previously treated (19%). One third of the teeth had a normal response to biting, 50% had no response to cold, 91% had normal mobility, 74% had normal response to palpation, and 4% had normal response to percussion. A complete summary of the patient and clinical characteristics is presented in Table 1 and a key is provided in Table 2.

*Table 1: Patient and Clinical Characteristics of Cases Included*

| Patient Characteristic | | n | % | Clinical Diagnostic Characteristic | | n | % |
|---|---|---|---|---|---|---|---|
| **Patient Sex** | | | | **Biting** | | | |
| | Female | 190 | 62% | | + | 120 | 39% |
| | Male | 115 | 38% | | ++ | 62 | 20% |
| **Age Group** | | | | | +++ | 21 | 7% |
| | 18-25 | 44 | 14% | | N | 102 | 33% |
| | 26-35 | 53 | 17% | **Cold** | | | |
| | 36-45 | 50 | 17% | | + | 20 | 7% |
| | 46-55 | 36 | 12% | | ++ | 34 | 11% |
| | 56-65 | 48 | 16% | | +++ | 97 | 32% |
| | 66+ | 74 | 24% | | 0 | 154 | 50% |
| **Tooth** | | | | **Mobility** | | | |
| | Molar | 222 | 73% | | 0 | 6 | 2% |
| | Premolar | 83 | 27% | | 1 | 15 | 5% |
| **Jaw** | | | | | 2 | 4 | 1% |
| | Maxilla | 156 | 51% | | 3 | 1 | 0% |
| | Mandible | 149 | 49% | | N | 279 | 91% |
| **Jaw/Tooth Combination** | | | | **Palpation** | | | |
| | Mandibular Molar | 133 | 43% | | + | 63 | 21% |
| | Mandibular Premolar | 23 | 8% | | ++ | 14 | 5% |
| | Maxillary Molar | 89 | 29% | | +++ | 2 | 1% |
| | Maxillary Premolar | 60 | 20% | | N | 226 | 74% |
| **Pulpal Diagnosis** | | | | **Percussion** | | | |
| | AIP | 10 | 3% | | + | 138 | 45% |
| | SIP | 139 | 46% | | ++ | 102 | 33% |
| | PN | 91 | 30% | | +++ | 53 | 17% |
| | PT | 58 | 19% | | N | 12 | 4% |
| | PIT | 7 | 2% | | | | |

*Table 2: Key to Interpreting Diagnostic Test Results*

| Clinical Diagnostic Characteristic | Symbol | Meaning |
|---|---|---|
| Biting | N | Normal |
| | + | Slightly tender |
| | ++ | Moderately tender |
| | +++ | Very tender |
| Cold | 0 | No response |
| | + | Normal |
| | ++ | Hyper response |
| | +++ | Hyper and Lingering response |
| Mobility | 0 | Ankylosis |
| | N | Normal |
| | 1 | Less than 1mm movement in horizontal direction |
| | 2 | More than 1mm movement in horizontal direction |
| | 3 | Horizontal and vertical movement of crown |
| Palpation | N | Normal |
| | + | Slightly tender |
| | ++ | Moderately tender |
| | +++ | Very tender |
| Percussion | N | Normal |
| | + | Slightly tender |
| | ++ | Moderately tender |
| | +++ | Very tender |

The average agreement across all pairings in the radiographic interpretation was moderate at 0.74 (95% CI: [0.67, 0.80]). This average represents the interrater reliability. The agreement between the two board certified endodontists was perfect (k=1.00). The agreement between the two General Practice dentists and the pair of endodontic residents were both k=0.62, considered Moderate. A summary of interrater reliability measures are provided in Table 3 and Kappa interpretation is provided in Table 5.

*Table 3: Interrater Reliability for Paired Raters*

| Pairing | Number of Pairs | Mean Kappa | SD | Range |
|---|---|---|---|---|
| All | 15 | 0.74 | 0.11 | 0.54-1.00 |
| Board Certified Endodontist | 1 | 1.00 | | |
| General Practice (GP) | | | | |
| Faculty | 1 | 0.62 | | |
| Endodontic Residents | 1 | 0.62 | | |
| Endodontist-Resident | 4 | 0.73 | 0.05 | 0.69-0.77 |
| Endodontist-GP | 4 | 0.73 | 0.04 | 0.70-0.77 |
| Resident-GP | 4 | 0.73 | 0.16 | 0.54-0.92 |

Since the raters demonstrated sufficient agreement in the interpretations, the scores of all teeth from each primary reviewer were used for further analysis.

Intra-rater reliability was determined using Kappa scores measured from 0.5-1.0 when comparing each of the scores by the raters to the scores agreed upon during the calibration exercise. Both board certified endodontists and one general dentist had perfect agreement with initial calibration ratings, one general dentist and one resident had a moderate level of agreement and one resident had a weak level of agreement. Due to the small sample size, the interquartile range and median were used to determine overall reliability of 0.87(0.72-1.0). These results can be seen in Table 4 and kappa interpretation is provided in Table 5.

*Table 4: Intrarater Reliability for Each Rater*

| Rater | Kappa | SE | 95% CI | |
|---|---|---|---|---|
| **Endodontist 1** | 1.00 | 0.00 | 1.00 | 1.00 |
| **Endodontist 2** | 1.00 | 0.00 | 1.00 | 1.00 |
| **General Dentist 1** | 1.00 | 0.00 | 1.00 | 1.00 |
| **General Dentist 2** | 0.74 | 0.23 | 0.29 | 1.00 |

| | | | | |
|---|---|---|---|---|
| **Resident 1** | 0.50 | 0.23 | 0.05 | 0.95 |
| **Resident 2** | 0.72 | 0.22 | 0.29 | 1.00 |

*Table 5: Kappa Interpretation*

| Value of Kappa | Level of Agreement | % of Data that are Reliable |
|---|---|---|
| 0-.20 | None | 0-4% |
| .21-.39 | Minimal | 4-15% |
| .40-.59 | Weak | 15-35% |
| .60-.79 | Moderate | 35-63% |
| .80-.90 | Strong | 64-81% |
| Above .90 | Almost Perfect | 82-100% |

There was a significant association between the lesion size and response to cold ($p<.0001$), palpation ($p=.0022$), percussion ($p=.0261$), and pulpal diagnosis ($p<.0001$). Teeth that had a positive response to cold were more likely to be considered normal on radiographs than those that had no response to cold (53% vs 23%). Teeth with an increased response to palpation were more likely to have lesions greater than 2mm (38% vs 17%). There were only 12 teeth with a normal response to percussion. Nonvital teeth were more likely to have lesions larger than 2mm than vital teeth (43% vs 1%). Clinical results from biting ($p=.3069$) and mobility ($p=.2823$) evaluations were not significantly associated with the lesion size. Lesion size was also significantly associated with the arch ($p=.0039$), with a greater percent of maxillary teeth being classified as “normal” and mandibular teeth more likely to have larger lesions. Lesion size was not significantly associated with the tooth type ($p=.2247$). Condensed results are presented in

Table 6 and a breakdown of these results are presented in Table 7. The p values associated with each category are different due to further breakdown of responses in Table 7.

*Table 6: (Condensed Version) Association Between Clinical Characteristics and Lesion Size*

| | Normal | Wide PDL | 0-2mm | 2.1-4mm | >4mm | P-value |
|---|---|---|---|---|---|---|
| **Biting** | | | | | | 0.3069 |
| Positive | 79, 39% | 50, 25% | 35, 17% | 14, 7% | 25, 12% | |
| Normal | 36, 36% | 20, 20% | 15, 15% | 13, 13% | 17, 17% | |
| **Cold** | | | | | | <.0001 |
| Positive | 80, 53% | 48, 32% | 19, 13% | 1, 1% | 3, 2% | |
| None | 36, 23% | 22, 14% | 31, 20% | 26, 17% | 39, 25% | |
| **Mobility** | | | | | | 0.2823 |
| None | 3, 50% | 0, 0% | 2, 33% | 0, 0% | 1, 17% | |
| Increased | 4, 27% | 2, 13% | 1, 7% | 3, 20% | 5, 33% | |
| Normal | 107, 38% | 67, 24% | 46, 16% | 24, 9% | 35, 13% | |
| **Palpation** | | | | | | 0.0022 |
| Increased | 27, 34% | 10, 13% | 12, 15% | 11, 14% | 19, 24% | |
| Normal | 89, 39% | 60, 27% | 38, 17% | 16, 7% | 23, 10% | |
| **Percussion** | | | | | | 0.0261 |
| Increased | 115, 39% | 66, 23% | 49, 17% | 26, 9% | 37, 13% | |
| Normal | 1, 8% | 4, 33% | 1, 8% | 1, 8% | 5, 42% | |
| **Pulpal** | | | | | | <.0001 |
| Vital | 79, 53% | 50, 33% | 19, 13% | 0, 0% | 2, 1% | |
| Nonvital | 37, 24% | 20, 13% | 31, 20% | 27, 17% | 40, 26% | |
| **Jaw** | | | | | | 0.0039 |
| Maxilla | 73, 49% | 29, 19% | 20, 13% | 12, 8% | 15, 10% | |
| Mandible | 43, 28% | 41, 26% | 30, 19% | 15, 10% | 27, 17% | |
| **Tooth Type** | | | | | | 0.2247 |
| Molar | 78, 35% | 55, 25% | 41, 18% | 18, 8% | 30, 14% | |
| Premolar | 38, 46% | 15, 18% | 9, 11% | 9, 11% | 12, 14% | |

*Table 7:(Full Version): Association between Clinical Characteristics and Radiographic Appearance*

| | Normal | Wide PDL | 0-2mm | 2.1-4mm | >4mm | P-value |
|---|---|---|---|---|---|---|
| **Biting** | | | | | | 0.6422 |
| + | 43, 36% | 33, 28% | 20, 17% | 9, 8% | 15, 13% | |
| ++ | 25, 40% | 14, 23% | 10, 16% | 5, 8% | 8, 13% | |
| +++ | 11, 52% | 3, 14% | 5, 24% | 0, 0% | 2, 10% | |
| N | 36, 36% | 20, 20% | 15, 15% | 13, 13% | 17, 17% | |
| **Cold** | | | | | | <0.0001 |
| **+** | 7, 35% | 8, 40% | 2, 10% | 1, 5% | 2, 10% | |
| **++** | 17, 50% | 12, 35% | 5, 15% | 0, 0% | 0, 0% | |
| **+++** | 56, 58% | 28, 29% | 12, 12% | 0, 0% | 1, 1% | |
| **0** | 36, 23% | 22, 14% | 31, 20% | 26, 17% | 39, 25% | |
| **Mobility** | | | | | | 0.2460 |
| 0 | 3, 50% | 0, 0% | 2, 33% | 0, 0% | 1, 17% | |
| 1 | 4, 27% | 2, 13% | 1, 7% | 3, 20% | 5, 33% | |
| 2 | 2, 50% | 1, 25% | 1, 25% | 0, 0% | 0, 0% | |
| 3 | 0, 0% | 0, 0% | 0, 0% | 0, 0% | 1, 100% | |
| N | 107, 38% | 67, 24% | 46, 16% | 24, 9% | 35, 13% | |
| **Palpation** | | | | | | 0.0447 |
| + | 20, 32% | 8, 13% | 10, 16% | 10, 16% | 15, 24% | |
| ++ | 6, 43% | 1, 7% | 2, 14% | 1, 7% | 4, 29% | |
| +++ | 1, 50% | 1, 50% | 0, 0% | 0, 0% | 0, 0% | |
| N | 89, 39% | 60, 27% | 38, 17% | 16, 7% | 23, 10% | |
| **Percussion** | | | | | | 0.1024 |
| + | 60, 43% | 25, 18% | 19, 14% | 14, 10% | 20, 14% | |
| ++ | 34, 33% | 28, 27% | 21, 21% | 9, 9% | 10, 10% | |
| +++ | 21, 40% | 13, 25% | 9, 17% | 3, 6% | 7, 13% | |
| N | 1, 8% | 4, 33% | 1, 8% | 1, 8% | 5, 42% | |
| **Pulpal** | | | | | | <0.0001 |
| AIP | 2, 20% | 6, 60% | 1, 10% | 0, 0% | 1, 10% | |
| PIT | 0, 0% | 4, 57% | 1, 14% | 1, 14% | 1, 14% | |
| PN | 23, 24% | 5, 6% | 17, 19% | 20, 22% | 26, 29% | |
| PT | 15, 26% | 11, 19% | 13, 22% | 6, 10% | 13, 22% | |
| SIP | 76, 54% | 44, 32% | 18, 13% | 0, 0% | 1, 1% | |

## Discussion

In endodontic diagnosis, the presentation of symptomatic apical periodontitis has exhibited a variety of symptoms and appearances. The present study showed that SAP is most commonly associated with the pulpal diagnosis of symptomatic irreversible pulpitis which was diagnosed in 45% of the cases. Following symptomatic irreversible pulpitis was pulp necrosis with 30% of cases. Half of the pulps responded to cold and 23% of these responsive pulps presented with radiographic deviations from normal. A total of 62% of the samples were classified as having either a wide PDL or a lesion. Of the posterior teeth included in this study, 73% were molars and 27% were premolars, 51% being maxillary and 49% mandibular. The diagnosis of SAP was seen in more frequently in females making up 62% of the cases vs 38% in males.

Apical periodontitis represents a defensive response to either a primary infection in an infected pulp or a secondary infection subsequent to endodontic treatment procedures. This response serves an important protective function, aimed at confining bacteria from the root canal space and preventing them from spreading into adjacent bone marrow spaces. Although the body can detect this infection, due to the lack of vascular support in the root canal, the body cannot eradicate the source of the infection. Periapical bone resorption, although representing tissue destruction, occurs as part of this defensive process. (23) Apical periodontitis may or may not present with clinical symptoms including pain, tenderness, and swelling. The current study focuses on apical periodontitis that presents with symptoms.

Odontogenic pain can be caused by the activation and sensitization of pulpal or periradicular nociceptors. This in turn can lead to a state of hyperalgesia and/or allodynia. Hyperalgesia is characterized by increased pain and/or an exaggerated response from a stimulus that normally provokes pain. This is generally evaluated by the application of a cold stimulus. Allodynia is characterized by pain due to a stimulus that does not normally elicit pain. This is typically evaluated by performing a percussion test. Several theories have been presented for apical mechanical allodynia, including pulpal mechanoreceptive neurons, inflammatory mediators/bacterial byproducts, and even central sensitization. (24)

One theory of pulpal mechanoreceptive neurons causing apical mechanical allodynia is by carious lesions allowing bacteria to access pulp tissue causing inflammation and activation of pulpal mechanoreceptors. This theory was suggested based on the hydrodynamic theory of dental pain which proposes that fluid movement is detected by mechanoreceptive nociceptors innervating the dentinal tubules. (25) A finding consistent with mechanoreceptors being present in the pulp is from a clinical study that showed teeth containing vital pulp could detect mechanical loads at twice the sensitivity of root filled teeth. (26) However, there is little support for this theory because this phenomenon does not occur in all patients with irreversible pulpitis.

A second theory of suggests that inflammatory mediators and bacterial byproducts from the coronal pulp diffuse apically causing inflammation and activation of periradicular mechanoreceptors found in the periodontal ligament. This theory is strengthened by the finding that histologic changes can occur in the periradicular tissue before total pulp necrosis. (17)

A third theory is that activation of pulpal nociceptors evokes mechanical allodynia by central sensitization. This is due to bacterial byproducts and inflammatory mediators activating and sensitizing nociceptors, which can lower the threshold for nociceptor firing. The barrage of nociceptive input from the periphery to the medullary dorsal horn results in an increased release of neuropeptides and neurotransmitters such as glutamate. This causes rapid expansion of the receptive fields and lowers the threshold for the development of mechanical allodynia at distant sites. (24) In support of this theory, a preclinical study suggested that this effect does not require chronic periods of sensitization, but can occur soon after sufficient stimulation of pulpal nociceptors occurs. (27)

Mechanical allodynia (presenting as SAP) can be associated with multiple pulpal diagnoses as demonstrated in the current study. The most commonly observed pulpal diagnosis in patients presenting with SAP was shown to be symptomatic irreversible pulpitis representing 46% of cases. When combined with asymptomatic irreversible pulpitis (3%), irreversible pulpitis was shown in 49% of the cases in the current study. It has been shown in a previous study that the incidence of SAP in patients presenting with irreversible pulpitis is 57.2%. (24) A reason for the discrepancy could be contributed to the source of patients that data was collected from in each study. Owatz used patients that presented to an emergency clinic for extraction and were in considerable pain. Patients in the current study were not all seen on an emergency basis. The study conducted by Owatz concluded that irreversible pulpitis presenting with mechanical allodynia was associated with significantly greater levels of past and present pain. This is clinically relevant as pre-operative pain has been documented to be a significant contributing factor to the presence of post-operative pain. (28) The presence of mechanical allodynia with preoperative pain should be considered in developing an appropriate postoperative pain management plan.

Following symptomatic irreversible pulpitis, the diagnosis of pulp necrosis was seen in 30% of patients. The transition from irreversible pulpitis to pulp necrosis is indicative of the spread of the infection from the pulp space to the periapical tissue. Following the pulpal diagnosis of pulp necrosis was previously treated representing 19% of the samples. Non-resolving or formation of periapical radiolucencies in previously root canal treated teeth are also referred to as endodontic failures. The most common reason endodontic treatment can fail is due to persistent microbial infection in the root canal system and/or the periradicular area. (29) A previous study conducted to assess the prevalence of apical periodontitis in root canal treated maxillary and mandibular posterior teeth in a Saudi Arabian population based on findings from images taken using cone-beam computed tomography (CBCT) found similar results. The overall prevalence in this study of 300 scans which included 433 teeth was found to be 18.2%. (30)

The sample in this study was comprised of 62% females and 38% males indicating that more females experience SAP. A previous study evaluating the prevalence of apical periodontitis in a Brazilian population showed that the frequency of AP was higher in females (64%) than among males (36%). (31) Both studies demonstrated that females are more likely to present with SAP. This gender discrepancy could be occurring due to more women seeking routine dental care than men making the detection of SAP more likely. (32)

Regarding the age of the subjects, the present study showed a relatively equal distribution of age which ranged from 18-94, with the exception of 24% being 66 years of age and older. Most studies have showed no significant difference in age and prevalence of SAP, while other studies have reported a significantly higher prevalence of SAP and conventional nonsurgical root canal treatment (NSRCT) among subjects older than 50 years. These findings are expected because of the physiological aging of the dental pulp, making a positive outcome of NSRCT in this population even more challenging resulting in a higher chance of endodontic failure. (33)

Another possibility for this finding is that the oral health status of the geriatric population is generally more deficient, with an elevated prevalence of caries and periodontal disease both of which can increase likelihood of SAP. (34)

The frequency of SAP according to tooth type showed that mandibular molars are the most affected teeth as seen in 44% of the cases in this study. Following mandibular molars were maxillary molars 29%, maxillary premolars 20%, and mandibular premolars 8%. Further, molars represented 73% of the samples and premolars the remaining 27%. A previous study evaluating the prevalence of apical periodontitis including all teeth in the mouth except third molars found similar results reporting the most frequent teeth presenting with SAP were molars making up 23% of the sample followed by premolars at 14%. (35) A more recent study evaluated 3672 endodontically treated teeth over eight years and found posterior teeth were most frequently treated comprising 80.1% of the total with molars making up 52.6% of the sample. The mandibular first molar was treated most often, 18.8%, followed by the maxillary first molar, 13.5% and the mandibular second molar 12.0%. The number of endodontically treated maxillary and mandibular teeth was similar at 50.8% and 49.2% respectively. (36) The permanent first molars are the first to erupt into the dental arch, bear heavy masticatory and occlusal forces, and are subjected to caries due to pits and fissures. When all those characteristics are taken into consideration, a higher prevalence of SAP in molars when compared to other teeth is expected.

The radiographic evaluation consisted of periapical radiographs taken with a digital sensor. To standardize the interpretation exercise, the diagnostic preoperative radiographs included in the study could not be not altered or enhanced. The examiners included two general dentists, two second year endodontic residents, and two board certified endodontists. Each examiner was required to complete a calibration exercise before interpreting their designated set of radiographs. The calibration exercise consisted of a compilation of periapical radiographs from five random subjects. As a group, the examiners determined the periradicular status of each tooth as either A) normal, B) wide PDL, C) 0-2mm lesion, D) 2.1-4mm lesion, or E) >4mm lesion (see Figure 1). When all examiners agreed, individual interpretations were completed. Each of the six examiners were responsible for the interpretation of a total of 65 periapical radiographs. Each group had a designated PowerPoint presentation including the radiographs from 48 random cases selected from the total sample of 305, the five calibration cases, and 12 cases that were included in all six groups. The 12 cases that were included in all six groups were used to determine interrater reliability. When all of the examiners returned their interpretations, answers for the designated 12 radiographs were compared. The five calibration cases were included to determine intrarater reliability. When all of the examiners returned their interpretations, answers for the five calibration cases were compared to the answers given during the calibration exercise.

Interrater reliability was assessed with Cohen's Kappa statistic for pairs of raters. Average Kappa was calculated based on the combination of raters. The average agreement across all pairings was moderate, 0.74 (95% CI: [0.67,0.80]). The agreement between the two board certified endodontists was perfect (k=1.00). The agreement between the two general dentists and between the two second year endodontic residents was moderate (k=0.62). These number could be an implication that with more experience, consistency of radiographic interpretation improves. A previous study comparing physician radiographic interpretation with radiologists and residents demonstrated that physician specialty and training level had significant associations with the accuracy of interpretation of emergency department radiographs. (37) The level of agreement seen in this study is considerably higher than what has been previously cited in the literature. In the classic study by Goldman utilizing film, agreement between six examiners regarding radiographic interpretation was less than 50%. (38) A similar but more recent study using digital radiography found the overall agreement between six examiners regarding radiographic interpretation was less than 25%. (39) One explanation for the low agreement in the study interpreting digital radiography is that each examiner could enhance or alter each film which could change the image considerably altering the appearance of the periapex. An explanation for the high level of agreement in the present study is that interrater reliability was based on the agreement of twelve radiographs. This is a smaller sample size than what was used in the previous studies.

Intrarater reliability was determined using Kappa scores measured from 0.5-1.0 when comparing each of the scores given by the raters to the scores agreed upon during the calibration exercise. Both endodontists and one general dentist had perfect agreement with initial calibration ratings. This could be higher than what has been found in previous studies when considering the small sample of just 5 radiographs in the current study. This is not a strong statistic as the individual score given by each rater was compared to the answers given during calibration after a group discussion to determine the correct interpretation.

In the presence of a wide PDL and/or periapical radiolucency, the most prevalent pulpal diagnosis was pulp necrosis 36%, followed by symptomatic irreversible pulpitis 33% and previously treated teeth 23%. Once the root canal is infected and pulp necrosis occurs, neither the host defense nor systemic antibiotic therapy is effective due to the absence of a local blood supply within the tooth which supports the relationship of pulp necrosis and periapical bony changes. (11) The prevalence of symptomatic irreversible pulpitis and the presence of a periapical radiolucency is an indication that the inflammatory conditions in the periapical tissues can develop more rapidly than any radiologically detectable changes in bone. Studies have shown that changes in bone occur early in the disease process, when the pulp is still vital. (9) These changes, however, are not always detected on a two-dimensional periapical radiograph. Cone beam computed tomography (CBCT) has been shown to be more sensitive in detecting changes in the apical bone anatomy. (20) Previously treated root canals with periapical bony changes indicate failed endodontic therapy and the persistence of bacteria either in the canal or outside of the canal. These bacteria can elicit an immune response resulting in symptoms and/or bony changes detected radiographically.

In addition to the research showing the presence of vital tissue in teeth with periapical radiolucencies, additional studies have demonstrated that our diagnostic testing is not always accurate. Pulpal diagnoses are made using pulp sensibility testing which includes thermal tests, hot and cold, as well as the electric pulp test (EPT). If the pulp does not respond to these tests it is considered to be necrotic and is given the diagnosis of pulpal necrosis. In a study by Petersson it was found that the accuracy of the cold test was 86%, 71% for the heat test, and 81% for the EPT. (40) These results indicate that our pulpal diagnostic tests can lead to a false positive, making our clinical diagnosis of the pulpal status incorrect. This could be another explanation of the presence of periapical radiolucencies in teeth with presumed vital pulp. Additionally, positive pulp sensibility testing has been shown in multirooted teeth with a periapical radiolucency. Pulp tissue in one canal could have vital tissue capable of responding to sensibility testing and have necrotic tissue in another canal. (41) It should also be noted that it is often difficult to clearly obtain an accurate history of clinical symptoms and responses to clinical testing due to the subjective nature of pain and the individual differences in pain threshold. Nonvital pulpal diagnoses of pulp necrosis, previously initiated treatment, and previously treated showed lesions larger that 2mm more frequently when compared to vital pulps (43% vs 1%). In a previous clinical histopathological study, it was found that when large periapical radiolucencies are present, the associated tooth did not respond to pulpal sensibility testing. This study found that the size of the periapical radiolucency seems to be related to the extent and degree of bacterial invasion and tissue disintegration of the pulp in the root canal system. (41)

The current study showed that teeth with an increased response to palpation were more likely to have lesions greater than 2mm (38% vs 17%). This trend is in agreement with a previous study concluding that isolated tenderness to palpation in the apical area of the tooth is suggestive of relatively advanced periapical inflammation and/or infection. (42) Although both studies have similar results, the trend should be considered a weak association. A key factor influencing this data is subjectivity from both the clinician and the patient. The patients' response will be related to their level of perceived pain. This makes both the patient response and the providers interpretation subjective information.

The current study is limited by the fact that the use of analgesics before the endodontic evaluation was not recorded. It has been shown that the intake of analgesics can affect endodontic diagnosis by decreasing the perception of pain or by decreasing the response to clinical tests. (43) NSAIDs have the ability to suppress local production of prostaglandins/inflammatory mediators to provide an analgesic effect, thereby altering endodontic diagnostic testing. (44) Specifically, it has been shown that ibuprofen affected testing values for vital teeth by masking palpation 40%, percussion 25%, and cold 25% on affected teeth with symptomatic irreversible pulpitis and symptomatic apical periodontitis. When nonvital teeth were included, the masking effect of ibuprofen was decreased. (24) However, of the teeth being evaluating in the present study, 96% displayed a painful response to percussion regardless of whether analgesics were used or not. Consequently, the influence of analgesics on the diagnostic testing performed during the evaluation is expected to be low.

The diagnosis of pulpal and periapical conditions can be complicated. It is often difficult to obtain an accurate history of clinical symptoms due to the subjective nature of pain. Adding to the difficulty is the psychological difficulty for the patient to differentiate and communicate their feelings of pain to the clinician. (45) Previous studies have shown that some patients have a reduction in mechanical allodynia, which is manifested as sensitivity to percussion, biting, or pressure. (24) Ultimately, this proves that these tests are subjective and produce a large margin for error as they do not provide quantitative data and yield variable results.

Although retrospective chart reviews can provide valuable information, several limitations accompany this study design. Retrospective chart reviews rely completely on documentation of previous providers leading to inaccurate, incomplete, or misinterpreted information. In the current study, all evaluations were completed by first- and second-year residents meaning all evaluators were still in training. When these diagnostic tests are performed and recorded by endodontic residents with less experience than practicing endodontists as in the current study, the diagnosis could be compromised.

Interpretation of a digital radiograph is subjective and varies depending on who is reading the radiograph. In a previous study including six evaluators, it was shown that the percentage of agreement among all six evaluators for all radiographs was less than 25% and the percentage of agreement for five of the six was approximately 50%. (39) This proves radiographic interpretation to be a major limitation of the current study. Not only is radiographic interpretation subjective, but the interpretation can also be subjected to bias. It has been shown that the radiographic appearance of coronal and intraradicular areas can influence the interpretation of periapical areas. (46) This finding has implications for all radiographic outcome assessments. In the current study, all raters were aware that all included samples had the periradicular diagnosis of SAP, which could have influenced their interpretation of the radiograph.

# Conclusion

The results found in the current study demonstrate the variety of symptoms and presentations the periapical diagnosis of symptomatic apical periodontitis can exhibit. Several previous studies have found similar associations increasing the validity of the presented information. It was concluded that the periapical diagnosis of symptomatic apical periodontitis is more commonly diagnosed in female patients with a roughly equal distribution of age in all patients. Mandibular molars are the most prevalent tooth type followed by maxillary molars, maxillary premolars, then mandibular premolars. Nearly all teeth presented with percussion sensitivity and half presented with pain to palpation. Common pulpal diagnoses seen with SAP in order of prevalence were symptomatic irreversible pulpitis, pulp necrosis, previously treated. There was a significant association between the lesion size and response to cold and palpation. Teeth that had a positive response to cold were more likely to have a normal periapex, wide PDL, or lesion less than 2mm. Symptomatic apical periodontitis is a diagnosis given frequently in endodontics and knowledge about patient demographics, clinical presentation, and radiographic presentation will help to guide the clinician to an accurate diagnosis and appropriate treatment.

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