Relationship between crown placement and the survival of endodontically treated teeth

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Statement of problem. Crowns have been considered the restoration of choice for endodontically treated teeth, but their selection has been based primarily on anecdotal evidence.

Purpose. This study tested the hypothesis that crown placement (coronal coverage) is associated with improved survival of endodontically treated teeth when preaccess, endodontic, and restorative factors are controlled.

Material and methods. A University of Iowa College of Dentistry treatment database was used to identify permanent teeth that had undergone initial obturation between July 1, 1985, and December 31, 1987. Study patients were restricted to persons with at least 1 dental visit in each 2-year interval from 1985 to 1996; a simple random sample of 280 patients (n = 400 teeth) was selected. Dental charts, radiographs, and computerized databases were examined to ascertain variables of interest and to verify study inclusion criteria. Kaplan-Meier survival estimates were generated for the 203 teeth that satisfied study inclusion criteria. Multivariate Cox proportional hazards regression models were developed, with standard errors adjusted to account for clustering of teeth within patients.

Results. When tooth type and radiographic evidence of caries at access were controlled, the final Cox model showed that endodontically treated teeth not crowned after obturation were lost at a 6.0 times greater rate than teeth crowned after obturation (95% confidence interval: 3.2 to 11.3).

Conclusion. Within the limitations of this study, a strong association between crown placement and the survival of endodontically treated teeth was observed. These results may impact treatment planning if long-term tooth retention is the primary goal. (J Prosthet Dent 2002;87:256-63.)

CLINICAL IMPLICATIONS

The results of this study strongly support the concept that the placement of crowns on endodontically treated teeth is significantly associated with the latter's long-term survival.

Reported success rates for conventional endodontic therapy range from 40% to 97% depending on differences in patient selection, experimental design, clinical procedures, criteria for evaluation, and length of postoperative observation.[1-6] This variation in success rate is in part due to the lack of a clear definition of the success and failure of endodontic treatment.[2,5,6] Although some studies have used tooth retention and the absence of clinical signs and symptoms to define success,[2,5] most studies have evaluated recall radiographs to determine endodontic success.[7]

Unfortunately, despite the extensive research on root-canal–treated (RCT) teeth, there is little information on RCT tooth loss or factors related to the long-term survival of endodontically treated teeth.[8,9] Reasons for RCT tooth extractions have included periodontal disease, caries, coronal and root fractures, prosthetic complications, and endodontic failures.[5,7,9,10]

In a multivariate analysis, Eckerbom et al[10] found that teeth with preoperative periapical pathosis, teeth in which the obturation was greater than 2 mm from the radiographic apex, and teeth with screw-type posts had a greater chance of loss over a 5- to 7-year period than teeth without these attributes. Caplan and Weintraub[9] identified 5 variables predictive of RCT tooth loss. These included the number of proximal contacts at access, patient age, increased levels of plaque, the overall number of missing teeth (excluding third molars), and a history of facial trauma. Teeth with 2 proximal contacts at access were 3 times less likely to be lost than teeth with 1 or no proximal contact. Interestingly, none of the postaccess variables evaluated, including crown status and dowel placement, had a statistically significant bivariate relationship with RCT tooth survival.

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As with endodontic studies, prosthodontic clinical studies on RCT teeth have generally not addressed tooth survival, have employed a variety of methodologies, and have used different criteria to define success. Creugers et al[3] assessed the survival of post-and-core restorations with the use of meta analysis. Only 3 out of 16 studies contained survival data that met their inclusion criteria. Survival estimates at 6 years ranged from 81% for resin composite buildups and screw-type posts to 91% for cast posts and cores. Weine et al[11] and Bergman et al[12] reported overall success rates of 98.5% and 90.6%, respectively, for RCT teeth restored with cast posts and cores and complete-coverage crowns. In a 3-year prospective study, Hatzikyriakos et al[13] found no difference between resin composite cores with screw-type posts or parallel-sided cemented posts and cast posts and cores. Teeth restored with individual crowns had only a 5.5% failure rate. Mentink et al[14] reported that anterior teeth restored with a cast post-and-core foundation and a crown had a higher risk of failure than similarly restored posterior teeth.

One of the most widely quoted series of studies on endodontically treated teeth[15-17] evaluated the effect of tooth location, coronal coverage, and intracoronal reinforcement on the success of 1273 RCT teeth over an observation period of 1 to 25 years. Failures were described as dislodgment, root or tooth fracture, and iatrogenic perforation. The results indicated that the placement of a post had no significant effect on the success rate for either anterior or posterior teeth. Crown placement had no significant effect on the success of anterior teeth but significantly improved clinical success rates of posterior teeth.[15] In 2 subsequent analyses of the same data set,[16,17] the authors described failure as either restorable (dislodgment or fracture) or nonrestorable (requiring extraction). No further analysis was performed on either of these failure categories. The greatest failure proportion (24.2%) was recorded for RCT teeth without a crown.

Although the results of these studies have been questioned due to a lack of controlled clinical procedures and of generalizability,[18,19] they have been used to support the concept that crowns generally should be used on endodontically treated posterior teeth and on anterior teeth with substantial loss of tooth structure.[20,21]

Other forms of coronal coverage—including gold, ceramic, or resin composite onlays and cusp-covering silver amalgam restorations—may also provide RCT teeth with protection against fracture. No reports in the literature were found to support the use of gold, ceramic, or composite onlays to restore posterior RCT teeth. Starr[22] advocated the use of complex cusp-covering silver amalgam restorations as an alternative to crowns on RCT posterior teeth, but no data were presented to support his recommendations. Plasmans et al[23] reported an 88% survival rate over a 100-month observation period for independently functioning complex silver amalgam restorations. Smales and Hawthorne,[24] however, reported lower 15-year survival rates for complex cusp-covering silver amalgam restorations (48%) compared to crowns (89%). Martin and Bader[25] also compared the survival of large 4- and 5-surface silver amalgam restorations to crowns and reported that crowns had both a higher success rate and a lower chance of catastrophic failure. These large silver amalgam restorations apparently did not include cuspal coverage. None of these studies specifically evaluated the use of complex silver amalgam restorations as an alternative to complete crowns for the restoration of RCT posterior teeth.

With the exception of these studies, anecdotal evidence has been the primary basis for deciding whether an RCT tooth should receive an artificial crown. Recent emphasis on evidence-based health care requires sound scientific evidence, based on clinical research, to support claims of treatment effectiveness.[26] If the survival of RCT teeth can be related to factors that can be determined during treatment planning, attention to these factors could help the patient and clinician select the most appropriate course of treatment.[9]

In the present study, a retrospective cohort design and multivariate proportional hazards regression were used to develop explanatory models for the loss of RCT teeth. The objective was to test the hypothesis that the placement of a crown (coronal coverage) is associated with improved survival of RCT teeth when other preaccess, endodontic, and restorative factors are controlled.

MATERIAL AND METHODS

The protocol was approved by the Committee on Research Involving Human Subjects, University of North Carolina School of Dentistry, as a secondary data analysis. Study data were collected in 1997 from existing dental records at the University of Iowa College of Dentistry (COD). An existing treatment database identified all permanent teeth that had received initial endodontic therapy between July 1, 1985, and December 31, 1987. The list was restricted to patients with at least 1 visit to the COD in each 2-year interval from 1985 to 1986 through 1995 to 1996, resulting in 1089 teeth from 734 patients. Teeth were grouped by patient, and patients were listed in random order. A simple random sample of teeth was chosen by selecting the first 400 teeth on the list (corresponding to the first 280 patients).

Patient records, radiographs, and computerized databases were examined to ascertain variables with potential relationships to tooth loss (Table I) and to verify that study inclusion criteria were satisfied. A

Table I. Collected variables and data sources

From computer databases
Age
Sex
[a]Insurance/Medicaid
[a]Provider type (for RCT)
From treatment notes
Tooth type
Pulp diagnosis
[a]Endodontic complication
[a]Time from access to obturation
[a]Time from obturation to foundation
[a]Foundation type (amalgam, composite, glass ionomer, preformed dowel and core, cast dowel and core)
[a]Crown status (crowned initially after obturation vs. never crowned)
[a]Endodontic retreatment/apicoectomy/root amputation
From patient health questionnaire
≥1 medication of any kind
Gums bleed when brushing teeth
From preaccess periapical radiograph
Tooth type
Number of proximal contacts
Caries
Periapical lesion on any root
Number of carious or filled coronal surfaces
From immediate postobturation periapical radiograph
[a]Root filling past apex of any root
[a]Root filling >2 mm short of apex in any root
[a]Root filling with lateral/apical voids in any root

[a]Value determined after endodontic access (other variables ascertainable before access).

total of 70 teeth did not satisfy the initial study inclusion criteria; these included teeth undergoing endodontic retreatment (n = 50), teeth with no recorded access date (n = 11), teeth with a miscoded procedure date or access date in the database (n = 4), and teeth with missing charts (n = 5). Of the remaining 330 teeth for which data were collected, third molars (n = 6) and teeth without documentation of receiving a definitive restoration (n = 18) were excluded. Teeth that served as abutments to fixed partial dentures (n = 24) and teeth that were crowned at access (n = 52) also were excluded for the following reasons: the relative preoperative condition of the remaining coronal tooth structure could not be assessed, and the presence of a crown or FPD retainer would necessitate that the tooth subsequently be crowned or serve as an abutment. Finally, teeth that became overdenture abutments (n = 1) and teeth missing a preoperative and postoperative radiograph (n = 26) were excluded.

A final total of 203 endodontically treated teeth in 156 patients (88 women and 68 men; mean age 54.1 ± 15.2 years) were analyzed. The tooth sample included 33 incisors, 25 canines, 72 premolars, 43 first molars, and 30 second molars. Carious lesions at the time of access were diagnosed from pretreatment periapical radiographs in 103 (50.7%) of the 203 teeth. Ninety-five teeth were restored with a preformed dowel-and-core or cast dowel-and-core foundation, whereas 108 teeth received a silver amalgam, resin composite, or glass ionomer foundation without a dowel. After endodontic therapy, a crown was placed on 129 teeth, while 74 teeth were restored with either an amalgam or a resin composite definitive restoration. Overall, 42 (20.7%) of the 203 RCT teeth were extracted during the follow-up period (14 with crowns and 28 with direct restorations).

The outcome evaluated was time to tooth loss, with follow-up beginning on the date of endodontic access. For teeth that were subsequently extracted, follow-up ended on the extraction date. For teeth that were not extracted, follow-up ended on the data collection date. The most recent radiograph was examined to verify extraction (or lack thereof) as documented in the treatment record.

Range checks were performed for each variable, and data sources were reexamined to confirm values of potential outliers. Kaplan-Meier survival estimates for RCT teeth were generated for the explanatory variables[27] (Proc Lifetest in SAS Version 6.12 for Windows; SAS Institute, Cary, N.C.). Cox proportional hazards (PH) models[27] then were developed to generate estimates for crude associations between explanatory variables and also for the association of interest, controlling for confounding factors. Because patients could contribute multiple teeth to the dataset, special software (SUDAAN Release 7.11 for Windows; Research Triangle Institute, Research Triangle Park, N.C.) was used to obtain appropriate variance estimates in the Cox models.[28]

To be eligible for inclusion in multivariate models, covariates were required to have a moderately strong bivariate relationship with tooth survival (P<.20), no greater that a 90/10 split in their univariate frequency distributions, and no more than 5% missing values. Mean values were imputed for missing values of eligible covariates. Interaction terms were not tested, and inclusion of time-dependent covariates was not necessary based on visual verification of PH assumptions with SAS log (-log survival) curves.

In developing the PH models, the first step was to obtain an unadjusted hazard ratio (HR) from a model containing only the main exposure variable. Next, the single covariate that most affected the parameter estimate of interest (β) was added to the previous model, but only if it changed the main exposure β by at least 5%. This process was repeated until the addition of no single covariate elicited a 5% change in the main exposure β, controlling for other variables in the model. At

Table II. Bivariate relationships between explanatory variables and RCT tooth survival

Explanatory factor	n	Level	N	Number failed	5-year survival estimate	10-year survival estimate	Wald chi-square *P* value
Crown after RCT	203	1 (yes)	129	14	0.94	0.89	<.0001
		2 (no)	74	28	0.77	0.62	
Number of proximal contacts	203	1 (2 contacts)	125	15	0.91	0.88	.0001
		2 (0, 1 contact)	78	27	0.83	0.65	
Caries at access	203	1 (no)	100	13	0.92	0.87	.0016
		2 (yes)	103	29	0.84	0.72	
Tooth type	203	1 (not a 2nd molar)	173	31	0.90	0.82	.0075
		2 (2nd molar)	30	11	0.80	0.63	
Foundation type	203	1 (no post)	108	29	0.83	0.73	.0111
		2 (post and core)	95	13	0.94	0.86	
Obturation-to-seal time	203	1 (≥8 days)	111	17	0.90	0.85	.0295
		2 (≤7 days)	92	25	0.86	0.73	
Tooth type	203	1 (2nd molars)	30	11	0.80	0.63	.0424
		2 (incisors)	33	7	0.82	0.79	
		3 (canines)	25	7	0.84	0.72	
		4 (premolars)	72	12	0.94	0.83	
		5 (1st molars)	43	5	0.91	0.88	
Patient taking medications	203	1 (no)	90	14	0.93	0.84	.0610
		2 (yes)	113	28	0.84	0.75	
Insurance status	201	1 (copayment)	76	11	0.89	0.86	.0783
		2 (fee for service)	125	31	0.87	0.75	
Age at access	203	1 (≤54)	85	15	0.93	0.82	.0804
		2 (55 ≤ 64)	63	10	0.87	0.84	
		3 (≥65)	55	17	0.82	0.69	
Periapical lesion at access	203	1 (no)	150	28	0.91	0.81	.1354
		2 (yes)	53	14	0.81	0.74	

this point, included covariates were given the opportunity to be removed from the model, one at a time, if their removal did not elicit a change in the main exposure β from the previous model by at least 5%. Allowing covariates to be removed from the regression models permitted different combinations of covariates to be included. The goal was to generate the most parsimonious model for which the main exposure β approximated that obtained from a model containing all eligible covariates.

RESULTS

Table II presents bivariate results in the form of Kaplan-Meier 5- and 10-year survival estimates for those variables eligible for multivariate analysis. Not controlling for confounding variables, RCT teeth that were crowned after obturation had significantly better survival than RCT teeth without crowns ($P<.0001$). In addition, the number of proximal contacts at access was significantly associated with survival ($P=.0001$): teeth with 2 proximal contacts had better survival estimates than teeth with 0 or 1 proximal contact. Teeth with dental caries at the time of access had significantly poorer survival rates at 5 and 10 years than teeth without caries ($P=.0016$). The effect of tooth type was analyzed with 2 different methods. First, incisors, canines, premolars, first molars, and second molars were evaluated separately, which yielded $P=.0424$. Because second molars appeared to have appreciably worse 10-year survival, tooth type was coded as second molars versus all other teeth in the second analysis. Second molars had significantly poorer survival ($P=.0075$) than all other tooth types combined. The foundation type was also significantly associated with survival, with teeth that received posts demonstrating better survival than teeth without posts ($P=.0111$). Finally, time from obturation to foundation placement was significantly associated with survival ($P=.0295$), with greater survival demonstrated by teeth that received a foundation ≥8 days after obturation. No other variable was significantly associated with the survival of the RCT teeth evaluated.

Table III presents βs, HRs, and 95% confidence

Table III. Estimates generated during model-building process

Variable	Model 1	Model 2	Model 3*	Model 4
Crown status	X	X	X	X
Tooth type		X	X	X
Caries			X	X
All other eligible variables, including number of proximal contacts, time from obturation to seal, insurance status, age at access, and presence of a periapical lesion at access				X
Parameter estimate (β)	1.43	1.68	1.80	1.93
Hazard ratio for no crown vs. crown	4.2	5.4	6.0	6.9
95% confidence interval	2.4-7.4	3.0-9.6	3.2-11.3	3.8-12.8

*Final model.

Table IV. Final multivariate Cox proportional hazards regression model for RCT tooth survival

Variable	Parameter estimate (β)	Standard error	*P* value	Hazard ratio (95% CI)
Crown status (uncrowned vs. crowned)	1.80	0.31	<.0001	6.0 (3.2-11.3)
Tooth type (2nd molars vs. other teeth)	1.36	0.35	.0002	3.9 (2.0-7.9)
Caries (yes/no)	1.04	0.28	.0003	2.8 (1.6-5.0)

intervals (CIs) for the main exposure variable during each stage of model building. To preserve the stability of the regression models, and because only 42 teeth were extracted during the follow-up period, models were allowed to contain a maximum of 4 variables.[29] Model 1 contained only the main exposure variable (uncrowned vs. crowned) and provided an unadjusted HR of 4.2, implying that RCT teeth without crowns were lost 4 times more frequently than teeth crowned after obturation. In Model 2, the covariate *tooth type* was added because its inclusion changed the β of the main exposure variable by at least 5% and to a greater degree than any other single covariate. As in the bivariate analysis, only second molars affected the main exposure variable. Therefore, the dichotomized exposure variable *tooth type* (second molars vs. all other teeth) was used, which resulted in an adjusted HR of 5.4, suggesting an even greater association of crowns with the survival of RCT teeth. In Model 3, addition of the covariate *caries* further increased the adjusted HR to 6.0. At this point, the addition of no single covariate elicited a change of greater than 5% in the β of interest, and the removal of no single covariate elicited a change of less than 5%. Model 3 therefore was deemed the final model. Model 4 included the addition of all other eligible variables, which increased the adjusted HR to 6.9. The main exposure β was similar for Models 3 and 4, indicating minimal confoundedness of the relationship of interest by the other eligible covariates.

The final model is shown in Table IV. When tooth type and caries at access were controlled, RCT teeth that were not crowned after obturation were lost at a 6.0 times greater rate than RCT teeth crowned after obturation (95% CI: 3.2 to 11.3) The model also showed that for endodontically treated teeth, second molars were lost at a greater rate than other teeth, and teeth with dental caries at the time of access were lost at a greater rate than teeth without caries at access.

DISCUSSION

This hypothesis-testing study indicated that the survival of RCT teeth was significantly associated with the placement of an artificial crown after obturation. It is presumed that the prognosis of endodontic therapy must have been considered favorable to warrant crown placement. Patients electing crown placement might have had a higher socioeconomic status and dental awareness, both of which have been associated with increased tooth survival.[30] In addition, coronal coverage presumably reduced the risk of tooth fracture, one of the most often cited reasons for RCT tooth loss.[1,7,9,10]

The results are consistent with previous studies and "expert" opinion papers that argue that crowns are indicated for endodontically treated teeth.[15-17,21,31] In a study on the incidence of tooth mortality in a Swedish population, Eckerbom et al[10] found that RCT teeth with crowns were lost at the same rate as vital teeth. In a study of 116 extracted RCT teeth, Vire[7] demonstrated that crowned teeth demonstrated a significant increase in longevity compared to uncrowned teeth.

Other forms of coronal coverage, such as gold, ceramic or resin composite onlays, and cusp-covering silver amalgam restorations, may also provide RCT teeth with protection against fracture. However, no reports in the literature were found to support the use of gold, ceramic, or composite onlays to restore posterior RCT teeth. Starr[22] advocated complex cusp-covering silver amalgam restorations as an alternative to crowns on RCT posterior teeth, but no data were presented to support this recommendation. Of other studies that examined the survival of complex amalgam restorations,[23-25] none specifically evaluated their use as an alternative to complete crowns for the restoration of RCT posterior teeth.

The significant decrease in the survival of second molars compared to other tooth types may be the result of increased occlusal stresses and difficult endodontic treatment due to tooth anatomy, compromised access, and restricted visibility. In addition, other endodontic and epidemiologic studies have reported that, in general, the mortality rate for molars is higher than for other teeth.[7,10,30,32] The greater than 5-fold decrease in survival of second molars compared to other teeth may affect whether endodontic therapy is pursued or the second molar is extracted. This may especially be true when the total cost of second molar endodontic therapy, a foundation, and a crown are considered. If the patient elects to retain the tooth and initiate endodontic therapy, then the results of this study suggest that the placement of a crown as a definitive restoration is critical to the long-term survival of the tooth.

Increased mortality among RCT teeth with radiographic evidence of caries at access is not surprising since dental caries has been cited as one of the leading causes of tooth loss in both epidemiologic studies[30] and studies on the success of endodontically treated teeth.[10]

Although the number of proximal contacts at access, foundation type, and the time between obturation and seal did not influence the multivariate model for RCT tooth survival, these variables were associated with survival of RCT teeth (Table II). The number of proximal contacts at access affected RCT tooth survival in a study by Caplan and Weintraub,[9] who reported that teeth with 2 proximal contacts at access were 3 times less likely to be extracted subsequently than teeth with 0 or 1 proximal contact. The authors hypothesized that adjacent teeth may help distribute occlusal forces and that teeth with fewer than 2 proximal contacts may serve as prosthesis abutments, which may increase the stresses on the RCT tooth in question. In addition, RCT teeth with fewer than 2 proximal contacts may represent teeth in patients with a greater number of missing teeth.

The literature contains numerous studies on the effect of dowels on the restoration of endodontically treated teeth. Several clinical studies have been reported, but conflicting results make it difficult to develop appropriate clinical treatment guidelines.[8] As with other studies, conflicting results are most likely due to differences in research methodologies, patient selection, clinical procedures, definitions of success, evaluation criteria, and length of observation.[1,3,5]

Success and failure rates reported in previous studies on RCT teeth are not directly comparable to each other or to this investigation because they all used somewhat different definitions for success and failure, such as dowel retention,[3,11-15] restoration retention,[3,11,13-15] need for re-restoration,[3,14] root fracture,[3,11,13,15] tooth fracture,[15] iatrogenic perforation,[15] periodontal factors,[11] endodontic complications,[11] caries,[13] and extraction.[3,14]

The bivariate results of this study indicate that the survival of RCT teeth restored with a post was significantly higher than those restored without posts. Data analysis revealed that this was most likely due to the use of post-and-core foundations in anterior teeth and premolars and the fact that all teeth with post-and-core foundations were restored with crowns. No difference was found in the survival of molars with or without post-retained foundations. The results of the multivariate analysis, however, indicated that crown placement eliminated the significant effect of foundation type on RCT tooth survival. The placement of a crown therefore appears more important than the type of foundation for the survival of RCT teeth.

Finally, the time from obturation to seal had a significant bivariate association with RCT tooth survival. Contrary to expectations, the longer time period (≥8 days) resulted in a higher survival rate than the shorter time period (≤7 days). This result was most likely due to the amount of time required to fabricate cast post-and-core foundations, which as noted above, were all restored with a crown. It should be emphasized that all RCT teeth that never received a definitive foundation were excluded from this investigation. Wong et al[33] also reported that teeth without a definitive restoration had an exceedingly high failure rate. It has been reported that coronal leakage is often associated with endodontic failure and that a well-constructed coronal restoration has a greater effect on endodontic success than the quality of the endodontic obturation.[4,34]

The number of carious and filled surfaces at access was among the remaining tooth- or patient-level variables that had no significant association with RCT tooth survival (P=.5). This result may be attributable to the fact that crowns were placed on teeth with 2 or more carious or filled surfaces, thereby negating the effect of coronal tooth structure loss on survival.

As with all retrospective studies, certain limitations apply.[8,33] Data were restricted to available information from the electronic database and patient records.

Certain variables that may be related to tooth loss, such as degree of bone loss and the patient's socioeconomic status, were unavailable. The validity of the data is based on the reliability and accuracy of the recorded entries. Variables such as the number of carious and filled surfaces at access could only be estimated from pretreatment radiographs. Finally, restorative procedures were not standardized, and there may have been bias in treatment selection based on the preexisting tooth condition and the clinical judgment of the dentists.

The results of this investigation can be generalized to other populations with certain restrictions. The sample included only patients with at least 1 dental visit every 2 years over an interval of 10 to 12 years. This sampling method was an attempt to restrict the population to only those patients whose treatment was provided solely at the COD. Treatment was provided at a university dental school; procedures different than those employed in a private practice setting may have been used due to different treatment philosophies and student educational requirements. In addition, the reduced fees provided at the COD may indicate a population sample with a lower socioeconomic status. Finally, the results are applicable only to teeth that would satisfy the inclusion criteria employed in this study. Teeth excluded from this analysis may have had systematically different survival rates.

Although a significant association between crowns and RCT tooth survival was shown in this study, a cause-and-effect relationship cannot be assumed. The determination of causality requires a randomized controlled clinical trial (RCT). Given the increasing emphasis on evidence-based health care, future research that includes RCTs should provide additional data to support endodontic and prosthodontic treatment decisions. Prospective designs that evaluate additional variables and outcomes, including cost-effectiveness of care, are recommended.

CONCLUSIONS

This retrospective cohort study differs from previously reported studies on the restoration of endodontically treated teeth, in that both a multivariate model and a proportional hazard survival analysis were used to evaluate the effect of crown placement on RCT tooth survival. RCT teeth without crowns were lost at a 6.0 times greater rate than teeth with crowns when tooth type and the presence of caries at access were controlled. Second molars and teeth with caries at the time of access also were lost at a greater rate. Though treatment recommendations should be made on an individual basis, the association between crowns and the survival of RCT teeth should be recognized during treatment planning if long-term tooth survival is the primary goal.

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