Endodontic Outcome Predictors Identified with Periapical Radiographs and Cone-beam Computed Tomography Scans

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Abstract

Introduction: The outcome predictors identified with data from periapical radiographs (PA) and cone-beam computed tomography (CBCT) scans might not be the same. This retrospective study evaluated various factors that might affect the outcome of root canal therapy. **Methods:** In total, 115 teeth (143 roots) with vital pulps were endodontically treated and followed up 2 years after treatment. Multivariate logistic regression was performed on the data from PA or CBCT to analyze outcome predictors. **Results:** At recall, PA detected periapical lesions in 18 roots (12.6%), as compared with 37 on CBCT images (25.9%). The length and density of root filling determined by PA and CBCT were often different ($p < .001$). Overall, 20 of the 25 short root fillings (80%) diagnosed by PA appeared as flush fillings on CBCT images. PA revealed 23 root fillings (16.1%) with voids, as compared with 66 on CBCT images (46.2%). When findings from PA were analyzed, density and apical extent of root filling were identified as predictors ($p < .05$). When findings from CBCT were analyzed, density of root filling and quality of coronal restoration influenced the outcome significantly ($p \leq .001$), whereas gender, tooth type, root curvature, number of visits, CBCT-determined apical extent of root filling, and use as abutment did not ($p > .1$). **Conclusions:** Treatment outcome, length and density of root fillings, and outcome predictors as determined with CBCT scans might not be the same as corresponding values determined with PA. *(J Endod 2011;37:326–331)*

Key Words

Cone beam computed tomography, outcome predictor, periapical radiography

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It is essential to understand which factors positively or negatively influence the outcome of root canal treatment. In a systematic review that analyzed the results of 63 outcome studies published between 1922 and 2002 (1), four factors were identified, namely presence or absence of preoperative apical periodontitis (AP), density and apical extent of root filling, and quality of coronal restoration.

Periapical radiographs (PA) were used in most previous outcome studies. However, AP could be radiographically undetectable when lesions are confined within the cancellous bone and covered by a thick cortex (2). Second, the quality of root filling as determined by two-dimensional PA could be questionable (3–5). In a number of studies, root fillings in extracted anterior and posterior teeth were buccolingually and mesiodistally radiographed; the mesiodistal radiographs, which are not clinically available, revealed significantly more voids along root fillings than the buccolingual radiographs, which are clinically available (4, 5). Therefore, it might be valuable to reanalyze risk factors more accurately by using reliable methods (6). Recently, cone-beam computed tomography (CBCT) has been introduced to the field of endodontics (7). The three-dimensional CBCT has been found to be more sensitive than PA in detecting extra canals (8), vertical root fractures (9, 10), and post-treatment periapical lesions (11–13).

The aim of this study was to compare the endodontic outcome predictors identified with PA and CBCT.

Materials and Methods

This study protocol was approved by the ethics committee at the Peking University School of Stomatology. Patients who had received vital pulpectomy and root canal treatment in at least 1 tooth in the Department of Operative Dentistry and Endodontics of Peking University School of Stomatology between January and September 2007 were consecutively recalled between October and December 2009. Thus, the follow-up period was 2 years. An invitation letter was sent to 204 subjects. Seventy-four subjects (32 men and 42 women; median age, 54 years) met the following criteria and were actually seen for a recall appointment. (1) Preoperatively, teeth had vital pulps without periapical radiolucency on PA. (2) Maxillary molars were not included because of radiographic overlap hindering the observation of periapical lesions on radiographs. (3) All participants were informed about the aim and radiation dose of the CBCT examination, and their consent was secured.

In total, 115 teeth (143 roots) were included in the study. Among them, 17 roots were treated because there was insufficient tooth structure for a permanent crown or the crown-root angulation needed to be changed; 14 of these were later used as abutments. The remaining 126 roots with vital pulps were treated as the result of symptomatic pulpitis.

The treatments were performed by department staff members who had limited their work to operative dentistry and endodontics for at least 5 years. After achieving coronal access, the working length was determined by using Root ZX (J. Morita Corp, Kyoto, Japan) and confirmed with PA. Crown-down technique with ProTaper (Dentsply Maillefer, Ballaigues, Switzerland) or Hero Shaper (Micro-Mega, Besancon, France) instruments were used to prepare root canals. Coronal flaring was performed with a ProTaper Sx or EndoFlare. The apical enlargement was completed with ProTaper F2 or F3 or Hero Shaper 30/0.06 or 30/0.04, depending on the root canal morphology.

Between uses of these instruments, each canal was irrigated with 2 mL of 1% sodium hypochlorite (NaOCl) solution by using a syringe and a 27-gauge needle. When a second visit was required, calcium hydroxide paste Calxyl (OCO, Dirmstein, Germany) was used in the canal between visits. All canals were filled with gutta-percha cones (Dentsply Maillefer) and zinc oxide–based sealer Cortisomol (Pierre Rolland Acteon Inc, Merignac Cedex, France) by using a cold lateral compaction technique. A file one size smaller than the master file was used to pick up the sealer 2 times from the mixing pad and placed into the canal, while rotating it counterclockwise. A standard master gutta-percha cone (Dentsply Maillefer) was lightly coated with sealer and placed in the canal to the full working length. Lateral compaction was achieved in each canal by using accessory gutta-percha cones (size 25) and an endodontic finger spreader size B (Dentsply Maillefer) that initially approached within 2 mm of the full working length. Permanent coronal restorations were placed within 1 week after the root canal treatment. The use of rubber dam was not recorded in patients' charts, and thus it was unknown whether rubber dam was used in all patients.

Clinical and Radiographic Examination

At the recall examination, pain, swelling, tenderness to apical and gingival palpation and percussion, as well as the quality of coronal restorations were recorded.

Two radiographic methods, intraoral PA and CBCT, were used to detect post-treatment periapical lesions. Straight projection intraoral PA were obtained with the digital imaging system Digora Optime (Soredex, Helsinki, Finland) with a parallel technique. Exposures (0.16–0.25 seconds) were obtained with a MinRay dental x-ray unit (Soredex) operating at 60 kV and 7 mA. The digital radiographs were obtained by immediately scanning the proprietary storage phosphor plates after exposure with the proprietary software (Dfw v.2.5.; Soredex). The selected scanning resolution was 400 dpi. The raw data images were then processed with the proprietary default processing algorithm and saved as 8-bit images. The CBCT images of the patients were made with a 3DX-Accuitomo CBCT scanner (J. Morita Mfg Corp), with the 4×4 cm field of view selection operating at 80 kVp, 4–5 mA, and an exposure time of 17.5 seconds. The CBCT images were reconstructed by using the system's proprietary software.

Two examiners, an endodontist and a radiologist, assessed the images from the 2 radiographic methods independently. In case of disagreement, the case was discussed until consensus was reached.

The absence of periapical lesions was defined as conditions such that the radiographic periodontal ligament space was not wider than 0.5 mm (14).

Clinical Factors Assessed

Preoperative Factors

Gender. Although a significant association between gender and success rate was not found in the majority of previous clinical studies (1), this factor was included in our analysis.

Tooth Type. The treatments performed in the anterior teeth, premolars, and mandibular molars were included.

Canal Curvature. The method of Schneider (15) was used to measure root canal curvature on PA or CBCT images. The greatest degree of curvature in either the coronal or sagittal plane was recorded for each root. All roots were divided into 3 categories depending on the curvature: <10°, 10–25°, and > 25°.

Intraoperative Factors

Apical Extent of Root Filling. The following categories were used to classify PA: flush, 0–2 mm short of apex; short, more than 2 mm short of apex; and long, beyond apex. In CBCT, the apical end of the root canal was used as a landmark. A short filling was diagnosed only when the root filling was short in all coronal and sagittal sections; long filling was diagnosed when the root filling extended beyond the apical end of the canal in at least 1 section.

Density (Quality) of Root Filling. The density (quality) of the root filling in each root was evaluated on the basis of both the buccolingual and mesiodistal CBCT images by using a modified scoring system originally suggested by Kersten et al (3). A score of 1, 2, or 3 was determined for each root, depending on the length of the longest void along the filling in at least 1 section. Absence of detectable voids or the longest void was <1 mm for score 1 (absence of voids), 1–2 mm for score 2 (short void), and > 2 mm for score 3 (long void).

Number of Treatment Visits. All treatment was completed in either 1 or 2 visits.

Postoperative Factors

Coronal Restoration. The quality of coronal restoration was examined both clinically and radiographically. Satisfactory restoration was defined as those with no evidence of discrepancy, discoloration, or recurrent caries at the restoration margin, with absence of a history of decementation (16). CT scans were not used for the evaluation because metal crowns create radiolucent areas, hindering the observation (17).

Use as Abutment for Prosthesis. The influence of use as abutment for prosthesis on treatment outcome was calculated.

Statistics

The recordings for apical extent and density of root fillings determined by PA and CBCT were compared with the χ^2 test. Multivariate logistic regression analysis was performed on the pooled data from PA or from CBCT separately to identify factors affecting treatment outcome. The presence of periapical lesions was the dependent variable; gender, tooth type, canal curvature, apical extent and density of root filling, number of treatment visits, coronal restoration, and use as abutment were considered as factors. The level of significance was set at $\alpha = .05$.

Results

A total of 130 subjects did not respond. The exact reasons for loss to follow-up were unknown.

All teeth were asymptomatic at recall. In clinical examination, 5 teeth were slightly tender to percussion.

Assessment of the PA and CBCT scans revealed interexaminer agreement of 0.60 and 0.75 (Cohen kappa), respectively. In case of disagreement, 2 observers reached agreement after discussion in all cases.

In 116 roots (81%), the observations made for both methods were in agreement; either a periapical defect was detected with both PA and CBCT, or no periapical defect was detected with either of these methods. PA revealed periapical lesions in 18 roots (12.6%) as compared with 37 on CBCT images (25.9%). All 37 lesions were visible in at least 2 planes (axial, coronal, or sagittal). In 4 roots (2.8%), a periapical lesion was visible on the radiographs but not visible on the CBCT images.

With regard to the apical extent of root filling, the same diagnosis was made with PA and CBCT scans in 104 roots (72.7%) (Table 1). Overall, 20 of the 25 short root fillings (80%) diagnosed by PA

TABLE 1. Number of Flush, Long, and Short Root Fillings Diagnosed by PA and CBCT

	PA			
	Flush	Long	Short	Total
CBCT				
Flush	81	8	20	109
Long	10	18	0	28
Short	1	0	5	6
Total	92	26	25	143

appeared as flush fillings on CBCT images. The difference between PA and CBCT in diagnosing apical extent was statistically significant ($p < .001$). On CBCT images, the apical extent of all root fillings was within 3 mm of the apical end of the root canal.

PA revealed 23 root fillings with voids (16.1%) (scores 2 and 3), as compared with 66 on CBCT images (46.2%) ($p < .001$). Of the 66 root fillings with voids, 51 (77.3%) showed a worse density score on their buccolingual images as compared with their mesiodistal view.

In CBCT, unfilled canals were present in the mesial roots of 3 mandibular molars; 2 roots with unfilled canals were associated with periapical lesions. Vertical root fracture or root perforation was not detected in any case.

The data analysis for the effects of clinical factors on the presence of post-treatment periapical lesions is summarized in Tables 2 and 3. When findings from PA were analyzed (Table 2), density and apical extent of root filling were identified as predictors ($p < .05$). When findings from CBCT were analyzed (Table 3), density of root filling and quality of coronal restoration significantly influenced treatment outcome ($p \leq .001$); gender, tooth type, root curvature, number of visits, CBCT-determined apical extent of root filling, and use as abutment did not ($p > .1$).

Of the 74 subjects, 53 had 1 treated tooth per person, and 21 had multiple treated teeth (2–6 roots per person). The association between quality and outcome for those 21 subjects was checked to determine whether including subjects with multiple treated teeth (roots) influenced the analysis. In 18 of 21 subjects, when both the density of root filling and the quality of coronal restoration were satisfactory, the root did not have a periapical lesion. When either the density of root filling or the quality of coronal restoration or both were unsatisfactory, a periapical lesion was present. In another 2 patients, when the quality of root filling and coronal restoration were satisfactory in all treated roots (n = 8), a periapical lesion was detected on 1 root from each patient. In 1 patient, all treated teeth (n = 2) did not have periapical lesions, despite the fact that the quality of root filling was substandard in 1 tooth.

Discussion

The recall rate was 36% (74 of 204), which is low but comparable to those reported in previous clinical studies (18). Ørstavik et al (19) reported that dropouts had more symptoms and perceived that treatment had failed. Marquis et al (18) reported that the attending and lost-to-follow-up populations differed significantly with regard to age. In the present study, the subjects could have declined the invitation to follow-up because of relocation, refusal to undergo CBCT, or the

TABLE 2. Summary of Data Analysis for Effects of Clinical Factors on the Presence of Post-treatment Periapical Lesions on the Basis of Findings from PA

		No. (%) of roots with or without periapical lesions		
Factors	No. of roots	With	Without	*p* value
Preoperative				
Gender				
Male	76	11 (14.5)	65 (85.5)	.175
Female	67	7 (10.4)	60 (89.6)	
Tooth type				
Anterior teeth	45	8 (17.8)	37 (82.2)	
Premolars	41	4 (9.8)	37 (90.2)	.672
Molars	57	6 (10.5)	51 (89.5)	
Curvature (degrees)				
< 10	52	6 (11.5)	46 (88.5)	
0–25	75	8 (10.7)	67 (89.3)	.311
> 25	16	4 (25)	12 (75)	
Intraoperative				
Apical extent of root filling				
Flush	92	8 (8.7)	84 (91.3)	
Short	25	4 (16)	21 (84)	.018
Long	26	6 (23.1)	20 (76.9)	
Density of root filling (voids)				
Score 1	120	8 (6.7)	112 (93.3)	
Score 2	2	1 (50)	1 (50)	<.001
Score 3	21	9 (42.9)	12 (57.1)	
Treatment visits				
Single	111	11 (9.9)	100 (90.1)	.169
Two	32	7 (21.9)	25 (78.1)	
Postoperative				
Coronal restoration				
Satisfactory	118	12 (10.2)	106 (89.8)	.465
Unsatisfactory	25	6 (24)	19 (76)	
Use as abutment				
No	124	15 (12.1)	109 (87.9)	.546
Yes	19	3 (15.8)	16 (84.2)	

Score 1, absence of voids; score 2, short voids; score 3, long voids.

TABLE 3. Summary of Data Analysis for Effects of Clinical Factors on the Presence of Post-treatment Periapical Lesions on the Basis of Findings from CBCT

Factors	No. of roots	No. (%) of roots with or without periapical lesions: With	Without	*p* value
Preoperative				
Gender				
Male	76	19 (25)	57 (75)	.668
Female	67	18 (26.9)	49 (73.1)	
Tooth type				
Anterior teeth	45	11 (24.4)	34 (75.6)	.504
Premolars	41	12 (29.3)	29 (70.7)	
Molars	57	14 (24.6)	43 (75.4)	
Curvature (degrees)				
< 10	52	14 (26.9)	38 (73.1)	.476
10–25	75	19 (25.3)	56 (74.7)	
> 25	16	4 (25)	12 (75)	
Intraoperative				
Apical extent of root filling				
Flush	109	28 (25.7)	81 (74.3)	.925
Short	6	2 (33.3)	4 (66.7)	
Long	28	7 (25)	21 (75)	
Density of root filling (voids)				
Score 1	77	7 (9.1)	70 (90.9)	<.001
Score 2	3	2 (66.7)	1 (33.3)	
Score 3	63	28 (44.4)	35 (55.6)	
Treatment visits				
Single	111	26 (23.4)	85 (76.6)	.417
Two	32	11 (34.4)	21 (65.6)	
Postoperative				
Coronal restoration				
Satisfactory	118	24 (20.3)	94 (79.7)	.001
Unsatisfactory	25	13 (52)	12 (48)	
Use as abutment				
No	124	28 (22.6)	96 (77.4)	.150
Yes	19	9 (47.4)	10 (52.6)	

Score 1, absence of voids; score 2, short voids; score 3, long voids.

above-mentioned reasons. The low recall rates reduce the impact of clinical outcome studies.

In Toronto studies, a success rate of 93% was recorded for vital teeth (18). Both periapical index scores 1 and 2 were considered as healed or successful, despite the fact that score 2 is representing mild periapical inflammation (20). When score 2 would not be considered successful, the success rate for vital teeth would drop to 70% (19). In the present study, absence of radiolucency was considered as success; the PA-determined success rate was 87.4%, which is comparable to those reported in previous clinical studies (18, 19).

However, CBCT detected more periapical lesions than PA, which concurs with the findings of a number of other studies (11–13). Our observations support the assertion that the value of PA in diagnosing periapical lesions is limited (2). Three studies have been performed to check whether CBCT-detected lesions are true lesions (21–23). In a dog experiment by Paula-Silva et al (21), each root where a periapical lesion was present on the CBCT images but absent on the radiograph was periapically inflamed, as determined histologically. In a study by Velvart et al (22), all 78 CBCT-scanned human periapical lesions were confirmed to be true bone defects during periapical surgery.

In 4 roots (2.8%), a periapical lesion was visible on the radiograph but not visible on the CBCT images. This result is in line with the finding of Christiansen et al (11), in which a periapical defect was detected on the PA but not on the CBCT images in 5% of cases. Because no histologic findings are available, it cannot be determined whether these radiolucencies were false negatives for CBCT or false positives for PA. Therefore, we have no explanation for this observation. The multivariate analysis performed on the data from PA and CBCT identified the density of root filling (presence or absence of voids) as a predictor. When voids were undetectable on CBCT images (score 1), AP was absent in 90.9% of roots; when voids were present (scores 2 and 3), however, this percentage dropped noticeably to 54.5% (Table 3). Coronal bacterial leakage and/or procedural contamination might have contributed to treatment failures (24). Voids along root fillings could provide bacteria with pathways to the periapex. However, it has been reported that CBCT was not sensitive enough to detect very fine voids (25).

On two-dimensional PA, 83.9% of root fillings had no detectable voids (Table 2), as compared with 83.6% recorded previously by Ng et al (1). However, the mesiodistal views on radiographs do not provide valid information for evaluating the quality of three-dimensional root fillings, and the true quality is unknown (3–5). CBCT detected root fillings with voids (scores 2 and 3) in 46.2% of roots, almost 3 times as many as those detected by PA (p < .001). In root fillings with voids diagnosed with CBCT, 77.3% displayed less density on the buccolingual view compared with the mesiodistal images, confirming previous findings where more voids were detected on radiographs that presented buccolingual images of root canals (3–5). However, only the mesiodistal image is available on PA.

It is commonly accepted that instrumentation and obturation should be terminated 0–2 mm short of the radiographic apex (26). On PA, it is difficult to identify the apical foramen, which might be located up to 3.8 mm short of the apex, particularly on the facial and lingual aspects of the root (27, 28). It has been found that when the tip of an instrument was placed 0–2 mm short of the apex on PA, the canal had been overinstrumented in many cases (28, 29). Notably, CBCT has been used to determine the apical extent of root fillings (13). In this study, the numbers of flush, long, and short fillings diagnosed by PA and CBCT (Table 1) were significantly different ($p < .001$). Of the 92 flush fillings (0–2 mm) identified on PA, 10 were too long, as confirmed by CBCT (Table 1). Only 20% of the short fillings (5 of 25) on PA were confirmed by CBCT, whereas 20 flush fillings were mistakenly diagnosed as too short by PA.

Only teeth with vital pulps were treated in the present study. Sjörgen et al (26) analyzed the influence of the apical extent of root filling on treatment outcome in teeth without preoperative AP. The authors did not find any association between length of root filling and outcome. However, unsatisfactory apical extent could negatively influence outcome in teeth with preoperative AP (26). With irreversible pulpitis (vital pulp), the bacterial colonization (if present) usually has not reached the apical one third or the tooth's dentinal tubules and ramifications (30). Instrumentation at the apical portion of the tooth seeks to remove the noninfected tissue and to shape the canal. For vital cases, the favorable point for the termination of instrumentation and obturation appears to be 2–3 mm short of the apical foramen, and it seems unnecessary to terminate the procedures close to the apical foramen (26, 31). In teeth with preoperative AP, the apical portion of the root canal is infected (32, 33). Disinfection of the root canal system might be compromised and periapical healing might be hindered when the instrumentation procedures are not terminated close to the apical foramen. Sometimes instrumentation is compromised because of morphologic complexities, as in multirooted teeth and those with severe curvature (1, 13, 18, 34). It seems logical that tooth type, root curvature, number of visits, and CBCT-determined apical extent of root filling were not found to be predictors in this study because only teeth with vital pulps were treated. Two outcome predictors were found when using the data from CBCT, namely density of root filling and quality of coronal restoration. These findings indicate that in cases with vital pulps, it is essential to prevent intraoperative and postoperative bacterial invasion in the root canal system (1, 18, 24). Isolation with rubber dam is also critical to the success of reducing contamination and impacts results. The periapical healing in this study could have been negatively influenced because we are not sure whether rubber dam was used in every patient.

CBCT can provide multi-slice imaging information in 3 dimensions that PA cannot. The treatment outcome as determined by PA, the apical extent and density of root fillings as diagnosed by PA, and the outcome predictors identified by using PA data could be incorrect (Tables 1–3). Furthermore, CBCT scans allow for accurate diagnosis of extra canals and vertical root fractures (9, 10). Although it provides useful information with respect to these items, CBCT, as any technology, has known limitations. The cost, both monetary and radiation dose, must be considered. Using the smallest possible field of view is recommended. According to recently published studies, the radiation dose for Accuitomo CBCT with a 4 × 4 cm field of view is 0.02 mSv, which is equal to the dose for 2 conventional radiographs in the molar region (35). Because teeth with multiple roots were included and the association between quality and outcome was investigated, the length and density of root filling and treatment outcome had to be recorded for each root rather than each tooth. In 21 subjects, multiple teeth were treated per person. One might argue that intersubject differences could bias the multivariate analysis if compromised health conditions negatively influence periapical healing (1). In 18 of 21 of these subjects, a periapical lesion was detected only in roots with either unsatisfactory root fillings or unsatisfactory coronal restorations; lesion absence was always associated with good treatment quality. It seems that in the present study, patient was not an influencing factor on outcome. It could be that our sample did not include enough subjects with adverse systemic health conditions.

Within the limitations of the present study, it can be concluded that 2 years after treatments were performed in teeth with vital pulps, CBCT detected periapical lesions in 25.9% of the teeth as compared with 12.6% by PA. Root fillings with voids and unsatisfactory coronal restorations negatively influenced the outcome.

Acknowledgments

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

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