Clinical Factors Related to Noncompletion of Root Canal Therapy

Daniel J. Caplan, DDS, PhD; B. Alex White, DDS, DrPH

Abstract

Objectives: *This study identified clinical factors related to noncompletion of root canal therapy (RCT) among patients in a dental health maintenance organization (HMO) based in Portland, OR.* ***Methods:*** *A secondary analysis of a case-control study was conducted using data from 303 individuals enrolled continuously in the HMO from January 1, 1987, through December 31, 1994, who received endodontic access on a permanent nonwisdom tooth in 1987 or 1988. Person- and tooth-level characteristics were evaluated to compare patients whose accessed tooth was obturated by December 31, 1994, with patients whose accessed tooth was not obturated by that date. Written and electronic records were reviewed to ascertain study variables, and multivariate logistic regression models were developed to describe differences between the two groups.* ***Results:*** *Incomplete RCT was more common among patients who were symptomatic prior to access and had more missing first molars at access. It also was more common among teeth that were decayed, had more pockets ≥5 mm, and had fewer decayed or filled surfaces at access.* ***Conclusions:*** *Because patients with greater evidence of past and current oral disease were less likely to have completed RCT, they may require additional counseling about the importance of carrying through with prescribed treatment. [J Public Health Dent 2001;61(1):6-13]*

Key Words: root canal therapy, endodontics, tooth loss, epidemiology, retrospective studies, treatment decision making.

Endodontic access is the first step in root canal therapy (RCT) and occurs when a dentist intentionally uncovers a tooth's pulp chamber to remove pulp tissue. Although a tooth must be endodontically accessed for RCT to be performed, the access procedure does not ensure completion of RCT. Endodontic therapy is not considered complete until the root canals are obturated, and numerous decisions must be made after access for that stage to be reached. In addition, RCT should be followed by placement of a permanent restoration to prevent coronal bacterial leakage (1-6) and appropriate clinical follow-up to ensure the absence of ongoing endodontic infection.

Several outcomes are possible for endodontically accessed teeth. Many patients progress smoothly from RCT initiation through completion. Other patients have no further treatment on the tooth, including those who do not return once their pain disappears or who postpone completion of therapy indefinitely for financial, family, health, or other reasons. Still others might opt for extraction rather than completion of RCT, especially if the treatment plan changes secondary to complications such as perforation or nonrestorable tooth fracture, or if the tooth was opened only to give the symptomatic patient time to consider his or her treatment options. Patients with incomplete RCT may return later with symptoms of apical periodontitis due to infection of the root canal space, requiring additional debridement or extraction. Even if the tooth can be salvaged, endodontic treatment might be more complicated and the tooth might have a poorer prognosis than if RCT had been completed in a timely fashion. Thus, incomplete RCT may lead to additional cost and pain for the patient and chair time for the dentist. This additional time is not inconsequential. One study conducted in a Canadian dental public health clinic estimated the mean treatment times for pulpectomy and extraction at 37 and 17 minutes, respectively (7).

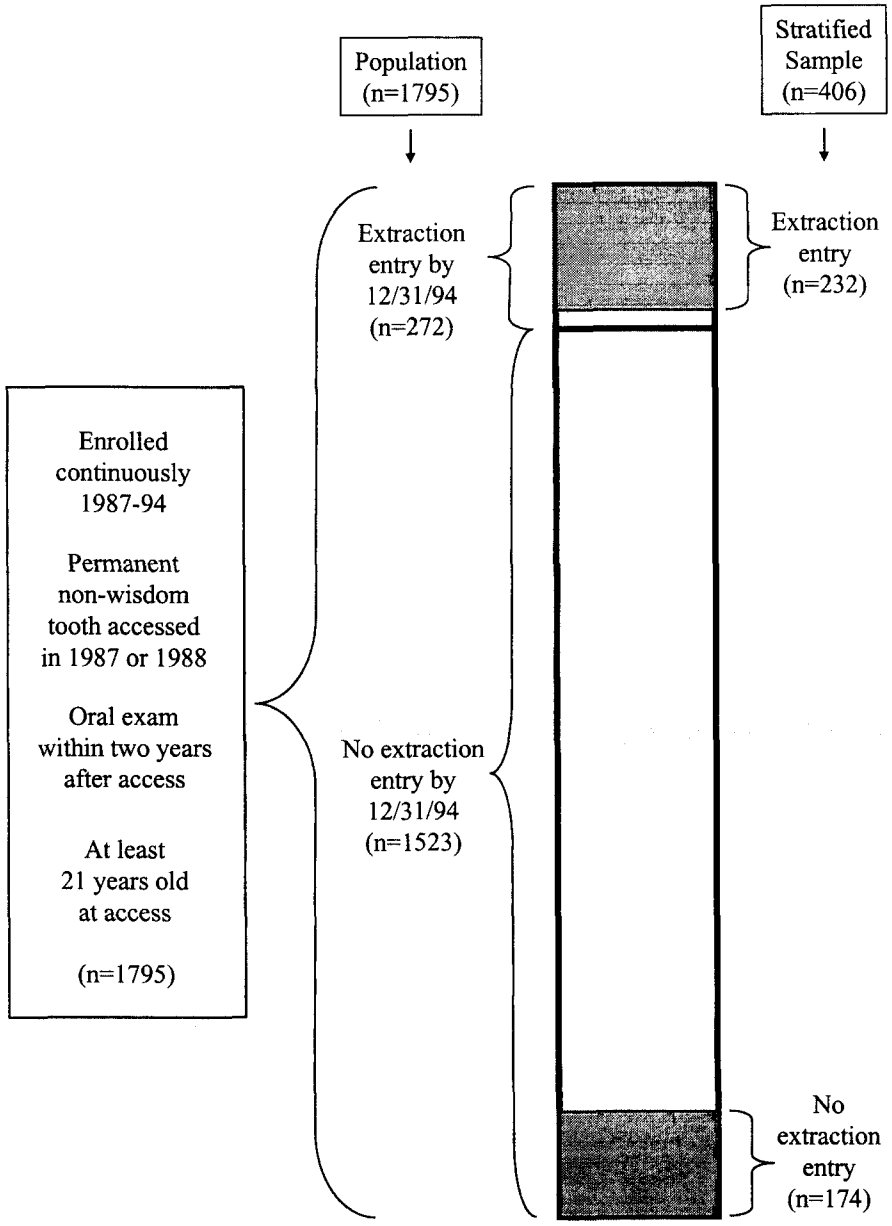
Given the costs of endodontic therapy and subsequent restorative treatment, the decision to undertake RCT is not always straightforward. When RCT requires multiple visits, the possibility exists that initiated endodontic therapy might not be completed. Although incomplete RCT benefits patients in that it can alleviate acute pain and postpone tooth extraction, RCT completion should be the goal, because incomplete RCT ultimately can lead to symptoms for patients, loss of chair time for practitioners, and frustration for both.

Patients carrying through with RCT might differ from individuals not completing RCT with respect to certain variables. If those factors can be identified, they could be used to determine which patients are most at risk of RCT noncompletion. Then, when such a patient decides to undergo endodontic access, the dentist could invest additional time and effort emphasizing the importance of completing endodontic therapy and the potential consequences of not doing so, with the ultimate goals being improved quality of care and better outcomes.

Evidence-based approaches to treatment decision making recommend that anecdotal reports describing successful therapies be replaced by systematic research into processes associated with beneficial treatment outcomes (8,9). Like risk assessment for dental disease, which incorporates statistical methods to identify factors related to disease development (10), this

Send correspondence to Dr. Caplan, Department of Dental Ecology, School of Dentistry, University of North Carolina, CB #7450, Chapel Hill, NC 27599-7450. E-mail: dan_caplan@unc.edu. Web site: http://www.dent.unc.edu/. Reprints will not be available. Dr. White is senior investigator, Kaiser Permanente Center for Health Research, Portland, OR. Supported by Permanente Dental Associates and NIDR grant 5T32DE07191-05. Abstract originally presented at the 75th General Session of the IADR, Orlando, FL, March 1997. Manuscript received: 5/17/99; returned to authors for revision: 7/16/99; accepted for publication: 3/8/00.

FIGURE 1
Identification and Sampling of Patients Using Computerized Treatment Database



study sought to identify factors related to the adverse outcome "RCT non-completion." Specifically, data from patients on whom endodontic therapy had been initiated were used to evaluate differences between those who subsequently completed RCT and those who did not. Implied in this comparison is that incomplete RCT is more likely to produce an undesired result than is completed RCT.

Methods

In this case-control study, cases were defined as patients who did not complete RCT within a specified time after endodontic access, while controls were defined as patients who did complete RCT during that interval. The present investigation was a secondary analysis that used data from a previous case-control study. The parent study (11) focused on variables related to loss of root canal filled (RCF) teeth among enrollees in the Kaiser Permanente Dental Care Program (KPDCP), a group-model dental health maintenance organization (HMO) based in Portland, OR. HMO enrollees were employed or retired individuals, or their dependents, who were eligible for dental benefits through the work place. Dentists providing care to enrollees were employed by Permanente Dental Associates, an independent contracting organization consisting of about 105 providers practicing in 12 dental clinics in Portland and Salem, OR, and Vancouver, WA.

To generate the parent study sample, computerized databases operated by KPDCP and Kaiser Permanente Northwest since 1987 were employed to identify patients who were enrolled continuously in the plan from January 1, 1987, to December 31, 1994, and had received endodontic access (i.e., intentional opening into the pulp chamber for any reason) on a permanent nonwisdom tooth in 1987 or 1988. For patients with multiple teeth accessed during those two years, the earliest accessed tooth was selected so that each patient had one tooth of interest. The list then was limited to the 1,795 patients who had at least one oral examination within two years after access and were at least 21 years old at access (Figure 1).

For the parent study (11), sample size calculations had dictated that about 110 subjects be selected at random from each of two groups: patients whose accessed tooth had been obturated and extracted by December 31, 1994, and patients whose accessed tooth had been obturated but not extracted by that date. The target value of 110 per group was based on assumptions of 5 percent two-sided Type I error, 90 percent power, 61 percent of controls with at least one missing nonwisdom tooth at endodontic access, and an odds ratio of 3.0 (12).

The treatment database contained codes representing extraction but not obturation. As such, the 1,795 patients in the target population were stratified into two lists, one containing the 272 patients for whom the treatment database contained an extraction entry for the accessed tooth prior to December 31, 1994, the other containing the 1,523 patients with no such entry (Figure 1). We anticipated that many teeth identified as having undergone endodontic access were teeth that were endodontic retreatments, never obturated, or miscoded in the database. Thus, we requested dental charts and demographic data for enough patients so that each group would contain approximately 110 qualifying subjects. A

TABLE 1
Collected Variables

Variable	Categories	Data Source
Age	Continuous (years)	Computerized database
Sex	Male, female	
Tooth arch	Upper, lower	Dentists' treatment notes
Tooth type	Anterior, premolar, molar	
Symptomatic within 3 mos. prior to access	Yes, no	
Perforation noted during endodontic procedure	Yes, no	
Decayed	Yes, no	Immediate preaccess periapical radiograph of accessed tooth
Coronal status*	Sound, 1,2,3 DF† surfaces, crown, bridge abutment	
Root status‡	Sound, 1,2 DF surfaces	
No. missing nonwisdom teeth	Count (0–28)	First Panorex after Jan. 1, 1987
No. missing 1st molars	Count (0–4)	
No. pockets ≥5 mm on tooth	Count (0–6)	Periodontal chart completed by hygienist previous to access
Proportion of teeth with at least 1 pocket ≥5 mm	Continuous (0.00–1.00)	
Stain	None, light, moderate, heavy	Clinical exam form completed by hygienist previous to access
Calculus	None, light, moderate, heavy	
Plaque	None, light, moderate, heavy	
Bleeding	None, light, moderate, heavy	
Brushing	Good, fair, poor	
Flossing	Good, fair, poor	
Anxious while having dental treatment	Yes, no	Health questionnaire completed by patient previous to access
Expect to keep natural teeth throughout lifetime	Yes, no	
Frequently consume sugar	Yes, no	
Ever worn denture or partial denture	Yes, no	

*Based on mesial, occlusal, and distal coronal surfaces only.
†DF=decayed or filled (permanent).
‡Based on mesial and distal root surfaces only.

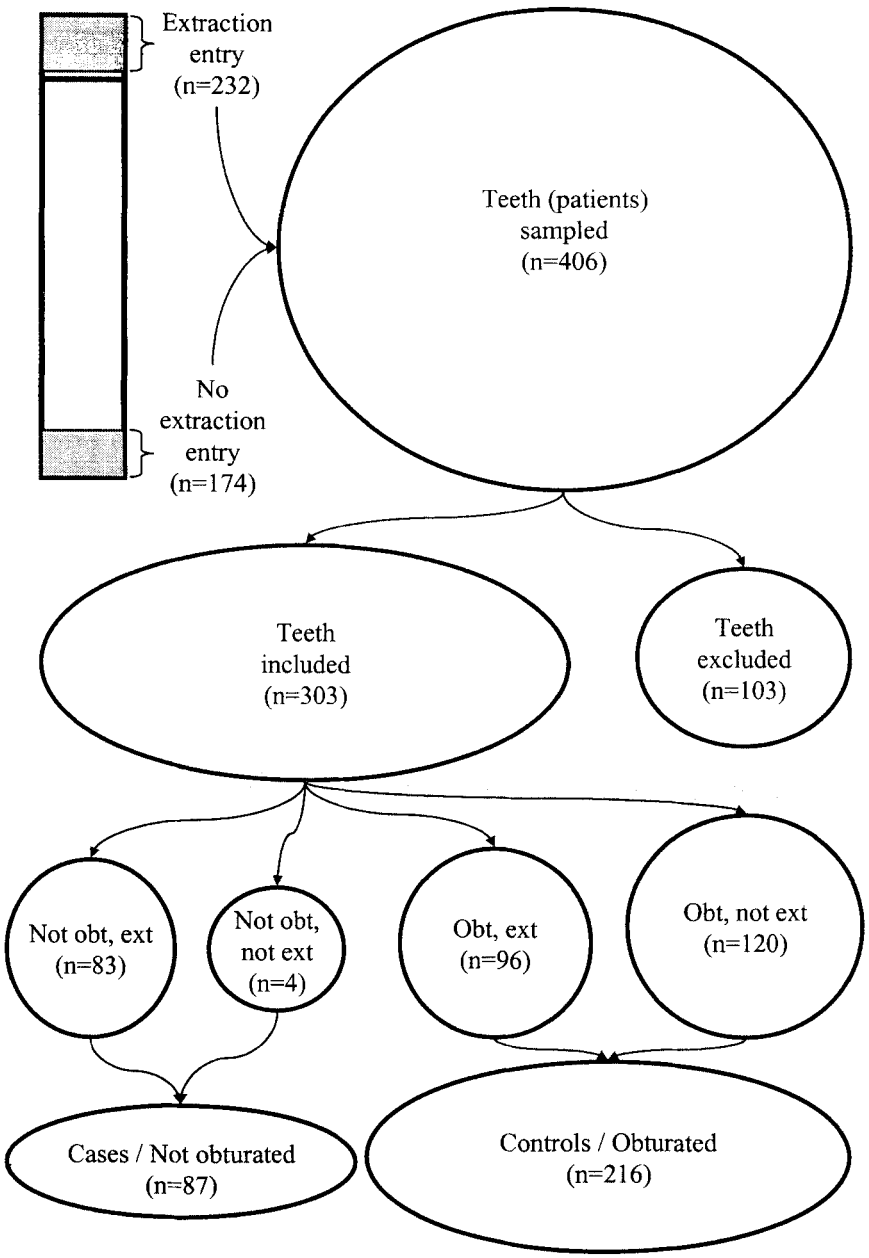
total of 406 records were requested: 232 selected at random from among the 272 who had an extraction entry plus 174 selected at random from among the 1,523 who did not (Figure 1). Sampling fractions from the two strata differed because the proportion qualifying for the study from the "extraction entry" group was much lower than that from the "extraction nonentry" group. Random selection was achieved by listing members of each stratum in random order using the RANUNI random number generator in SAS Version 6.04 (Cary, NC), then selecting subjects from each stratum in the order listed. Personnel and time restrictions prohibited data collection from additional subjects.

Four trained dentists reviewed providers' treatment notes, and one of these (DJC) examined radiographs. One trained dental hygienist gathered information from periodontal charts, clinical examination forms, and health histories. All data collectors were masked regarding subjects' case-control status. Table 1 shows the variables collected and their corresponding sources.

Figure 2 is a continuation of Figure 1 and shows the disposition of patients whose records were requested. Of these 406 individuals, seven had a miscoded patient record number, tooth number, or procedure in the database (and should not have been listed), and 21 had no Panorex radiograph after January 1, 1987 (this radiograph was needed to estimate the number of missing teeth at access). According to dentists' treatment notes, no patent canal was found in five of the accessed teeth, 23 had previously undergone RCT and were being retreated, and 36 were accessed either on an unknown date or prior to 1987. Eleven patient records were unavailable for review. Exclusion of these 103 individuals left 303 subjects for whom data were collected.

For the present study, the research question required a comparison between patients with obturated and those with nonobturated teeth. Of the 303 subjects for whom data had been collected, 87 were classified as cases because their accessed tooth had not been obturated by December 31, 1994 (Figure 2). This case definition applied regardless of the reason for nonobturation, because that variable had not been collected for the parent study. The other 216 subjects were classified as controls because their accessed tooth had been obturated by December 31, 1994. Presence or absence of the accessed tooth as of December 31, 1994, was verified by inspection of the

FIGURE 2
Case-control Group Assignments Using Patient Records



most recent radiograph of that tooth space. If the tooth had been extracted, the reason for extraction was determined from dentists' treatment notes.

Statistical analyses were conducted using SUDAAN, Version 7.11 for Windows (Research Triangle Institute, Research Triangle Park, NC). SUDAAN can account for the stratified selection mechanism employed to generate the parent study sample and also can apply the proper weight to each observation (13).

First, covariates' bivariate relationships with case-control status were evaluated. Bivariate associations for continuous variables were assessed via Student's unpaired *T*-tests, while chi-square and extended Mantel-Haenszel tests were used to evaluate bivariate relationships for categorical variables. The assumption of linearity was verified for ordinal variables recoded as continuous variables, and predictive models were generated to describe differences between cases and controls using multivariate logistic regression. To be eligible for use in multivariate analyses, variables were required to have moderately strong bivariate relationships with case-control status ($P \leq .20$) and no more than 5 percent missing values.

When data from a stratified sample are used in a multivariate analysis to evaluate an outcome that is not the stratification variable, the analyst must take the stratification variable into account or biased estimates of effect can result (14-16). One way to achieve unbiased parameter estimates is to include the stratification factor as an explanatory variable in the models (15). Thus, because only 87 subjects were in the case group, we limited each model to (at most) eight variables and included the stratification variable from the parent study in each model.

It was decided a priori that factors eligible for multivariate analysis would be classified into distinct domains of 4–7 variables each. Starting with all variables in a domain, backward selection based on *P*-values was employed to arrive at a model for the domain that contained only factors with $P \leq .05$. Variables remaining in domain-level models then were combined, and a similar backward selection procedure based on *P*-values was undertaken, with the final model including only factors with $P \leq .05$.

The parent study had been approved by the Committee for the Protection of Human Subjects at the Kaiser Permanente Center for Health Research. The present study was exempt from review because it was a secondary analysis using data generated during the previously approved parent study.

Results

The 96 obturated teeth extracted by December 31, 1994 (Figure 2) were lost for the following reasons: nonrestorable fracture (30%), periodontal disease (22%), nonrestorable caries (16%), pain or patient request (14%), and other or unknown reasons (19%) (percentages may not add to 100 due to rounding). In contrast, the 83 nonobturated teeth extracted by that date were lost due to nonrestorable fracture (13%), periodontal disease (16%), nonrestorable caries (31%), pain or patient request (31%), and other or unknown reasons (8%). Thus, reasons for tooth loss differed significantly between obturated and nonobturated teeth ($P = .001$, Cochran-Mantel-Haenszel chi-square test with 4 df).

Due to the stratified nature of the sample, univariate statistics are not re-

TABLE 2
Bivariate Relationships Between Covariates and Case-control Status

Characteristic	Cases/Incomplete RCT (*n*=87)		Controls/Completed RCT (*n*=216)		
	n	% or Mean (SE)	*n*	% or Mean (SE)	*P*-value*
Mean number of missing 1st molars	87	1.5 (0.1)	216	0.9 (0.1)	<.001
Mean number of pockets ≥ 5mm on tooth	86	1.3 (0.2)	205	0.6 (0.1)	<.001
Plaque†	86	67	213	44	<.001
Bleeding†,‡	80	74	201	49	<.001
Decayed	87	48	216	27	.002
Stain†,‡	84	50	201	28	.002
Brushing§	85	29	209	12	.002
Flossing‡§	83	59	198	41	.007
Keep teeth for lifetime‡	73	67	182	80	.007
Mean proportion of teeth w/ at least 1 pocket ≥ 5mm	86	0.31 (.04)	205	0.20 (.02)	.012
Mean number of missing nonwisdom teeth	87	5.1 (0.6)	216	3.5 (0.3)	.013
Male	87	50	216	37	.039
Coronal status¶,•	87		215		.045
0 DF surfaces		4		3	
1 DF surface		8		6	
2 DF surfaces		38		26	
3 DF surfaces (no crown or bridge abutment)		35		49	
3 DF surfaces (crown)		15		12	
3 DF surfaces (bridge abutment)		1		5	
Calculus†	86	62	213	50	.068
Symptomatic	87	87	216	80	.077
Root status¶	86		215		.102
0 DF surfaces		64		72	
1 DF surface		30		26	
2 DF surfaces		6		2	
Lower tooth	87	53	216	42	.102
Frequently consume sugar‡	84	47	197	37	.121
Tooth type¶	87		216		.124
Anterior		17		14	
Premolar		29		42	
Molar		54		43	
Mean age	87	47.3 (2.0)	216	45.6 (0.9)	.446
Denture or partial‡	82	30	200	25	.506
Anxious during dental treatment‡	79	29	195	32	.758
Perforation	87	2	216	2	.867

*Student's unpaired *T*-test for continuous variables; chi-square and extended Mantel-Haenszel tests for categorical variables.
†Percent "moderate" or "heavy" as opposed to "none" or "light."
‡Ineligible for multivariable analysis: ≥ 5% missing values.
§Percent "poor" as opposed to "good" or "fair."
¶Percentages may not add to 100 due to rounding.
•DF=decayed or filled (permanent).

ported. Instead, bivariate relationships between the covariates and case-control status are presented (Table 2). Of the 23 variables evaluated, 13 comparisons between those who did and did not complete RCT were statistically significant ($P \leq .05$). Compared to controls, cases were more likely to have poor oral hygiene ("moderate" or "heavy" plaque, stain, and bleeding, as well as "poor" brushing and flossing), a higher proportion of teeth with at least one pocket ≥5 mm, and more missing first molars and nonwisdom teeth. More cases than controls were male, and fewer cases than controls reported planning to keep their natural teeth for their lifetime. Teeth with incomplete RCT tended to have more pockets ≥5 mm, fewer decayed or filled (DF) surfaces at access, and a

TABLE 3
Final Multivariable Logistic Regression Model for Noncompletion of Root Canal Therapy*,†

Variable	Parameter Estimate	SE	*P*-value	Odds Ratio (95% CI)
Symptomatic within 3 months prior to access: yes=1, no=0	1.06	0.31	.001	2.9 (1.6–5.3)
Coronal status‡: 0–2 DF surfaces=1, 3 DF surfaces=0	0.86	0.34	.011	2.4 (1.2–4.6)
Decayed: yes=1, no=0	0.92	0.37	.013	2.5 (1.2–5.2)
No. pockets ≥ 5mm on tooth: (≥ 2)=1, (≤ 1)=0	1.01	0.41	.013	2.8 (1.2–6.1)
No. missing 1st molars: (3–4)=2, (1–2)=1, (0)=0	0.61	0.26	.020	1.8 (1.1–3.1)

*Includes all 87 cases and 216 controls.
†Controlling for stratification variable from parent study.
‡DF=decayed or filled (permanent).

TABLE 4
Final Multivariable Logistic Regression Model for Noncompletion of Root Canal Therapy (Excluding 39 Cases with Nonobturated Teeth Extracted Within 6 Months of Access)*,†

Variable	Parameter Estimate	SE	*P*-value	Odds Ratio (95% CI)
Symptomatic within 3 months prior to access: yes=1, no=0	1.39	0.46	.003	4.0 (1.6–9.9)
Coronal status‡: 0–2 DF surfaces=1, 3 DF surfaces=0	1.32	0.44	.003	3.7 (1.6–8.8)
Decayed: yes=1, no=0	1.10	0.48	.022	3.0 (1.2–7.7)
No. pockets ≥ 5mm on tooth: (≥ 2)=1, (≤1)=0	1.19	0.50	.016	3.3 (1.2–8.7)
No. missing 1st molars: (3–4)=2, (1–2)=1, (0)=0	0.90	0.31	.004	2.5 (1.3–4.6)

*Includes 48 cases and 216 controls.
†Controlling for stratification variable from parent study.
‡DF=decayed or filled (permanent).

higher likelihood of existing decay.

Fourteen variables were eligible for multivariate analyses and were separated into two domains of seven factors each. The full model for the domain "tooth-level factors" contained the variables tooth arch, tooth type, coronal status, root status, decayed, number of pockets ≥5 mm, and symptomatic within three months prior to access, plus the stratification variable from the parent study. The full model for the domain "patient-level factors" contained the variables sex, number of missing first molars, number of missing nonwisdom teeth, proportion of teeth with at least one pocket ≥5 mm, plaque, brushing, and calculus, plus the stratification variable from the parent study. Backward selection within each domain resulted in a total of seven variables plus the stratification variable comprising the combined full model. The final backward selection process eliminated the variables plaque and number of missing nonwisdom teeth, resulting in a model containing five factors plus the stratification variable (Table 3). Patients who were symptomatic prior to access and who were missing more first molars at access were less likely to complete RCT, as were those whose tooth was decayed, had more pockets ≥5 mm, and had relatively less coronal destruction at access.

Finally, because the reason for RCT noncompletion had not been ascertained, another model was generated using the same variables in the previous model, but excluding data from 39 cases whose nonobturated tooth was extracted within six months of access. This exclusion was performed to make the case group more homogeneous by including only patients who we thought would have had ample opportunity to have the tooth obturated had they chosen to do so. Our assumption was that patients whose nonobturated tooth was extracted prior to six months after access might have had the tooth opened only to allow them to make the "endodontic vs exodontic" decision while they were not in pain, or because the definitive treatment plan changed after the tooth was accessed. The six-month cutpoint was decided upon arbitrarily, but we felt that teeth extracted after this time likely had not been slated for extraction in the patient's definitive treatment plan. In this analysis (Table 4), all five variables remained statistically significant and exhibited substantially greater odds ratios than those obtained using all 87 cases.

Discussion

Several important study limitations should be recognized before the results are considered. First, retrospective studies depend on the quality of existing data. The success of any record audit hinges on the presence and legibility of chart entries and examination forms. Although data used herein were not collected for research purposes, the requested information tended to be available, orderly, and legible. Further, any inconsistencies noted would not be expected to differ systematically between cases and controls. Second, misclassification was possible for many variables, especially those requiring estimation of three-dimensional tooth characteristics from two-dimensional radiographs, such as the variables "coronal status" and "decayed." Errors in categorization would tend to wash out true differences between comparison groups with respect to the misclassified factors as long as the misclassification does not differ systematically between cases and controls. Third, variables potentially associated with RCT noncompletion were unavailable (e.g., smoking history, socioeconomic

status, care-seeking behavior, reason for RCT). These factors could account for part of the observed differences between comparison groups. Fourth, causality was not determinable using the present study design. Hence, a factor's presence in the final model (Table 3) means only that it was associated with RCT noncompletion, not necessarily that it caused it. Fifth, the possibility exists that patients underwent treatment outside the dental plan, and if so, those procedures would have gone unrecorded in KPDCP records. This possibility is considered unlikely because members' services in the plan are prepaid and inclusion criteria restricted the sample to those with eight years' continuous payment of premiums. Finally, we should emphasize that the sample was generated from data gathered for a different purpose, and that extracted teeth were intentionally oversampled. Thus, the proportions of accessed, obturated, and extracted teeth in the sample cannot be extrapolated to the target population without accounting for various sampling fractions and study inclusion criteria (13).

Generalizability of the findings may be limited because the sample was drawn from one HMO population and was comprised of individuals with continuous dental insurance. In addition, results should be applied only to patients who received endodontic access rather than all patients with pulpal involvement. Subjects in the present study represented the tip of the iceberg in a hypothetical population of endodontically involved teeth. For a tooth to be accessed, the patient first must present to the dentist's office. Although this may seem obvious, many individuals, particularly those with asymptomatic periapical pathology, might not seek dental treatment. Next, the dentist must diagnose a condition warranting endodontic access (e.g., irreversible pulpitis or pulpal necrosis), decide whether the tooth is restorable, and offer RCT as a treatment option. Finally, the patient must accept RCT, or at least endodontic access, as the first step in addressing his or her condition. The proportion of endodontically involved teeth that ultimately receive endodontic access is not known, depends on the characteristics of the population and practitioners under study, and was not estimated here.

Literature is sparse regarding the consequences of incomplete RCT, and factors associated with RCT noncompletion have not been widely reported. Wong et al. (17) described the relationship between RCT noncompletion and several factors (including preobturation pain and subsequent tooth extraction) among patients attending a military dental clinic. Because the interval of follow-up was not reported in that study, direct comparisons with the present study are difficult to make. However, the two studies are consistent in at least two respects. First, the proportion of patients who lost the tooth due to nonrestorable caries was about twice as high for patients with incomplete RCT as for patients with completed RCT. Second, the proportion of patients whose teeth had been causing pain or symptoms prior to access was greater among patients with incomplete RCT than with completed RCT.

The proportion of obturated teeth extracted for various reasons is consistent with that reported elsewhere (18,19). We are unaware of any published studies where the primary focus is the reason for loss of teeth with incomplete RCT. Here, the reason for extraction of such teeth may in fact be responsible for the decision not to complete RCT (e.g., nonrestorable fracture prior to obturation). Because the reason for RCT noncompletion was unavailable, it was impossible to exclude from the analyses any teeth for which the reason for noncompletion and the reason for extraction were coincident.

The final model (Table 3) suggests that patients with evidence of past oral disease (e.g., number of missing first molars) and current oral disease (e.g., symptomatic, number of pockets ≥5 mm on the tooth, decayed) were more likely not to complete RCT. These characteristics generally indicate poorer oral health, but also could reflect factors that were impossible to measure using the present study design, such as variability in previous providers' treatment decisions or the value placed by patients on maintaining a healthy dentition. The last variable in the model—fewer DF coronal surfaces at access—may be related to RCT noncompletion for several reasons. First, all coronal surfaces of crowned and abutted teeth were considered DF, and patients with such teeth probably place greater value on them than would patients whose teeth had not undergone such extensive restorative treatment. Second, more DF coronal surfaces might indicate more dental utilization among controls, which in turn may reflect more comfort with dental care in this group. Third, teeth with fewer DF coronal surfaces that were damaged badly enough to warrant RCT likely had deep occlusal, proximal, or root caries, which may indicate dental neglect.

Theoretically, one could identify patients who did not return for care or had no intention of completing RCT and use them as the case group in a case-control analysis. If such an analysis were conducted, odds ratios for variables representing "low dental IQ" or "dental neglect" would be hypothesized to increase. Our exclusion of 39 cases whose nonobturated tooth was extracted within six months after access (Table 4) was an attempt to achieve this objective using available data. Although misclassification with respect to this variable was likely, the greater odds ratios observed in Table 4 compared with Table 3 are consistent with this hypothesis.

The contents of the final model may not surprise practitioners who already have formed their own impressions of patient characteristics associated with incomplete RCT. The value of the model lies in (1) its identification of specific, objective clinical factors related to incomplete RCT, as opposed to the "gut feeling" of the individual practitioner based on his/her subjective evaluation; and (2) its quantification of the relative effect that each factor has on the likelihood of incomplete RCT. With the increasing call for "evidence-based" treatment decisions, studies that employ objective criteria to evaluate the success of therapeutic outcomes should gain greater acceptance.

The reason for RCT noncompletion was not ascertained in the original study, and thus was not available here. Even if attempts had been made to collect this variable, it would not consistently be in the records, especially for patients with no further treatment of the tooth after access. Accessed teeth sometimes remain nonobturated despite the original intentions of the patient and dentist. Many potential reasons exist for RCT noncompletion, including preobturation extraction

secondary to catastrophic tooth fracture and changes in patients' access to care due to moving. Some reasons for RCT noncompletion are driven by the dentist's clinical expertise and treatment recommendations, some by the patient's desires and behaviors, and others by interactions between the dentist and patient.

Certain patients may opt for endodontic access over extraction when saving the tooth for the long term really is not their objective. If the dentist suspects this to be true, after the decision has been made to initiate RCT, he or she should consider the factors in Table 3 when counseling the patient about follow-up care. For patients with these conditions, dentists may want to spend more time than usual emphasizing the importance of completing RCT and the consequences of not doing so. We do not, however, suggest using these factors to justify a recommendation of extraction rather than RCT for a patient who presents with these conditions and a salvageable tooth.

Recommendations for or against any treatment alternative should be based on the practitioner's clinical judgment, the value placed on the tooth by the patient, and the importance of the tooth in the overall treatment plan. Finally, although there is controversy about the appropriateness of single-visit RCT (20-23), when clinically indicated and logistically feasible, RCT should be carried out in one appointment to minimize the opportunity for incomplete RCT to occur. This recommendation may especially be appropriate for patients with the characteristics shown in Table 3.

To address this topic further, additional retrospective studies should be conducted; however, prospective studies also should be undertaken in which variables are recorded that are not consistently available retrospectively, such as the reason for RCT noncompletion, tobacco use and other health behaviors, patient and provider treatment preferences, and psychosocial outcomes. To help calculate the economic burden attributable to additional treatment of teeth with incomplete RCT, the time and costs devoted to providing multiple treatments for these teeth should be estimated.

References

1. Swanson K, Madison S. An evaluation of coronal microleakage in endodontically treated teeth. Part I. Time periods. J Endodont 1987;13:56-9.
2. Madison S, Wilcox LR. An evaluation of coronal microleakage in endodontically treated teeth. Part III. In vivo study. J Endodont 1988;14:455-8.
3. Madison S, Swanson K, Chiles SA. An evaluation of coronal microleakage in endodontically treated teeth. Part II. Sealer types. J Endodont 1987;13:109-12.
4. Torabinejad M, Ung B, Kettering JD. In vitro bacterial penetration of coronally unsealed endodontically treated teeth. J Endodont 1990;16:566-9.
5. Chailertvanitkul P, Saunders WP, MacKenzie D. Coronal leakage in teeth root-filled with gutta-percha and two different sealers after long-term storage. Endodont Dent Traumatol 1997;13:82-7.
6. Chailertvanitkul P, Saunders WP, MacKenzie D. Coronal leakage of obturated root canals after long-term storage using a polymicrobial marker. J Endodont 1997;23:610-13.
7. Woodward GL, Csima A, Leake JL, Ryding WH, Main PA. Estimation of procedure times in a publicly funded dental programme. Community Dent Health 1995;12:155-60.
8. Dodson TB. Evidence-based medicine: its role in the modern practice and teaching of dentistry. Oral Surg Oral Med Oral Pathol Oral Radiol Endodont 1997;83: 192-7.
9. Bray KK, Williams K. An evidence-based approach to clinical practice guidelines in periodontics. Curr Opin Periodontol 1997;4:96-103.
10. Beck J. Identification of risk factors. In: Bader J, ed. Risk assessment in dentistry. Chapel Hill, NC: University of North Carolina Dental Ecology, 1990:316.
11. Caplan DJ, Weintraub JA. Factors related to loss of root canal filled teeth. J Public Health Dent 1997;57:31-9.
12. Schlesselman J. Case-control studies. Design, conduct, analysis. New York: Oxford University Press, 1982.
13. Caplan DJ, Slade GD, Gansky SA. Complex sampling: implications for data analysis. J Public Health Dent 1999;59:52-9.
14. Fears TR, Brown CC. Logistic regression methods for retrospective case-control studies using complex sampling procedures. Biometrics 1986;42:955-60.
15. Lee AJ, McMurchy L, Scott AJ. Reusing data from case-control studies. Stat Med 1997;16:1377-89.
16. Breslow NE, Zhao LP. Logistic regression for stratified case-control studies. Biometrics 1988;44:891-9.
17. Wong M, Shelley JJ, Bodey T, Hall R. Delayed root canal therapy: an analysis of treatment over time. J Endodont 1992; 18:387-90.
18. Vire DE. Failure of endodontically treated teeth: classification and evaluation. J Endodont 1991;17:338-42.
19. Sjogren U, Hagglund B, Sundqvist G, Wing K. Factors affecting the long-term results of endodontic treatment. J Endodont 1990;16:498-504.
20. Albashaireh ZS, Alnegrish AS. Postobturation pain after single- and multiple-visit endodontic therapy. A prospective study. J Dent 1998;26:227-32.
21. Wahl MJ. Myths of single-visit endodontics. Gen Dent 1996;44:126-31, quiz 141-2.
22. Fava LR. Single visit root canal treatment: incidence of postoperative pain using three different instrumentation techniques. Int Endodont J 1995;28:103-7.
23. Trope M. Flare-up rate of single-visit endodontics. Int Endodont J 1991;24:24-6.