Prevalence of Apical Periodontitis in Endodontically Treated Premolars and Molars with Untreated Canal: A Cone-beam Computed Tomography Study

Bekir Karabucak, DMD, MS, Alf Bunes, DMD, FC,* Christel Chehoud, AB,† Meetu R. Kohli, BDS, DMD,* and Frank Setzer, DMD, PhD, MS**

Abstract

Introduction: The purpose of this retrospective cohort study was to evaluate the incidence of missed canals in endodontically treated teeth in the Greater Philadelphia area patient population and to evaluate the effect of untreated canals on endodontic outcome. **Methods:** A total of 1397 cone-beam computed tomography (CBCT) volumes taken from January 2013 to July 2015 were investigated. Limited view CBCT images were taken with Kodak 9000 3D System field of view at voxel size, 76 μm or Morita Veraviewpocs 3D F40 field of view at voxel size, 125 μm. All root canal–treated premolars and molars were included in the study. Unfilled canals appearing from cementoenamel junction to apex including splitting from a main canal at coronal, mid, or apical third were defined as missed-untreated canal. A periapical lesion was diagnosed when disruption of the lamina dura was detected and the low density area associated with the radiographic apex was at least twice the width of the periodontal ligament space. **Results:** The overall incidence of missed canals was 23.04%. The incidence of missed canals per tooth was highest in tooth #14 at 46.5% and tooth #3 at 41.3%. The incidence of missed canals was highest in the upper molars at 40.1% and lowest in the upper premolars at 9.5%. There was a significant difference in lesion prevalence when a canal was missed-untreated ($P < .05$). Teeth with a missed canal were 4.38 times more likely to be associated with a lesion. **Conclusions:** Limited field-of-view CBCT should be examined before any endodontic retreatment to identify missed canals. This knowledge would not only help clinicians to locate missed canals clinically but would also help in deciding the surgical approach. *(J Endod 2016;■:1–4)*

Key Words

Apical periodontitis, CBCT, endodontic outcome, incidence of missed canals, missed canal, prevalence of apical periodontitis

Optimal prognosis for root canal treatment depends essentially on the successful reduction of microorganisms from the infected root canals and prevention of microorganisms to enter into the root canal system (1, 2). However, the cause of unsuccessful outcome for endodontic treatments is multifactorial and cannot be associated with 1 factor (3, 4). Many prognostic studies have investigated the prevalence of apical periodontitis and tried to identify the potential risk factors affecting endodontic outcome. Factors such as existence of preoperative disease, pulpal status, working length level, shaping and disinfection of the canal system, and the quality of obturation and restoration have been correlated to endodontic prognosis (1–5) and well-documented in the endodontic literature. However, it is a problem inherent in epidemiologic studies that differences in clinical practice are difficult to control, and still many prognostic factors remain unknown.

Many prognostic studies collected information on risk factors such as diagnosis, presence of apical periodontitis, cleaning-shaping procedures, and obturation techniques from well-documented treatment records and incorporated radiographic images to evaluate technical quality of root filling. However, the criteria to evaluate the risk factors should rely on measurable, reproducible, and quantifiable indicators (6, 7). The parameters defining the quality of root filling differ among investigators, and different thresholds have been adopted when categorizing root fillings as adequate or inadequate. In some studies, the quality parameter was defined as the level of final root filling in relation to the root apex, the homogenous density of filling without voids, or the combination of the 2 indicators. Sjogren et al (2) compared the quality of treatment on the level of filling with radiographic apex, whereas Ray and Trope (4) combined the level and the density of filling material to evaluate the technical quality of the root canal treatment. Chugal et al (8) incorporated in their outcome risk assessment not only radiographic images but also clinical information on loss of working length during treatment.

Limitations of two-dimensional radiographic images to display three-dimensional (3D) structures are well-established. Even though the epidemiologic studies documented extensively that the technical quality of root filling is one of the few factors that can be reliably correlated to outcome, researchers pointed out repeatedly the limitation of intraoral radiographs to diagnose apical periodontitis and to identify lateral voids in oval-shaped root canals or in multirooted teeth (9, 10).

From the *Department of Endodontics, School of Dental Medicine, and †Department of Microbiology, School of Medicine, University of Pennsylvania, Philadelphia, Pennsylvania.

Address requests for reprints to Dr Bekir Karabucak, Department of Endodontics, School of Dental Medicine, University of Pennsylvania, 240 South 40th Street, Philadelphia, PA 19104. E-mail address: bekirk@dental.upenn.edu

0099-2399/$ - see front matter

http://dx.doi.org/10.1016/j.joen.2015.12.026

Recently, limited field-of-view (FOV) cone-beam computed tomography (CBCT) has been introduced into endodontics, and its use has quickly become widespread. Accurate and 3D images obtained with CBCT provide higher sensitivity in correlating images to actual structures (11) and eliminate several limitations of conventional radiographs (12). High-resolution images help detect extra canals, anatomic deviations, perforations, root resorptions, and pathologies affecting hard tissues (13–15).

The importance of locating all existing canals within the root system to achieve optimal prognosis has been discussed by many, and potential negative effects of untreated canals on endodontic prognosis have been debated. Overwhelming evidence of missed canals in failed cases requiring endodontic retreatment has been reported previously (13, 16, 17). However, to date, the incidence of missed canals and its effect on endodontic prognosis have not been reported.

Therefore, the purpose of this retrospective cohort study was to evaluate the incidence of missed canals in endodontically treated teeth in the Greater Philadelphia area patient population and also to evaluate the effect of untreated canals on endodontic outcome.

Materials and Methods

This study included all CBCT images taken from patients referred to the University of Pennsylvania Department of Endodontics for dental treatment between January 2013 and July 2015. The investigated patient population's dental treatment needs were various, and the reasons for referral and the types of treatment requested were not included in the data analysis of this study.

Limited-view CBCT images were taken with Kodak 9000 3D System F.O.V 50 × 37 mm at voxel size 76 μm (Carestream, Rochester, NY) (n = 903) or Morita Veraviewpocs 3D F40 F.O.V 40 × 40 mm at voxel size 125 μm (Morita Mfg, Kyoto, Japan) (n = 494).

All axial, sagittal, and coronal slices of each scan were evaluated by 2 readers as a group, an endodontist experienced with reading CBCT images and a second-year endodontic resident. Scans were viewed with the software provided with the CBCT unit, and investigators had full access to each software's features to manipulate images. Scans were viewed in a clinical environment on 24-inch monitors (resolution 1920 × 1200 at 60 Hz) provided by the CBCT companies.

All root canal–treated premolars and molars were included in the study. Axial, sagittal, and coronal images of each root were aligned to the vertical (canal orifice to apex) and horizontal (mesial to distal) marking lines parallel to the long axes of each canal. Initially, axial views were investigated for unfilled canal space, and subsequently the findings were confirmed by examining sagittal and coronal views. Unfilled canals appearing from cementoenamel junction to apex including canals splitting from a main canal at coronal, mid, or apical third were defined as missed-untreated canal.

A periapical lesion was diagnosed when disruption of the lamina dura was detected and the low density area associated with the radiographic apex was at least twice the width of the periodontal ligament space (10, 18).

The Fisher exact probability and odds ratio tests were used to assess the relationship between missed canals and occurrence of apical periodontitis.

Results

A total of 1397 CBCT volumes were examined. Six hundred fifty-five scans showing 1 or multiple endodontically treated maxillary or mandibular posterior tooth/teeth were selected for further examination. Eliminated group included scans of anterior region, premolar and molars with perforation, teeth with extensive root resorption altering root anatomy, previous periapical surgery with root-end resection, teeth with C-shape anatomy, and scans without endodontically treated teeth as well as images of unsatisfactory quality because of strong beam hardening and scattering effect of metals.

Six hundred fifty-five scans included a total of 1137 endodontically treated teeth (Tables 1 and 2). Overall prevalence of apical lesions was 59.5% (676 of 1137). The prevalence of lesions was highest in the lower molars and upper molars, 250 of 385 (64.9%) and 237 of 369 (64.2%), respectively.

The overall incidence of missed canals was 262 of 1137 or 23.04%. The incidence of missed canals per tooth was highest in tooth #14, 67 of 144 (46.5%), and tooth #3, 50 of 121 (41.3%). The incidence of missed canals was highest in the upper molars, 148 of 369 (40.1%), and lowest in the upper premolars, 25 of 262 (9.5%).

Prevalence of apical lesion in teeth with missed canal was 217 of 262 (82.8%). All lesions were around the root with a missed canal. There was a significant difference in lesion prevalence if a canal was missed ($P < .05$). A tooth with a missed canal was 4.38 times more likely to be associated with a lesion.

The results showed that the most frequently missed canal in maxillary molars was the mesiobuccal 2 canal (65%). Sixty-two percent of missed canals in mandibular first molars were the second distal canal. Seventy-eight percent of missed canals in mandibular second molars were in the mesial root.

Discussion

Cross-sectional studies are investigations in which information is collected in a systematic way in a well-defined population at a given point of time to describe disease prevalence and relate the disease to subjects' exposure to etiologic agents and pathogenic factors (6). The goal of this study was to capture the prevalence of apical periodontitis and correlate untreated canals identified on CBCT images to apical periodontitis. The limitation of this kind of data collection is that the data do not capture all causal factors affecting outcome or dynamic progress of healing, such as time of treatment, qualification of treating doctor, quality of obturation, treatment methodology, or quality of restoration.

TABLE 1. Distribution of Teeth Included in the Study

Tooth no.	No. of teeth included	No. of teeth without lesion	No. of teeth with lesion	Prevalence of lesion per tooth (%)	Incidence of missed canal per tooth (%)
1	1	0	1	100	0
2	51	22	29	56.9	33.3
3	121	33	88	72.7	41.3
4	65	31	34	52.3	12.3
5	58	29	29	50	5.2
12	58	27	31	53.4	10.3
13	81	41	40	49.4	9.9
14	144	51	93	64.6	46.5
15	47	23	24	51.1	27.7
16	5	3	2	40	20
17	1	0	1	100	0
18	63	30	33	52.4	20.6
19	138	51	87	63	18.1
20	37	24	13	35.1	2.7
21	17	8	9	52.9	35.3
28	22	11	11	50	18.2
29	45	23	22	48.9	4.4
30	139	36	103	74.1	20.1
31	44	18	26	59.1	22.7
32	0	0	0	0	0
Total	1137				

Tooth numbers were defined by using universal numbering system.

TABLE 2. Incidence of Missed Canal per Mandibular and Maxillary Premolars and Molars

Tooth	No. of teeth without lesion	No. of teeth with lesion	Incidence of missed canal per tooth classification (%)
Mandibular molar	135	250	19.7
Mandibular premolar	66	55	10.7
Maxillary molar	132	237	40.1
Maxillary premolar	128	134	9.5

In the present study the reasons for capturing 3D images or referral were not reviewed, and all endodontically treated teeth captured on scans were examined. It could be speculated that the defined population in this study, patients referred to the endodontic clinic, may have elevated incidence of apical periodontitis. Regardless, the results showed a strong relationship between the presence of an untreated-missed canal and apical disease.

High incidence of missed canals in cases requiring endodontic retreatment has been previously shown in the endodontic literature. Huumonen et al (13) compared the diagnostic information obtained from intraoral radiography and CT images of maxillary molars requiring retreatment. In their cohort, the mesiobuccal root was found to have 2 canals in 30 teeth out of 39 (76.9%). Periapical lesions around the mesiobuccal root were detected in 81.4% of cases (22 of 27) when an untreated-missed canal was seen. In a prospective clinical investigation, Hoen and Pink (16) found missed canals in 42% of all teeth that they retreated nonsurgically. In the present study, the overall incidence of missed canals was 23.04%. The difference between the present and the previously reported data could be attributed to differences in the cohort where the present study included not only endodontically failed teeth but all treated teeth.

The results showed that mesiobuccal 2 was the most frequently missed canal in maxillary molars. Sixty-two percent of missed canals in mandibular first molars were the second distal canal. However, it was an unexpected finding that 78% of missed canals in mandibular second molars were in the mesial root. To our knowledge, this finding has not been reported in the endodontic literature before. The difficulty in visualizing the entire pulp chamber and indirect access to mesial canals in mandibular second molars may be the contributing factors in locating all mesial canals.

Matherne et al (19) evaluated the accuracy of CBCT images and digital periapical radiographs taken from 2 different angles in *in vitro* conditions. When compared with CBCT evaluations, the endodontists, on average, failed to identify 1 or more root canal systems 40% of the time, even when the samples were radiographed without any interfaces of surrounding anatomic structures. American Association of Endodontists and American Academy of Oral and Maxillofacial Radiology joint position statement published in 2015 recommends that limited FOV CBCT should be considered the imaging modality of choice for initial treatment of teeth with the potential for extra canals and suspected complex morphology and dental anomalies (20). However, the joint position statement recommends acquiring FOV CBCT on retreatment cases to evaluate root fracture, root resorption, apical periodontitis, and length and density of root filling. Previously reported evidence and the present data on incidence of missed canals strongly suggest that limited FOV CBCT should be recommended before any retreatment case to identify possible missed untreated canals. The knowledge obtained from 3D images would not only help clinicians locate missed canals clinically but would also help in making decisions for surgical approach. However, as low as reasonably achievable principles should be observed when radiographic examination is used, and clinical judgment should be exercised when the knowledge gained from CBCT images and radiation exposure is assessed.

Over the years, several studies and case reports have investigated the incidence of canals and tried to interpret the signs and predictors of extra canals on radiographic images to help clinicians identify all canals during root canal treatment. Disappearance and narrowing of a canal, described as "fast break", have been interpreted on preoperative radiographs as indicator of canal bifurcation. In previously treated cases, acentric appearance of a canal filling compared with root outline was identified as an indicator of an additional canal (16). Three-dimensional, high-resolution images obtained with CBCT eliminate several limitations of conventional radiographs (12). In the present study, the combination of all axial, sagittal, and coronal slices of each tooth was examined. The presence of untreated canal space was confirmed on all views before it was counted as untreated. A correlation of an acentric appearance of root filling and the presence of extra canal was also observed on axial and coronal views of CBCT scans. This concept could be a useful clinical tool and should be considered when CBCT images are investigated. However, it is important to point out that the limitation of CBCT images is the scatter and beam hardening artifacts caused by high-density adjacent structures such as enamel and radiopaque materials such as metal posts, restorations, and root-filling materials (21, 22). Therefore, even though some cases were eliminated because of heavy scattering, it is possible that untreated canal space very close to radiopaque filling material may have been missed and not identified in this study.

In cross-sectional studies apical periodontitis was often observed in root-filled teeth, and frequencies between 25% and 50% have been reported. Our data showed overall prevalence of 59.45% apical periodontitis in root-filled teeth. Incidence of apical periodontitis detected in this patient group may seem higher than previously observed; however, a high detection rate of small changes in periapical bone structure with CBCT has been shown by many researchers. When the apical status was evaluated on CBCT and periodical radiographs by using the well-established periapical index scoring system, investigators concluded that CBCT tends to provide greater scores than periapical and panoramic radiographs (15, 23). The prevalence of apical periodontitis lesions detected with CBCT was shown to be significantly higher with the symptomatic irreversible pulpitis cases compared with the asymptomatic irreversible pulpitis cases (10). Velvart et al (24) correlated the information gathered from high-resolution CBCT scans with clinical findings and were able to visualize all lesions diagnosed with CBCT during surgery. When healing was evaluated after apical surgery in an animal study, it was concluded that the results obtained from CBCT and micro-CT corresponded to the histologic results (11). These findings suggest that the CBCT images present high accuracy for the detection of apical periodontitis. However, caution must be used when the appearance of apical tissues is evaluated on CBCT images, especially images revealing small changes. Histologic verification of these appearances is still lacking in the endodontic literature. The correlation between CBCT images and histologic findings needs to be studied further.

Acknowledgments

The authors deny any conflicts of interest related to this study.

References

1. Chugal NM, Clive JM, Spångberg LS. Endodontic infection: some biologic and treatment factors associated with outcome. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2003;96:81–90.
2. Sjögren U, Figdor D, Persson S, Sundqvist G. Influence of infection at the time of root filling on the outcome of endodontic treatment of teeth with apical periodontitis. Int Endod J 1997;30:297–306.

3. Byström A, Happonen RP, Sjögren U, Sundqvist G. Healing of periapical lesions of pulpless teeth after endodontic treatment with controlled asepsis. Dent Traumatol 1987;3:58–63.
4. Ray HA, Trope M. Periapical status of endodontically treated teeth in relation to the technical quality of the root filling and the coronal restoration. Int Endod J 1995;28:12–8.
5. Ng YL, Gulabivala K. Outcome of non-surgical re-treatment. Endod Topics 2011;25:1–28.
6. Eriksen HM, Kirkevang LL, Petersson K. Endodontic epidemiology and treatment outcome: general considerations. Endod Topics 2002;19:1–9.
7. Kirkevang LL, Horsted-Bindslev P. Technical aspects of treatment in relation to treatment outcome. Endod Topics 2002;2:89–102.
8. Chugal NM, Clive JM, Spångberg LS. A prognostic model for assessment of the outcome of endodontic treatment: effect of biologic and diagnostic variables. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2001;91:342–52.
9. Eckerbom M, Magnusson T. Evaluation of technical quality of endodontic treatment: reliability of intraoral radiographs. Dent Traumatol 1997;13:259–64.
10. Abella F, Patel S, Duran-Sindreu F, et al. Evaluating the periapical status of teeth with irreversible pulpitis by using cone-beam computed tomography scanning and periapical radiographs. J Endod 2012;38:1588–91.
11. Chen I, Karabucak B, Wang C, et al. Healing after root-end microsurgery by using mineral trioxide aggregate and a new calcium silicate-based bioceramic material as root-end filling materials in dogs. J Endod 2015;14:1–11.
12. Liang YH, Yuan M, Li G, et al. The ability of cone-beam computed tomography to detect simulated buccal and lingual recesses in root canals. Int Endod J 2012;45:724–9.
13. Huumonen S, Kvist T, Gröndahl K, Molander A. Diagnostic value of computed tomography in re-treatment of root fillings in maxillary molars. Int Endod J 2006;39:827–33.
14. Shemesh H, Cristescu RC, Wesselink PR, Wu MK. The use of cone-beam computed tomography and digital periapical radiographs to diagnose root perforations. J Endod 2011;37:513–6.
15. Estrela C, Bueno MR, Leles CR, et al. Accuracy of cone beam computed tomography and panoramic and periapical radiography for detection of apical periodontitis. J Endod 2008;34:273–9.
16. Hoen MM, Pink FE. Contemporary endodontic retreatments: an analysis based on clinical treatment findings. J Endod 2002;28:834–6.
17. Arx von T. Frequency and type of canal isthmuses in first molars detected by endoscopic inspection during periradicular surgery. Int Endod J 2005;38:160–8.
18. Zhang MM, Liang YH, Gao XJ, et al. Management of apical periodontitis: healing of post-treatment periapical lesions present 1 year after endodontic treatment. J Endod 2015;41:1020–5.
19. Matherne RP, Angelopoulos C, Kulild J, Tira D. Use of cone-beam computed tomography to identify root canal systems *in vitro*. J Endod 2008;34:87–9.
20. AAE and AAOMR joint position statement. J Endod 2015;30:1–7.
21. Katsumata A, Hirukawa A, Noujeim M, et al. Image artifact in dental cone-beam CT. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2006;101:652–7.
22. Barrett JF, Keat N. Artifacts in CT: recognition and avoidance. Radiographics 2004;24:1679–91.
23. Ørstavik D, Kerekes K, Eriksen HM. The periapical index: a scoring system for radiographic assessment of apical periodontitis. Endod Dent Traumatol 1986;2:20–34.
24. Velvart P, Hecker H, Tillinger G. Detection of the apical lesion and the mandibular canal in conventional radiography and computed tomography. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2001;92:682–8.