Root Canal Filled Versus Non-Root Canal Filled Teeth: A Retrospective Comparison of Survival Times

Daniel J. Caplan, DDS, PhD; Jianwen Cai, PhD; Guosheng Yin, PhD; B. Alex White, DDS, DrPH

Abstract

__Objective:__ This matched cohort study used data from a large dental HMO in the Pacific Northwest to evaluate the degree to which pulpal involvement and subsequent endodontic therapy affects tooth survival. Root canal filled (RCF) teeth were used as an indicator of pulpal involvement. Our hypothesis was that RCF teeth would be extracted sooner than non-RCF teeth matched within subjects, controlling for tooth-level variables of interest. __Methods:__ The HMO's treatment databases and a subsequent chart audit were used to identify 202 eligible subjects, each of whom had one tooth endodontically treated in 1987-88 and a similar contralateral tooth that was non-RCF at that time. Both teeth were followed from the endodontic access date through the extraction date, the endodontic access date (for initially non-RCF teeth), or 12/31/94, whichever was earliest. Time-to-event analyses were carried out, with Kaplan-Meier curves generated and multivariable marginal proportional hazards regression models fitted to describe the effect of RCF status on tooth survival. All statistical analyses accounted for the complex sampling strategy used in generating the dataset. __Results:__ Teeth were followed for up to eight (median=6.7) years. RCF teeth had substantially worse survival than their non-RCF counterparts (p<0.001), with a greater effect of RCF status evident among molars than non-molars. Adjusted hazard ratios (95% confidence intervals) for loss of RCF versus non-RCF molars and non-molars were 7.4 (3.2-15.1) and 1.8 (0.7-4.6), respectively. __Conclusion:__ Though endodontic therapy can prolong tooth survival, pulpal involvement still may hasten tooth loss, underscoring the importance of caries prevention and prompt restorative care.

Key words: epidemiology, proportional hazards regression, root canal therapy, survival analysis, tooth loss

Introduction

Teeth with small or medium-sized carious lesions generally can be restored and be expected to remain in the mouth for many years afterwards. However, pulpal involvement can occur when caries or restorations are deep, necessitating root canal therapy (RCT) or extraction. The impact of pulpal involvement and subsequent RCT on tooth survival has not been quantified. Though many root canal filled (RCF) teeth last a lifetime, others are lost shortly after completion of endodontic therapy (1). Non-RCF teeth can be lost due to non-restorable caries, advanced alveolar bone loss, catastrophic fracture, or prosthetic reasons (2, 3), or because saving the tooth might be too expensive for the patient. RCF teeth can be lost for these reasons as well, but also secondary to endodontic mishaps (e.g., perforation) or post-endodontic restorations (e.g., vertical root fracture from intracanal posts) (1, 4). For these reasons one might expect that once the pulp is affected by caries, tooth fracture or restoration, a tooth's expected survival is reduced compared to its expected survival without pulpal involvement.

The primary purpose of this study was to quantify the degree to which endodontic involvement and subsequent RCT affects tooth survival. We used RCF teeth as an indicator for pulpal involvement, our hypothesis being that RCF teeth would be extracted sooner than non-RCF teeth matched within subjects, controlling for tooth-level variables of interest. A secondary goal was to determine whether this relationship was different for molars and non-molars.

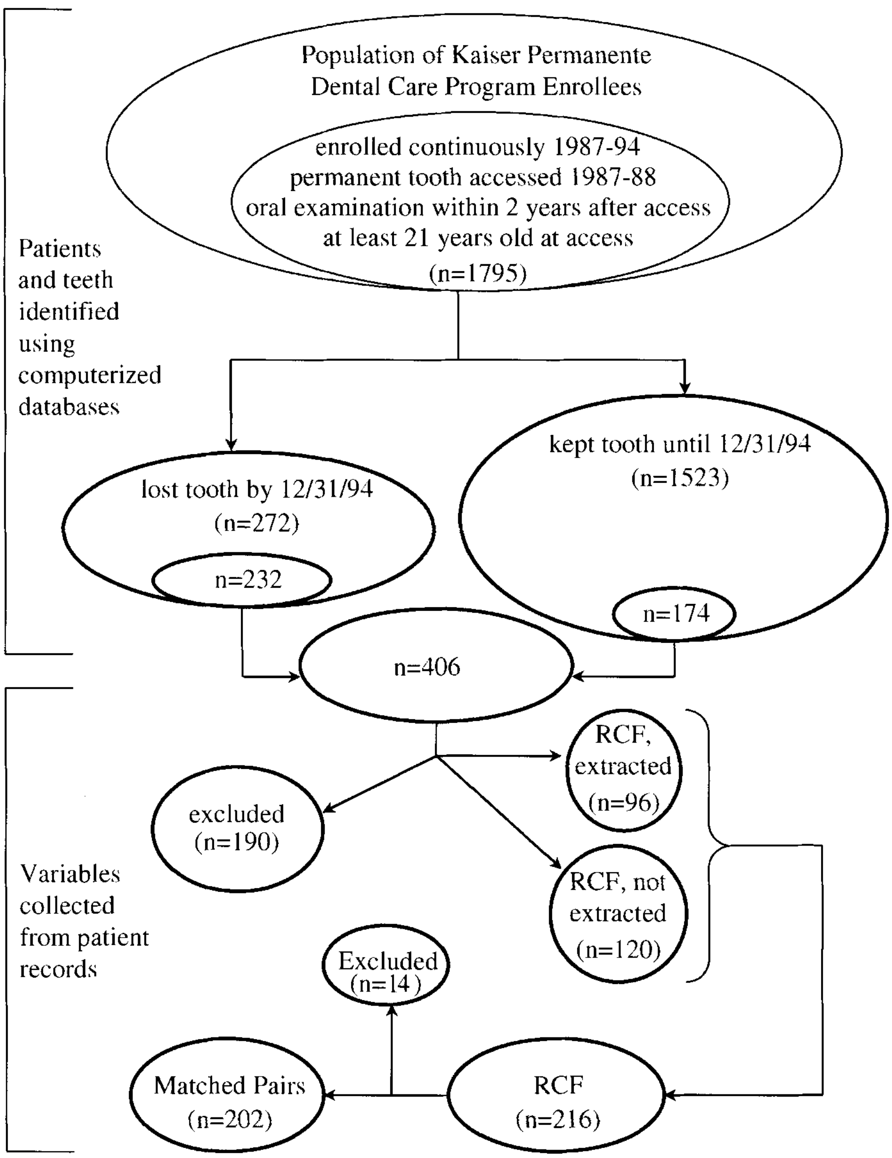
Methods

The sample was drawn from the population of enrollees in the Kaiser Permanente Dental Care Program (KPDCP), a dental HMO located in Portland, Oregon. Enrollees are current or retired employees (or their dependents) of companies with dental insurance through KPDCP. In turn, KPDCP maintains a contract with Permanente Dental Associates (PDA), a group practice serving only KPDCP members. In 1995, when the sample was identified, KPDCP had over 144,000 enrollees, and PDA employed 105 general dentists and specialists practicing in 12 clinics in the Portland area.

Since January 1, 1987, KPDCP has operated several databases, including one containing patient-specific demographic and insurance information and another containing dental treatment data (e.g., procedure codes and dates). The latter was used to identify and track treatment history for patients receiving initial, completed RCT. Prior to data collection, approval for this retrospective cohort study was obtained from Human Subjects Committees at the Kaiser Permanente Center for Health Research and the University of North

Send correspondence and reprint requests to: Daniel J. Caplan, DDS, PhD, Department of Dental Ecology, School of Dentistry, University of North Carolina, CB #7450; Chapel Hill, NC, 27599-7450. Phone: (919) 966-2787; Fax: (919) 966-6761. E-mail: dan_caplan@unc.edu. No reprints will be available. Dr. Cai is Professor, Dept. of Biostatistics, University of North Carolina; Dr. Yin is Assistant Professor, Dept. of Biostatistics, M.D. Anderson Cancer Center, University of Texas; Dr. White is Director, Oral Health Research, Delta Dental Plan of Massachusetts, Boston, MA, formerly Senior Investigator, Kaiser Permanente Center for Health Research, Portland, OR. Acknowledgement: This investigation was supported in part by NIH/NIDCR Grant DE-07191; NIH/NHLBI Grant HL-57444; Permanente Dental Associates; and the University of North Carolina. Manuscript received 10/14/2003; returned to authors for revision 12/18/2003; final version accepted for publication 8/27/2004.

FIGURE 1
Selection of eligible patients, RCF teeth, and Non-RCF teeth



Carolina School of Public Health.

Figure 1 delineates the selection of eligible patients, RCF teeth, and non-RCF teeth analyzed in the present study. Subjects originally were identified for a prior case-control study in which the goal was to identify factors related to loss of RCF teeth (1). In that study, subjects who had undergone completed RCT were identified; cases were defined as those who lost the RCF tooth during an eight-year period, while controls were defined as those not losing the RCF tooth during that time. Because there were many more controls than cases in the underlying population, cases were oversampled relative to controls, necessitating a weighted analysis to allow appropriate inferences to the population of KPDCP enrollees who satisfied study eligibility criteria. The original selection protocol is described in detail elsewhere (1) and summarized below.

Selection of RCF teeth. KPDCP databases were used to identify all patients who: 1) were continuously enrolled from 1/1/87 through 12/31/94; 2) had an eligible permanent tooth endodontically accessed in 1987 or 1988; 3) had an oral examination within two years after access; and 4) were ≥ 21 years old on the date of access. Teeth were deemed ineligible if they were third molars or if the endodontic code represented re-treat-ment. Patients with ≥ 1 eligible tooth then were restricted to the tooth with the earliest access date, so each patient contributed only one endodontically treated tooth to the analysis. At this point the list contained 1795 patients.

Patients then were stratified as those with an extraction code for the RCF tooth prior to 12/31/94 (cases) and those without such a code (controls). A target sample size of 110 in each stratum had been calculated based on 5% Type I error, 90% power, an odds ratio of three, and data from a pilot study indicating that approximately 61% of controls had at least one missing permanent tooth on the endodontic access date (this variable was of primary interest in that study).

The target population included only those patients with a panoramic radiograph (required to determine the number of missing teeth in the prior study) whose RCF tooth a) was being treated endodontically for the first time, and b) received completed treatment. Because electronic databases did not contain this information, study eligibility could be confirmed only through record review, so many extra records had to be reviewed before the target sample size was reached. A total of 406 charts was requested, including 232 randomly selected from among 272 cases, and 174 randomly selected from among 1523 controls. Of these 406 charts, 190 were excluded for the reasons mentioned above. This left 216 patients, each with one tooth that had received initial, completed RCT. Of these, 96 had been extracted and 120 had not been extracted by 12/31/94.

Selection of non-RCF teeth. Dental records were examined to identify non-RCF teeth with which to compare the 216 RCF teeth. If the exact contralateral tooth was present, it was selected. If that tooth was missing or already RCF on the RCF tooth's access date (hereafter called the "index date"), the tooth of the same type (i.e., anterior, premolar, or molar) adjacent to the exact contralateral tooth was selected. Ten of the 216 patients were excluded: nine because both the contralateral and adjacent teeth were ineligible for comparison, and one because the dental record was not located. Another four were excluded because data for their comparison tooth were incomplete (see below), leaving 202 matched tooth pairs for analysis.

Data collection. Subject- and tooth-level covariates were ascertained from the electronic databases and from radiographs (bitewing, periapical, panoramic) and clinical periodontal recordings taken most recently before the index date. Tooth-level covariates included:

- Tooth type: molar, non-molar
- Proximal Contacts (PCs): Because the number of PCs is related to loss of RCF teeth (1,5), four mutually exclusive categories were created: bridge abutment; non-bridge abutment with zero PCs; non-bridge abutment with one PC; and non-bridge abutment with two PCs.
- Number of decayed or filled (DF) coronal surfaces: A number from 0-3 represented the number of DF surfaces from among the occlusal, mesial, and distal coronal surfaces.
- Number of DF root surfaces: A number from 0-2 represented the number of DF surfaces from among the mesial and distal root surfaces.
- Number of periodontal pockets ≥ 5 mm: Pocket depths had been recorded at six sites per tooth. If a given site had no recording it was assumed to be ≤ 4 mm.

Databases and charts were examined to determine all treatment received by the study teeth between the index date and 12/31/94, and the most recent radiograph was examined to validate extraction status.

Statistical analysis. Time-to-event analyses (6) were used to describe the relationship between root canal status and tooth survival. For both RCF and non-RCF teeth, follow-up started on the index date and continued through the date of extraction or 12/31/94, whichever came first. If an initially non-RCF tooth was accessed endodontically during that interval, the tooth was censored on its endodontic access date.

TABLE 1
Characteristics of matched tooth pairs

Table 1A: Number of DF* coronal surfaces

		RCF†			
		≥ 1	**2**	**3**	**Total**
Non-RCF	**≥ 1**	9	20	21	**50**
	2	4	19	26	**49**
	3	3	11	89	**103**
	Total	**16**	**50**	**136**	**202**

Concordance: RCF = Non-RCF (58%); RCF > Non-RCF (33%); RCF < Non-RCF (9%)

Table 1B: Number of DF root surfaces

		RCF		
		0	**≥ 1**	**Total**
Non-RCF	**0**	128	50	**178**
	≥ 1	15	9	**24**
	Total	**143**	**59**	**202**

Concordance: RCF = Non-RCF (68%); RCF > Non-RCF (25%); RCF < Non-RCF (7%)

Table 1C: Number of proximal contacts

		RCF				
		0	**1**	**2**	**BA‡**	**Total**
Non-RCF	**0**	2	2	2	1	**7**
	1	3	38	20	0	**61**
	2	2	16	97	10	**125**
	BA	0	2	2	5	**9**
	Total	**7**	**58**	**121**	**16**	**202**

Concordance: RCF = Non-RCF (70%); RCF > Non-RCF (17%); RCF < Non-RCF (12%)

Table 1D: Number of pockets ≥ 5 mm

		RCF			
		0	**1**	**≥ 2**	**Total**
Non-RCF	**0**	119	15	7	**141**
	1	11	8	8	**27**
	≥ 2	8	7	19	**34**
	Total	**138**	**30**	**34**	**202**

Concordance: RCF = Non-RCF (72%); RCF > Non-RCF (15%); RCF < Non-RCF (13%)

*DF = Decayed or Filled
†RCF = Root Canal Filled
‡BA = Bridge Abutment

Because the parent study sample had overselected extracted RCF teeth, a weighted analysis incorporating the design effect (7) was carried out. The weighted analysis enabled inferences to be made about the original KPDCP population of eligible patients based on data from the biased sample. Each subject's weight was equal to the inverse of his/her selection probability. Since 232 cases were sampled from 272 cases in the population, each sampled case represented 272/232 population cases. Similarly, since 174 controls were sampled from 1523 controls in the population, each sampled control represented 1523/174 population controls. In this manner, and by using statistical software that incorporates weights, the present analysis provides information generalizable to the entire KPDCP population of enrollees who satisfied study eligibility criteria.

Weighted Kaplan-Meier curves were generated to compare overall and subgroup tooth survival probabilities for RCF and non-RCF teeth. Again, weights were used so that results from the sample, which had been generated originally by oversampling extracted RCF teeth, could be extrapolated to the entire population of eligible subjects. In addition, because of non-independence of observations due to within-patient clustering, methods for analyzing correlated failure time data were used (8,9). Specifically, a weighted version of the log-rank test (10) was utilized for two-sample comparison of survival curves, and the weighted version of the marginal proportional hazards models (8) was fitted to evaluate the effect of root canal status on tooth survival controlling for important covariates, with the patient as the clustering unit.

The proportional hazards assumption was assessed by examining the Schoenfeld residual (11). An unadjusted model was developed, followed by a full model that included all tooth-level covariates plus the interaction term between root canal status and tooth type. A final model was generated by selectively removing from the full model those variables that did not change the estimate of effect of root canal status by more than 10% and had p-values > 0.05. All analyses were conducted using S-Plus (12).

TABLE 2
Kaplan-Meier survival estimates at four and eight years, by root canal status

	Root Canal Status	4-Year Survival Estimate (%)	8-Year Survival Estimate (%)
All Teeth	Non-RCF*	98.0	96.0
	RCF	94.0	89.5
Molars	Non-RCF	99.0	98.5
	RCF	93.6	89.6
Non-Molars	Non-RCF	97.4	94.1
	RCF	94.8	89.4

*RCF = Root Canal Filled

TABLE 3
Marginal proportional hazards regression models describing the relationship between root canal status and tooth survival

Model	Tooth Type	Root Canal Status	Hazard Ratio (Reference = Non-RCF)	95% Confidence Interval
Unadjusted	All Teeth	RCF*	3.0	1.4-6.1
		Non-RCF	1.0	----
Minimally Adjusted†	Molars	RCF	6.7	3.2-14.0
		Non-RCF	1.0	----
	Non-Molars	RCF	2.0	0.8-5.0
		Non-RCF	1.0	----
Final‡	Molars	RCF	7.4	3.2-15.1
		Non-RCF	1.0	----
	Non-Molars	RCF	1.8	0.7-4.6
		Non-RCF	1.0	----

*RCF = Root Canal Filled
†Minimally Adjusted model includes:
Root canal status *(Root Canal Filled vs. non-Root Canal Filled)*
Tooth type *(molars vs.non-molars)*
Interaction term *(Root canal status * Tooth type)*
‡Final model is the Minimally Adjusted model PLUS:
Proximal contacts *(3 dummy variables representing four mutually exclusive categories)*
Number of pockets ≥ 5 mm *(continuous)*

Results

The 202 analyzed subjects represented approximately 1078 patients in the KPDCP population who would have satisfied study inclusion criteria. Population medians (interquartile ranges) were: age=42 (36-52) years; number of missing teeth (not including third molars)=1 (0-4); and number of dental visits from 1987-94=29 (21-36). Males comprised 38% of the population, and 22% reported wearing upper and/or lower removable prostheses.

Of the 202 analyzed tooth pairs, 16% were comprised of anterior teeth, 41% were comprised of premolars, and 44% were comprised of molars. The exact contralateral tooth was used as the matched tooth for 83% of the RCF teeth, while the surrogate tooth was used for the other 17%. Tables 1A-D present other tooth-level characteristics of the matched tooth pairs. For each table, rows represent the non-RCF teeth, columns represent the RCF teeth, and cells represent the number of pairs corresponding to that row/column combination (e.g., Table 1A shows that there were 26 tooth pairs in which the RCF tooth had three DF coronal surfaces and the non-RCF tooth had two). For proximal contacts, pockets ≥ 5 mm, DF coronal surfaces, and DF root surfaces there was concordance between the paired teeth about 58-72% of the time. When pairs were discordant, RCF teeth tended to have more DF coronal and root surfaces than non-RCF teeth, while there was roughly an even split between RCF and non-RCF teeth with respect to proximal contacts and pockets ≥ 5 mm.

Follow-up times ranged from 0.01 to 8.0 years, with the median being about 6.7 years. Figures 2-4 show Kaplan-Meier survival estimates and corresponding 95% confidence intervals for the RCF and non-RCF teeth. Figure 2 shows that overall, RCF teeth had substantially worse survival than their non-RCF counterparts

FIGURE 2
Kaplan-Meier survival estimates and 95% confidence intervals for RCF and non-RCF teeth

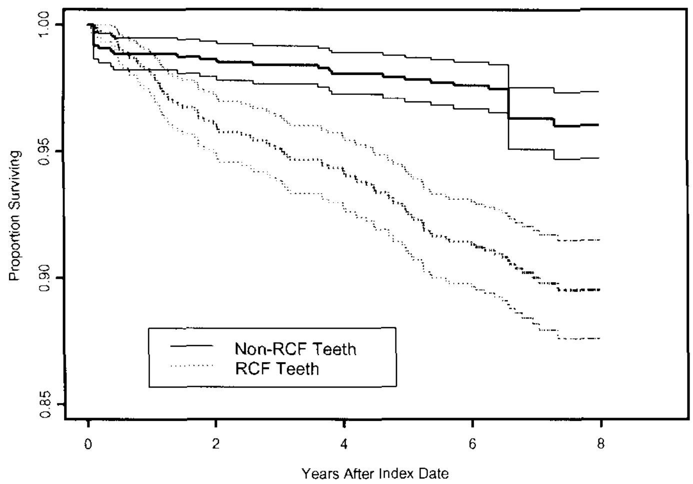


FIGURE 3
Kaplan-Meier survival estimates and 95% confidence intervals for RCF and non-RCF molars

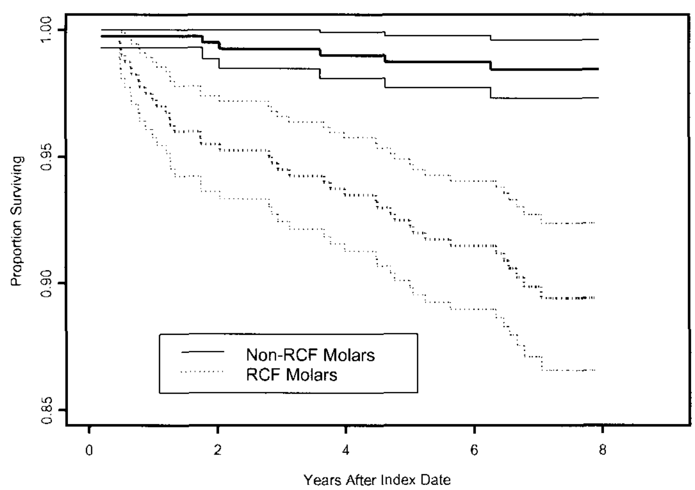
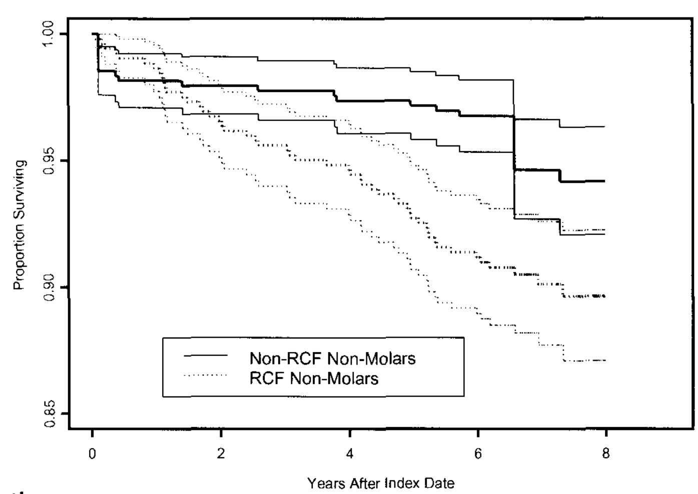


FIGURE 4
Kaplan-Meier survival estimates and 95% confidence intervals for RCF and non-RCF non-molars



Abbreviations:
Non-RCF = Non-Root Canal Filled
RCF = Root Canal Filled

($p<0.001$). Figures 3 and 4 show that the survival discrepancy between RCF and non-RCF teeth was much greater for molars than for non-molars. For reference purposes, Table 2 presents survival estimates at four and eight years after baseline.

Table 3 presents the results of several regression models. The unadjusted model generated a hazard ratio (HR) and 95% confidence interval (CI) of 3.0 (1.4-6.1) for RCF versus non-RCF teeth, indicating that overall, RCF teeth were extracted at a rate three times that of non-RCF teeth. For comparative purposes, a "minimally adjusted" model is shown rather than the full model. This model included only root canal status, tooth type, and the interaction between the two, leading to separate estimates for molars and non-molars. In the final model, no statistically significant effect was seen among non-molars (HR = 1.8; 95% CI = 0.7-4.6), but a strong, significant effect was seen among molars (HR = 7.4; 95% CI = 3.2-15.1), indicating that RCF molars were extracted at a rate over seven times that of non-RCF molars.

Discussion

This study's most important findings were that 1) even if pulpally involved teeth are saved via RCT, their longevity is decreased compared to similar, pulpally non-involved teeth; and 2) the effect of endodontic involvement and subsequent completed RCT appears to be much stronger among molars than non-molars. The lower hazard ratio observed among non-molars can be inferred by comparing Figures 3 and 4; the two Kaplan-Meier curves in Figure 3 (molars) are farther apart than the two corresponding curves in Figure 4 (non-molars). The major reason for this difference is that non-treated molars had relatively better survival compared to non-treated non-molars, which can be seen by comparing the upper curves in Figures 3 and 4. Several reasons for this could be postulated, including a) dentists and/or patients might value molars more than non-molars for chewing and for retaining fixed or removable partial dentures; b) given the same amount of bone loss, molars probably are less mobile than non-molars due to their having multiple roots; and c) non-molars might be more often catastrophically fractured than molars, which have more tooth structure available to retain restorations.

In the endodontic literature the usual measure of prognosis is "endodontic success," a variable normally assessed by a combination of clinical and radiographic findings consistent with periapical healing (13,14). In contrast, the outcome used here was tooth loss, which may not correspond to "endodontic success" because a) teeth for which endodontic treatment has been successful may be extracted for non-endodontic reasons, and b) teeth with failing endodontic treatment may remain in the mouth long after treatment, especially if the patients are asymptomatic. In addition to being evaluated in terms of "endodontic success", endodontically treated teeth have been investigated previously in terms of intracanal restorative techniques (15) and post-endodontic tooth fracture (16,17). Loss of teeth has been addressed longitudinally (18,19) but the endodontic status of the lost teeth generally has not been determined. Only a few studies specifically address loss of RCF teeth (1,4,13,20). To our knowledge, the present investigation is the first to compare survival of RCF and non-RCF teeth.

In the present study, rather than comparing tooth survival among two groups of patients (one group with RCF teeth and one group with non-RCF teeth), we matched one RCF tooth with one non-RCF tooth within patients. This method was more efficient because it minimized the opportunity for variation in subject-level factors (e.g., oral hygiene, patient age) to affect tooth loss differentially across comparison groups. In other words, tooth-level confounding was more effectively controlled by matching RCF with non-RCF teeth within subjects. Survival data from dental implants clustered within subjects have been analyzed (9), but to our knowledge such methods have not been applied to examine longevity of teeth based on endodontic status.

This study has several limitations. First, as with all retrospective studies, data quality was dependent on the quality of existing documentation, especially legibility and completeness of entries in patient records and accuracy of coding in the treatment database. Second, generalizability may be limited, since determinants of health care utilization include demographic, socioeconomic, and attitudinal variables (21) and insured populations use dental services more frequently than non-insured populations (22,23). Third, of roughly 75,000 members of KPDCP in January 1987, only about 29,000 (39%) were insured continuously for the next eight years; these enrollees may differ substantially from those without continuous coverage with regard to stability of employment, education, age, or other factors potentially related to tooth loss. Fourth, several tooth-level factors that could influence tooth survival were unavailable, including presence/absence of opposing teeth. Fifth, some RCF teeth could not be matched with their exact contralateral tooth and instead had to be matched to the tooth of the same type adjacent to the exact contralateral tooth. In this case, the two teeth being compared could have been in the patient's mouth for different intervals during his/her lifetime (e.g., first and second molars normally erupt at about six and twelve years of age, respectively). Hence, teeth in these tooth pairs would have been subjected to different total lifetime burdens of insult. We expect that any bias due to this phenomenon would be both small (since only 17% of the tooth pairs met this condition and since important tooth-level factors were controlled for) and non-differential (since this discrepancy would tend to be distributed equally between RCF and non-RCF teeth).

Finally, the observed hazard ratios underestimate the true effect of pulpal involvement on tooth survival because only one category of pulpally involved teeth (i.e., teeth with completed RCT) was selected for comparison. A true estimate of the overall effect of pulpal involvement would require assessment of additional types of pulpally involved teeth, including: 1) teeth that could have received RCT but were extracted instead; and 2) teeth with non-completed RCT. The present retrospective study design precluded determination of which teeth that were extracted had been savable or whether patients were offered the option of RCT. Teeth with non-completed RCT were excluded because the parent study concerned only RCF teeth. Teeth with non-completed RCT have poorer survival than teeth with completed RCT (24). Thus, because RCF teeth survive longer than these other pulpally involved teeth, and also because these other pulpally involved teeth probably are more common in uninsured populations than in insured populations, the observed effects represent a best-case scenario regarding the influence of pulpal involvement on tooth survival.

Even if RCF teeth generally are lost sooner than comparable non-RCF teeth, these results do not imply that all pulpally involved teeth should be extracted, since that decision should be made on a case-by-case basis. Outcomes research is vital to treatment-decision-making in dentistry, since valid outcomes data can support dentists' recommendations and patients' decisions. Knowing that pulpal involvement can influence tooth longevity may encourage patients not to postpone treatment of asymptomatic carious lesions, which often occurs due to financial reasons, convenience, or dental fear. Future investigations should be carried out prospectively so that all pulpally involved teeth can be investigated and so that potentially important variables could be collected that were unavailable here.

Acknowledgements

The authors wish to thank everyone at Permanente Dental Associates, Kaiser Permanente Center for Health Research and the University of North Carolina who contributed their efforts to this project.

References

1. Caplan DJ, Weintraub JA. Factors related to loss of root canal filled teeth. J Public Health Dent 1997;57(1):31-9.
2. Bailit HL, Braun R, Maryniuk GA, Camp P. Is periodontal disease the primary cause of tooth extraction in adults? J Am Dent Assoc 1987;114(1):40-5.
3. Phipps KR, Stevens VJ. Relative contribution of caries and periodontal disease in adult tooth loss for an HMO dental population. J Public Health Dent 1995;55(4):250-2.
4. Vire DE. Failure of endodontically treated teeth: classification and evaluation. J Endod 1991;17(7):338-42.
5. Caplan DJ, Kolker J, Rivera EM, Walton RE. Relationship between number of proximal contacts and survival of root canal treated teeth. Int Endod J 2002;35(2):193-9.
6. Kleinbaum D. Survival analysis: a self-learning text. New York: Springer; 1996.
7. Binder D. Fitting Cox's proportional hazards models from survey data. Biometrika 1992;79:139-147.
8. Lee E, Wei L, Amato D. Cox-type regression analysis for large numbers of small groups of correlated failure time observations. In: Klein J, Goel P, editors. Survival analysis: state of the art. Norwell, MA: Kluwer Academic; 1992. p. 237-247.
9. Chuang SK, Tian L, Wei LJ, Dodson TB. Predicting dental implant survival by use of the marginal approach of the semi-parametric survival methods for clustered observations. J Dent Res 2002;81(12):851-5.
10. Michalek J, Mihalko D. Linear rank procedures on litter-matched data. Biometrics 1984;40:487-491.
11. Therneau T, Grambsch P. Modeling survival data: extending the Cox model. New York: Springer-Verlag; 2000.
12. StatSci. S-Plus. In. Seattle; 1996.
13. Sjogren U, Hagglund B, Sundqvist G, Wing K. Factors affecting the long-term results of endodontic treatment. J Endod 1990;16(10):498-504.
14. Smith CS, Setchell DJ, Harty FJ. Factors influencing the success of conventional root canal therapy—a five-year retrospective study. Int Endod J 1993;26(6):321-33.
15. Heydecke G, Butz F, Hussein A, Strub JR. Fracture strength after dynamic loading of endodontically treated teeth restored with different post-and-core systems. J Prosthet Dent 2002;87 (4):438-45.
16. Hansen EK, Asmussen E. In vivo fractures of endodontically treated posterior teeth restored with enamel-bonded resin. Endod Dent Traumatol 1990;6(5):218-25.
17. Hansen EK, Asmussen E. Cusp fracture of endodontically treated posterior teeth restored with amalgam. Teeth restored in Denmark before 1975 versus after 1979. Acta Odontol Scand 1993;51(2):73-7.
18. Hand JS, Hunt RJ, Kohout FJ. Five-year incidence of tooth loss in Iowans aged 65 and older. Community Dent Oral Epidemiol 1991;19(1):48-51.
19. Hujoel PP, Loe H, Anerud A, Boysen H, Leroux BG. Forty-five-year tooth survival probabilities among men in Oslo, Norway. J Dent Res 1998;77 (12):2020-7.
20. Eckerbom M, Magnusson T, Martinsson T. Reasons for and incidence of tooth mortality in a Swedish population. Endod Dent Traumatol 1992;8(6):230-4.
21. Andersen R, Newman JF. Societal and individual determinants of medical care utilization in the United States. Milbank Mem Fund Q Health Soc 1973;51(1):95-124.
22. Grembowski D, Conrad D, Milgrom P. Utilization of dental services in the United States and an insured population. Am J Public Health 1985;75(1):87-9.
23. Manning WG, Bailit HL, Benjamin B, Newhouse JP. The demand for dental care: evidence from a randomized trial in health insurance. J Am Dent Assoc 1985;110(6):895-902.
24. Caplan DJ, White BA. Clinical factors related to noncompletion of root canal therapy. J Public Health Dent 2001;61(1):6-13.