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CLINICAL RESEARCH

Long-Term Survival of Primary Root Canal Treatment Following Indirect Cuspal Coverage Restoration in Posterior Teeth: A 10-year Retrospective Study



SIGNIFICANCE

This retrospective study confirms the long-term survival of primary root canal treatment with cuspal coverage restoration. Several treatment-related factors had a significant effect on the outcome.

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ABSTRACT

Introduction: This study aimed to evaluate the long-term survival of primary root canal treatment in posterior teeth restored with indirect cuspal coverage restorations. **Methods:** Dental records of patients were retrospectively screened for primary root canal treatments between 1998 and 2019, followed by the placement of an indirect cuspal coverage restoration. Individual-, tooth-, and treatment-related variables were recorded. Surgical retreatment, apicoectomy and extraction were defined as failures. Survival rates of the primary root canal treatment were assessed by Kaplan-Meier statistics, and the mean annual failure rate after 10 years was calculated. The effect of the assessed variables on survival was determined by Log-rank tests and both univariable and multivariable Cox regression analyses ($P < .05$). **Results:** Overall, 607 teeth were included. The 10-year survival of primary root canal treatment was 89.1% (95% confidence interval [CI]: 85.3-93.1, 10-year mean annual failure rate: 1.14%). Three variables were significantly associated with survival in the multivariable model ($P < .05$): type of indirect restoration (partial crown: hazard ratio [HR] (95% CI) = 2.36 (1.11-5.00) [reference: full-coverage crown]), post placement (yes: HR (95% CI) = 2.77 (1.04-7.40) [reference: no]), and time interval between obturation and restoration placement (>1 year: HR (95% CI) = 2.03 (1.05-3.92) [reference: ≤1 year]). **Conclusions:** Primary root canal treatment in teeth restored with cuspal coverage restorations demonstrated a high long-term survival rate. Post placement was associated with reduced survival, whereas improved outcomes were observed in teeth restored with full-coverage crowns and in those receiving indirect restoration within the first year after root canal obturation. (*J Endod* 2026;52:1598-1604.)

KEY WORDS

Cuspal coverage restoration; delayed restoration; primary root canal treatment; survival

Primary root canal treatment is indicated in cases of irreversible pulpitis or pulp necrosis. Its main objective is to prevent or heal apical periodontitis resulting from infection within the root canal system. Epidemiological studies have reported a worldwide prevalence of apical periodontitis of 3%, only considering teeth without previous root canal treatment¹. Despite this apparently low percentage of apical periodontitis, the worldwide prevalence of root canal treated teeth in the 20th and 21st centuries was reported to be 8.2%, with more than half of the population having at least one root canal treated tooth². These findings indicate that primary root canal treatment remains a widely performed intervention for tooth preservation in a substantial proportion of the population².

Although less invasive approaches, such as partial or cervical pulpotomies, have been shown to successfully manage cases of irreversible pulpitis³, root canal treatment continues to be the most commonly performed therapy and has been demonstrated to be a reliable option for maintaining the function of the affected tooth in the medium to long term⁴⁻⁶.

Several studies have assessed the survival of root canal treated teeth, reporting 5- and 10-year survival rates ranging from 36% to 95% and 62% to 89%, respectively⁷⁻¹². The wide ranges of the reported outcomes demonstrate substantial heterogeneity among these studies. In particular, differences with regard to the inclusion criteria such as tooth type, operator experience, type of post-endodontic restoration, and treatment type (primary/secondary treatment) limit the comparability of reported outcomes. Despite these differences, consistent evidence indicates that the type of post-endodontic restoration influences treatment outcomes, particularly with improved survival observed in teeth restored with indirect restorations^{4,6,8,11-15}. However, the optimal time interval between root canal filling and definitive restoration remains unclear, with recommendations ranging from within the first week to up to 4 months after root canal obturation¹⁵⁻¹⁷.

According to the S3-level clinical practice guideline of the European Society of Endodontology, 'tooth survival' is the most critical measure in relation to estimating the outcome of endodontic treatments and has been used in numerous studies¹⁸. However, in addition to 'tooth survival', other patient-related outcome measures, such as 'pain, tenderness, swelling, need for medication', 'tooth function', 'need for further intervention', 'adverse effects', and 'oral health-related quality of life', are justified and may provide valuable additional information to the evaluation of treatment outcome¹⁸⁻²⁰. For instance, several studies have investigated the survival of root canal treatment by considering both tooth extraction and the need for surgical or nonsurgical retreatment as failure events, thus reflecting the outcome measure 'need for further intervention'²¹⁻³⁰.

While tooth survival is widely considered the most critical outcome measure, it does not necessarily reflect the success of the root canal treatment itself. Therefore, the aim of the present study was to evaluate the 10-year survival of primary root canal treatment in teeth restored with indirect cuspal coverage restorations, using the need for further endodontic intervention or extraction as the primary outcome measure.

MATERIALS AND METHODS

Study Design

This retrospective study was approved by the local ethics committee of the University Medical Centre Göttingen (no. 20/2/20), conducted in accordance with the Declaration of Helsinki, and registered at [ClinicalTrials.gov](https://www.clinicaltrials.gov)

(ID: NCT06441058). Data were extracted from digital and paper-based dental records of patients who had undergone primary nonsurgical root canal treatment on at least one permanent tooth between 1998 and 2019, followed by the fabrication and definitive cementation/luting of a post-endodontic restoration with cuspal coverage (partial or full-coverage crown, ceramic or metal). Both procedures were performed at the Department of Preventive Dentistry, Periodontology and Cariology at the University Medical Centre Göttingen.

Data Collection

Initially, cases were automatically retrieved based on treatment fee codes from patients' digital dental records (highdent plus; CompuGroup Medical, Koblenz, Germany). Subsequently, relevant information was extracted by the investigators (F.H., T.-E.M., and P.K.). For this purpose, the digital and paper-based clinical and radiographic records were assessed.

Cases without any recorded follow-up visit after restoration placement were excluded. All data were entered into a pseudonymized dataset (Excel; Microsoft, Redmond, WA, USA).

The following data were collected from the patients' records:

1. Individual-related variables (age, sex)
2. Tooth-related variables (tooth type [premolar vs. molar], jaw [upper vs. lower], presence of preoperative apical periodontitis [yes vs. no], number of proximal teeth [<2 vs. 2], presence of an antagonistic tooth [yes vs. no])
3. Treatment-related variables (number of visits [single visit vs. multiple visits], type and material of the indirect restoration [partial vs. full-coverage crown, metal vs. ceramic], placement of a post [yes vs. no], time interval between root canal filling and restoration placement [≤ 1 vs. > 1 year]).

Outcome

In the present study, three complications were defined as failures (i.e., events): surgical or nonsurgical endodontic retreatment and extraction of the tooth. The date of intervention was regarded as the failure date. All teeth remaining *in situ* without having received one of the above-mentioned interventions until the date of censoring (last follow-up visit) were considered as having survived.

Statistical Analysis

Statistical analysis was performed using the software R (version 4.5.2, www.r-project.org)

and the packages "survival" (version 3.8-6) and "survminer" (version 0.5.2). The level of significance was set at $\alpha = 0.05$.

For each tooth, time to event or censoring was calculated from the date of root canal filling. Subsequently, the survival of the root canal treatment was assessed by Kaplan-Meier statistics, and the mean annual failure rate after 10 years was calculated³¹.

The effect of the assessed variables on survival was determined using Log-rank tests as well as univariable and multivariable Cox regression analyses. First, Log-rank tests (categorical variables) and univariable Cox regression analyses (continuous variables) were performed. Second, to reduce model complexity in relation to the limited number of observed events, only variables with a univariable P value $< .5$ were included in the multivariable Cox regression model with shared frailty to account for clustering of teeth within patients. For each variable, hazard ratios and their corresponding 95% confidence intervals were calculated.

RESULTS

A total of 756 patients with 976 endodontically treated teeth with subsequent cuspal coverage restorations were initially identified. Of these, 219 patients with 340 teeth were excluded due to missing documentation ($n = 11$), secondary root canal treatment prior to coronal restoration ($n = 226$), insufficient information concerning cementation procedures ($n = 6$), prolonged temporary crown cementation (≥ 6 months, $n = 79$), uncertain crown material ($n = 2$), pre-existing crown which was not removed prior to root canal treatment ($n = 6$), root canal treatment performed before 1998 or after 2019 ($n = 9$), surgical retreatment prior to coronal restoration ($n = 1$), and treatment of anterior teeth ($n = 29$). Finally, 607 teeth from 516 patients were included in the analysis. Of these, 391 teeth were restored with a partial crown and 216 with a full-coverage crown.

At the time of root canal treatment, the patients' mean age was 40.6 ± 14.6 years (minimum: 14.6 years, maximum: 81.9 years). Of all patients, 44.5% were female and 55.5% were male. The mean follow-up time was 5.7 ± 4.8 years (minimum: 43 days, maximum: 21.8 years).

In total, 37 teeth were affected by an untoward event (6.1%), of which 22 teeth were extracted (59.5%), 13 teeth were retreated nonsurgically (35.1%), and 2 teeth received an apicoectomy (5.4%). Accordingly, extraction was the most frequent complication. With regard to the distribution over time, 69.2% of the nonsurgical and

50.0% of the surgical retreatments occurred within the first 5 years of follow-up, compared with only 27.3% of all extractions. Therefore, retreatments were predominantly observed in the first half of the observation period, whereas extractions occurred more frequently in the later stages. The mean time to crown placement was 11.9 ± 19.9 months (median [IQR]: 5.7 [1.9 – 12.6]) after root canal treatment (minimum: 0 days, maximum: 17.4 years). The cumulative 10-year survival rate was 89.1% (95% confidence interval: 85.3 – 93.1), with a 10-year mean annual failure rate of 1.14% (Fig. 1).

Table 1 summarizes patient characteristics, tooth characteristics, and treatment-related variables, of which seven were subsequently evaluated using multivariable Cox regression analysis. Finally, three treatment-related variables were significantly associated with survival in the multivariable model ($P < .05$): type of indirect restoration (partial crown: hazard ratio [HR] = 2.36 [reference: full-coverage crown]), post placement (yes: HR = 2.77 [reference: no]), and time interval between root canal filling and restoration placement (>1 year: HR = 2.03 [reference: ≤ 1 year]).

DISCUSSION

The present study assessed the 10-year survival rate of primary root canal treatment in teeth restored with indirect cuspal coverage restorations. While tooth survival is widely

regarded as the most critical outcome measure¹⁸, treatment longevity has also been identified as an important patient-related factor when evaluating treatment options for teeth with apical periodontitis¹⁹. However, to date only a limited number of studies have assessed this aspect using Kaplan-Meier survival analysis^{16,22,27-29}. Therefore, the present study used the need for further endodontic intervention or extraction as the primary outcome, as it reflects the patient-relevant question of how long a treatment remains effective before additional intervention is required.

However, the composite outcome measure is associated with specific limitations: The decision to perform any of these interventions may be influenced by clinician judgment, patient preferences, symptoms, radiographic findings, and individual treatment philosophies. Moreover, while retreatment and surgical retreatment are commonly based on the interpretation of endodontic signs and symptoms, extractions may additionally be affected by factors such as restorability, structural integrity of the tooth, periodontal status, and prosthetic treatment planning. Consequently, the included events may represent different clinical pathways and do not necessarily reflect the biological success or failure of the root canal treatment alone. Due to the retrospective design and the long observation period, the specific indications leading to retreatment, surgical retreatment, or extraction could not be

consistently reconstructed from the available records. Nevertheless, the composite endpoint was intentionally chosen to reflect treatment longevity from a clinical and patient-centered perspective by capturing the occurrence of any major intervention following primary root canal treatment. Therefore, the reported survival estimates should be interpreted as the longevity of the initial treatment without further intervention rather than as a direct measure of biological healing.

Although teeth with pre-existing root canal treatment represent a clinically important group, the inclusion criteria were intentionally restricted to primary endodontically treated posterior teeth, excluding secondary treatments and teeth with prior surgical intervention. This approach ensured comparability with previously published studies^{16,22,28} and provided uniform baseline conditions across all failure events (retreatment, apicoectomy, or extraction), as previously treated or apically resected teeth may follow different clinical pathways and may be predisposed to specific failure events. This is particularly relevant when using multiple outcomes such as the need for further endodontic intervention and extraction. In contrast, studies assessing tooth survival alone may include both primary and secondary treatments, as extraction represents a uniform and clearly defined endpoint^{4,6,11-13}.

Previous studies reported a significant effect of the restoration type on the outcome of endodontically treated teeth, with higher survival rates observed for indirectly restored teeth compared to direct restorations^{4,6,8,11-15}. Although indirect restorations are most commonly full or partial crowns covering all cusps, the term 'indirect restoration' may also include inlays^{4,6}. However, inlays do not provide the same degree of cuspal protection, which represents a potential prognostic factor for survival of root canal treated teeth⁶. Therefore, the present study aimed to evaluate the prognosis of primary root canal treated teeth restored exclusively with indirect cuspal coverage restorations, in order to specifically reflect outcomes under standardized restorative conditions.

The 10-year survival rate of 89.1% is similar to previously reported rates, which ranged from 73.3% to 92.7% in studies evaluating the survival of root canal treatment^{16,22,27,28}. Among these studies, only Yee et al. (2018) exclusively examined teeth with cuspal coverage, reporting a slightly lower 10-year survival of 83.8%¹⁶. Regarding the occurrence of untoward events, extraction was the most frequent failure type followed by nonsurgical retreatment and apicoectomy, which is consistent with previous

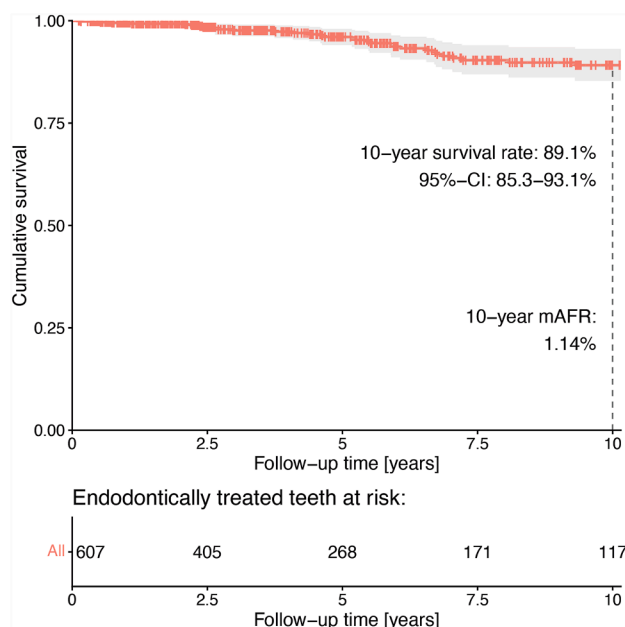


FIGURE 1 – Kaplan-Meier survival graph. The cumulative survival rate with 95% confidence interval (95% CI) and the mean annual failure rate (mAFR) after 10 years are presented.

TABLE 1 - Descriptive Data with Absolute Numbers, p Values From the Univariable Analyses and Results From the Multivariable Cox Regression Analysis (p-Values, Hazard Ratios with 95% Confidence Intervals)

Variable	n	P value (univariable analysis)	P value (multivariable analysis)	Hazard ratio (95% CI)
Age	n = 607	.021	.090	1.03 (1.00–1.06)
Gender	Female (n = 270), male (n = 337)			
Male vs. female (=reference)		.898	—	—
Tooth type	Premolar (n = 165), molar (n = 442)			
Premolar vs. molar (=reference)		.534	—	—
Jaw	Upper (n = 336), lower (n = 271)			
Lower vs. upper (=reference)		.794	—	—
Preoperative apical periodontitis	No (n = 291), yes (n = 316)			
Yes vs. no (=reference)		.350	.199	0.66 (0.36–1.24)
Proximal teeth	<2 (n = 141), 2 (n = 466)			
2 vs. <2 (=reference)		.219	.401	0.73 (0.34–1.53)
Antagonist tooth	No (n = 26), yes (n = 581)			
Yes vs. no (=reference)		.504	—	—
Visits	Multiple (n = 592), single (n = 15)			
Single vs. multiple (=reference)		.018	.055	3.97 (0.97–16.23)
Indirect restoration	Full-coverage crown (n = 216), partial crown (n = 391)			
Partial vs. full-coverage crown (=reference)		.067	.025	2.36 (1.11–5.00)
Crown material	Metal (n = 490), ceramic (n = 117)			
Ceramic vs. metal (=reference)		.595	—	—
Post	No (n = 563), yes (n = 44)			
Yes vs. no (=reference)		.307	.042	2.77 (1.04–7.40)
Time interval between root canal filling and restoration placement	≤1 year (n = 442), >1 year (n = 165)			
>1 year vs. ≤1 year (=reference)		.073	.034	2.03 (1.05–3.92)

CI, confidence interval.

Within the multivariable model, P values <.05 are marked in bold.

studies^{23,24,26,32}. Furthermore, the temporal distribution of these events showed that retreatments predominantly occurred within the first 5 years of follow-up (69.2%), whereas the majority of extractions were observed in the later stages (years 6–10, 69.6%). This pattern aligns with other studies, which similarly report earlier occurrence of retreatment and a tendency for extractions to occur later or at least evenly distributed over the observation period^{23,25,27,32}.

The multivariable analysis identified three treatment-related factors with a significant impact on the survival of primary root canal treatment. First, a partial crown following root canal treatment was associated with a significantly higher probability of failure compared to full-coverage crowns. In line with these findings, a recent systematic review and meta-analysis reported significantly better technical performance for full-coverage crowns compared to partial crowns³³. With regard to biological success, full-coverage

crowns also tended to outperform partial crowns, but without significant difference³³. Although these findings are consistent with the present results regarding the influence of the restoration type, it should be noted that the inclusion criteria and outcome measures differ substantially. In contrast, a study on the survival of root canal treated teeth did not observe a negative effect of partial restorations on tooth survival compared to full-coverage crowns¹³. Therefore, the results of the present study regarding the restoration type can only be interpreted with caution. One possible explanation may relate to the characteristics of partial restorations in terms of indication and tooth preparation. In particular, full-coverage crowns may potentially mask underlying biological complications, whereas defects such as caries may be detected more easily and at an earlier stage in partially restored teeth, potentially leading to earlier intervention³³.

The second influencing factor was the presence of an intraradicular post. Thus, in teeth with posts failure events were 2.77 times more likely to occur than in teeth without a post. Previous studies have reported that post placement has either no significant influence on survival^{5,11–13} or may be associated with lower survival rates^{14,17,26,34}. However, the definition of failure differs across studies, assessing either tooth survival^{5,11–14,17}, survival of root canal treatment²⁶, or success in terms of periapical healing³⁴. Although post placement may have an adverse effect on tooth survival, it is likely not due to the post itself but rather to additional loss of tooth structure resulting from pre-existing damage or excessive dentin removal during post space preparation.

The third significant influencing factor was an extended time interval between the root canal filling and the placement of the cuspal coverage restoration. In this respect, our results indicate that an indirect cuspal

coverage restoration should be placed within the first year following root canal obturation.

However, evidence remains limited with regard to two aspects of post-endodontic restorations: First, the recommended time interval between root canal obturation and placement of the definitive restoration varies substantially, ranging from within the first week to up to 4 months¹⁵⁻¹⁷. Other studies have reported no significant effect of an extended delay of the definitive restoration on the outcome of endodontically treated teeth^{21,35}. Second, in addition to these differing recommendations, there is considerable variability in how 'definitive restoration' is defined across studies, with only a few restricting its definition to indirect cuspal coverage restorations, such as partial or full-coverage crowns^{15,16}, while others also include direct restorations^{21,34,35}, further contributing to the heterogeneity of reported outcomes. When focusing exclusively on studies defining an indirect restoration as a cuspal coverage restoration, the time interval between root canal obturation and restoration placement has been reported to be an influencing factor that should not be neglected^{15,16}. This is in accordance with the results of the present study, even though the recommended time intervals differ, ranging from approximately the first three to 4 months after root canal filling^{15,16}. However, the observed association between delayed placement of the definitive restoration and reduced treatment survival should be interpreted with regard to the study design. As only teeth that ultimately received an indirect cuspal coverage restoration were eligible for inclusion, teeth experiencing an untoward event before definitive restoration were not represented in the study cohort. Consequently, the findings regarding restoration timing apply specifically to teeth that successfully completed the planned restorative treatment and may not be generalizable to teeth experiencing early failure before definitive restoration.

Moreover, regarding the causal relationship, delayed restoration may either

affect treatment outcomes through biological mechanisms, such as coronal leakage and secondary contamination, or through mechanical mechanisms related to prolonged provisionalization. Due to the composite endpoint and the lack of information on the specific causes of failure, the present study cannot distinguish between these two potential pathways. Therefore, the observed effect should be regarded as an association rather than evidence of a specific causal mechanism.

In addition to the limitations related to the composite outcome measure discussed above, the retrospective design of the present study and its reliance on dental records may have resulted in incomplete or inconsistent documentation in some cases. Consequently, the availability of potentially relevant baseline characteristics was limited. Apart from the presence of a pre-operative apical periodontitis, other factors, including periodontal status, systemic conditions, medications, smoking status, and structural integrity of the tooth, were not consistently documented and therefore could not be incorporated into the analysis. As a result, residual confounding cannot be excluded and should be considered when interpreting the identified prognostic factors. Finally, the long inclusion period (1998–2019) likely results in heterogeneity due to changes in treatment protocols over time. In addition, treatments were performed by multiple operators with varying levels of experience, which may have affected the outcomes. However, this variability may also reflect real-world clinical conditions. All these limitations should be considered when interpreting the findings, particularly with regard to their generalizability and comparability with existing literature. However, one of the major strengths of the present study is the long follow-up period of up to 10 years, allowing the assessment of long-term treatment outcomes. Moreover, the use of 'need for further endodontic intervention' as the primary outcome provides a clinically relevant and patient-related outcome measure beyond tooth retention. Finally, including only posterior teeth restored

with indirect cuspal coverage restorations reduced heterogeneity and allowed for a more focused assessment of the effect of the time interval between root canal filling and definitive restoration.

CONCLUSION

The present study demonstrated a high 10-year survival rate of primary root canal treatment of approximately 90% in posterior teeth restored with cuspal coverage restorations. In cases of failure, extraction was the most common untoward event, followed by non-surgical retreatment and apicoectomy. Moreover, post placement was associated with reduced survival, whereas improved outcomes were observed in teeth restored with full-coverage crowns and in those receiving definitive restoration within the first year after root canal obturation.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Franziska Haupt: helped in, Conceptualization, Investigation, Methodology, Project administration, Writing – original draft. **Toma-Elise Mielke:** was a part of, Investigation, Writing – review & editing. **Tim Hausdörfer:** helped in, Methodology, Writing – review & editing. **Annette Wiegand:** took part in, Conceptualization, Writing – review & editing. **Philipp Kanzow:** helped in, Conceptualization, Investigation, Formal analysis, Methodology, Project administration, Visualization, Writing – review & editing.

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