Eight-Year Retrospective Study of the Critical Time Lapse between Root Canal Completion and Crown Placement: Its Influence on the Survival of Endodontically Treated Teeth

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Abstract

Introduction: The purpose of this study was to investigate the effects of factors associated with various coronal restorative modalities after root canal treatment (RCT) on the survival of endodontically treated teeth (ETT) and to assess the effect of time lapse between RCT and crown placement after RCT to form a tooth loss hazard model. **Methods:** Computerized analysis was performed for all patients who received posterior RCT from 2008 to 2016 in the graduate endodontic department. Data collected included dates of RCT, type of post-endodontic restoration, and time of extraction if extracted. Teeth that received crown after RCT were also divided into 2 groups: receiving crown before 4 months and after 4 months after RCT. Data were analyzed by using Kaplan-Meier log-rank test and Cox regression model ($\alpha = 0.05$) by using SPPS Statistic 21. **Results:** Type of restoration after RCT significantly affected the survival of ETT ($P = .001$). ETT that received composite/amalgam buildup restorations were 2.29 times more likely to be extracted compared with ETT that received crown (hazard ratio, 2.29; confidence interval, 1.29–4.06; $P = .005$). Time of crown placement after RCT was also significantly correlated with survival rate of ETT ($P = .001$). Teeth that received crown 4 months after RCT were almost 3 times more likely to get extracted compared with teeth that received crown within 4 months of RCT (hazard ratio, 3.38; confidence interval, 1.56–6.33; $P = .002$). **Conclusions:** Patients may benefit by maintaining their natural dentition by timely placement of crown after RCT, which otherwise may have been extracted and replaced by implant because of any delay in crown placement. *(J Endod 2016;42:1598–1603)*

Key Words

Endodontically treated teeth, restoration, root canal treatment, survival analysis, survival rate

Significance

This study demonstrated that timing of the crown placement after root canal treatment can significantly affect the survival rate of endodontically treated teeth.

Numerous studies have focused on a different set of preoperative, intraoperative, and postoperative factors such as the periapical status, quality of root canal treatment (RCT), and prosthetic restorability of the tooth that can affect the survival of endodontically treated teeth (ETT) (1–4). Crown and root fractures are among the main causes of tooth loss after RCT (5). This finding might be explained by a catastrophic sequela that has been attributed to reinfection of the root canal system through coronal microleakage or complete loss of coronal tooth structure after crown fracture (6). Consequently, coronal restoration has been considered one of the major factors affecting the survival of ETT (7).

Different clinical studies have investigated the effect of coronal restorations on the outcome of RCT. Ray and Trope (8) concluded that periapical health depends significantly more on the coronal restoration than on the quality of the endodontic treatment. Also, Gillen et al (7) reported that appropriate coronal coverage after RCT is as critical as high-quality RCT for the integrity of the periapical tissue. Analysis from an epidemiology study on extracted ETT notably revealed that 85% had no coronal restorations after RCT (9).

Although studies increasingly emphasize the importance of the coronal seal after RCT, others have questioned the influence of coronal restorations (10). Nevertheless, dental practitioners still debate about the most appropriate restorative modality after RCT that can improve the longevity of ETT (11). Controversy exists regarding the effect of the type of coronal restoration after RCT on the survival of ETT. Aquilino and Caplan (12) reported that ETT not crowned are 6 times more likely to get extracted than teeth crowned after RCT. However, Safavi et al (11) reported that there is no significant difference between the survival of ETT that have been restored with amalgam, composite fillings, or cast crowns.

Considering the importance of coronal restoration on the survival of ETT (3), we performed an extensive search of the literature to gain a deeper understanding of the

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factors specific to coronal restoration that may influence the long-term survival of ETT. To the best of our knowledge, there was no clinical study that investigated the effect of time lapse between endodontic intervention and the placement of coronal restorations on the survival of ETT. Therefore, the purpose of this study was to investigate the effects of factors associated with various coronal restorative modalities after RCT on the survival of ETT and, second, to assess the effect of time lapse between endodontic intervention and crown placement after RCT to form a tooth loss hazard model.

Materials and Methods

The protocol of the present retrospective study was approved by the Committee on Research Involving Human Subjects, Case Western Reserve University (CWRU). Study data were collected and managed by using electronic data capture tools hosted at CWRU. Existing patients' electronic records that were based on the American Dental Association (ADA) Code on Dental Procedure and Nomenclature (CDT) identified all mature permanent posterior teeth that had received nonsurgical endodontic therapy (NSRCT) at the endodontic department done by postgraduate students under the surgical operating microscope between January 1, 2008 and January 1, 2016. Records were restricted to active school patients who regularly came to CWRU School of Dental Medicine for follow-ups, resulting in 1374 ETT from 1123 patients.

Patient records, radiographs, and computerized databases were examined to identify samples that matched the inclusion criteria in the present study. Inclusion criteria for the ETT were as follows:

1. Posterior ETT with preoperative and postoperative radiographs and complete records with ADA CDT treatment dates
2. Restorable ETT that received coronal restorations including single full coverage crown, composite/amalgam buildup restorations, or temporary restoration within 24 months after primary RCT
3. Periodontally sound teeth with no detectable crack during RCT
4. ETT that showed an acceptable quality of RCT on the basis of the criteria by Tronstad et al (13)

Teeth with loss of follow-up, no information regarding the coronal restoration that was done, any restoration redone after initial placement, or were periodontally compromised with a questionable prognosis were excluded. Also, ETT with any operative mishaps including perforations and separated files were excluded.

Screening of the ETT that met the inclusion criteria yielded 882 samples, from which 880 patients were included in the final analysis. The following characteristics were collected from the patients' records:

1. Patient's age, gender, the type of tooth (premolar or molar), the location or dental arch of the ETT (maxilla versus mandible), and the existence of opposing dentition (natural teeth, fixed, none)
2. Date of NSRCT initiation and completion, related information including single or multiple visit sessions for NSRCT, type of coronal restoration placed after NSRCT (full coverage crown, composite/amalgam buildups, temporary restoration), and the presence of a post
3. Date of coronal restoration placement subsequent to NSRCT, including start and finish dates
4. Date and reason of an event (extraction) if available

On the occasion that access was performed through an existing crown, the preceding permanent restoration was considered as such. Undergraduate clinicians within the School of Dental Medicine performed all definitive restorations.

The time that had passed from the endodontic treatment to the placement of the restoration (time of restoration) was registered for all ETT. To assess the survival of ETT, ADA CDT codes for extraction in computerized records, if available, were considered as failure. Time lapse between NSRCT and extraction was registered for this group of teeth. Survival was defined as the presence of the ETT in the oral cavity by the end of the study (January 1, 2016). ETT with no extraction codes were considered to have survived, and the time lapse between NSRCT and the end of this study was calculated for these teeth. The date of the last recall visit of the patient was also recorded as the censoring date for ETT that were not extracted during the study period.

Statistical analysis was performed by using SPSS 19 (SPSS Inc, Chicago, IL) and R version 2.8.0 (Foundation for Statistical Computing, Vienna, Austria). The 8-year survival rate of ETT was analyzed by using Kaplan-Meier statistics and log-rank tests for differences between groups ($P < .05$). The annual failure rates were calculated from life tables. A multivariate Cox regression was performed to analyze the influence of variables at a significance level of 0.05.

Results

Distribution and Characteristics of ETT

In the present study, 882 teeth from 880 individuals (male, 48%; female, 52%) with a mean age of 46 years were included for analysis. From 882 examined teeth, 441 teeth (50%) received a full coverage crown after RCT, 198 teeth (23%) received composite/amalgam buildup restorations, and 243 teeth (27%) never received a final restoration after RCT. One patient contributed more than 2 teeth. Table 1 presents the distribution and characteristics of the included teeth.

Survival Analysis of ETT

In this 8-year retrospective study, 105 teeth (11.9%) were extracted, and 777 (88.1%) survived to the end of the study (January 1, 2016). Twenty-three percent, 11.6%, and 5.7% of the teeth in the no restoration, buildup restoration, and crown coverage groups, respectively, were extracted.

Eight cases (7.6%) were extracted for reasons related to endodontics. The majority of the extractions were carried out because of crown fractures (Table 2).

Survival analyses based on clinical variables were assessed by using the Kaplan-Meier method, and significance was identified by using the log-rank test. Prognostic variables for univariate survival analysis included type of restoration after RCT, opposing dentition, dental arch, sex, type of tooth, single/multiple visit RCT, and the presence of a post. Table 3 captures the effect of different clinical variables on the survival rate of ETT. Kaplan-Meier analysis and log-rank tests revealed that only the type of restoration ($P = .001$) was significantly correlated with survival rates for ETT.

Figure 1 details the Kaplan-Meier survival curve as a function of the different types of restorations. On the basis of the life table, the overall 8-year survival rate of ETT regardless of the type of restoration after RCT was 79%. The 8-year survival rate after RCT was 84% with full coverage crowns. For ETT that received core buildup restorations without placement of a full coverage crown, the 8-year survival rate after RCT was 71%. Also, teeth that did not receive a permanent restoration after RCT showed the lowest 8-year survival rate of 58%. This difference was statistically significant between groups ($P = .001$).

To further analyze the effect of the type of restoration placed after RCT on the survival rate of root canal treated teeth, the hazard ratio (HR) was calculated for the selected variable. On the basis of the Cox proportional hazard model, the type of restoration was the only factor that significantly affected the survival of ETT. ETT that received composite/amalgam buildup restorations were 2.29 times more likely to be extracted (HR, 2.29; confidence interval [CI], 1.29–4.06; $P = .005$). Also,

TABLE 1. Distribution and Characteristics of ETT

	n (%)			
	Crown *n* = 441 (50%)	Buildup restoration *n* = 198 (23%)	No restoration *n* = 243 (27%)	*P* value* (χ^2, *t* test)
Age (y)	52	47	42	.88
Sex				.9
Male	221 (50)	97 (48.9)	106 (43.6)	
Female	220 (50)	101 (51.1)	137 (56.4)	
Dental arch				.45
Maxillary	220 (50)	96 (48.4)	119 (49)	
Mandibular	221 (50)	102 (51.6)	124 (51)	
Opposing dentition				.065
Natural	297 (67.3)	139 (70)	189 (77.7)	
Fixed prosthetic	116 (26.3)	45 (22.7)	37 (15.3)	
None	28 (6.4)	14 (7.3)	17 (7)	
Type of tooth				.11
Molar	325 (73.6)	136 (68.6)	188 (77.4)	
Premolar	116 (26.4)	62 (31.4)	55 (22.6)	
No. of visits				.77
Single	202 (45.8)	112 (56.5)	134 (55.1)	
Multiple	239 (44.2)	86 (43.5)	109 (44.9)	
Post			N/A	.06
Yes	302 (68.4)	118 (59.6)		
No	139 (31.6)	80 (40.4)		

*Significance level is $P = .05$.

ETT that did not receive any follow-up permanent restoration were 4 times more likely to get extracted compared with those that received a full coverage crown (HR, 4.08; CI, 2.54–6.54; $P = .001$).

Effect of Timing of Crown Placement after RCT on Survival Rate of Root Canal Treated Teeth

Because we reported that ETT restored with full coverage crown showed the highest survival rate, we also investigated the effect of timing of the crown placement subsequent to RCT on the survival rate of ETT. The mean time of receiving a crown was 8.2 months after RCT. On the basis of the median time of crown placement, teeth that received crowns after RCT were divided into 2 groups, receiving a crown within 4 months of RCT and receiving a crown after 4 months. There was no significant difference between the 2 groups regarding the type of opposing dentition, dental arch, sex, age, and type of tooth ($P > .05$).

Survival analysis of ETT based on the time of crown placement was assessed by using the Kaplan-Meier method, and significance was identified by using the log-rank test. Figure 2 shows the Kaplan-Meier survival curve that was based on the time of crown placement after RCT. On the basis of the life table, the 8-year survival rates of ETT that received crown within 4 months and after 4 months of RCT were 85% and 68%, respectively. Log-rank tests revealed that the time of crown placement after RCT ($P = .001$) was significantly correlated with the survival rates of ETT.

Cox proportional hazard was assessed as a function of the timing of crown placement after RCT. It was shown that ETT that received a crown 4 months after RCT were extracted at 3 times the rate of teeth that received a crown within 4 months after RCT (HR, 3.38; CI, 1.56–6.33; $P = .002$).

Also, the effect of the time of crown placement after RCT on the survival rate of ETT was assessed in greater detail by breaking the time of crown placement after RCT into different time intervals (Table 4). The tooth loss HR showed a dramatic increase after 4 months and remained constant up to 18 months. However, after 18 months, the HR of tooth loss experienced another sharp rise compared with ETT that received crown within 4 months of RCT (Fig. 3).

TABLE 2. Reasons for Extraction of ETT after RCT

Reason for extraction	*N* (%)
Crown fractures	64 (60)
Prosthetic reasons (restoration failure)	21 (20)
Endodontic reasons (vertical root fracture)	8 (7.6)
Unknown reason	12 (12.4)

Discussion

To the best of our knowledge, this is the first study that investigated the effect of time of crown placement after RCT on the survival rate of ETT. In this study, none of the patient-related factors such as sex and

TABLE 3. Eight-Year Survival of ETT Depending on Different Clinical Variables

Variables	8-year survival based on life table	*P* value (log-rank)
Type of restoration after RCT		.001*
Crown	84	
Amalgam/composite restoration	71	
None	58	
Sex		.23
Male	77	
Female	78	
Dental arch		.98
Maxillary	82	
Mandibular	78	
Opposing dentition		.88
Natural	79	
Fixed prosthetic	71	
None	68	
Type of tooth		.34
Molar	82	
Premolar	85	
No. of visits		.91
Single	81	
Multiple	78	
Post		.76
Yes	86	
No	83	

*Significance level is $P = .05$.

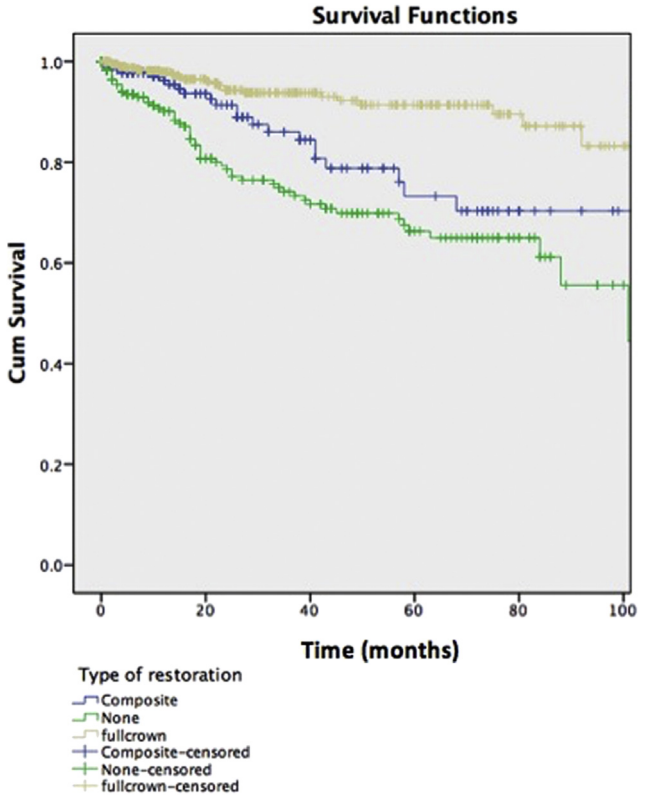

Figure 1. Kaplan-Meier survival curve as a function of the different types of restorations. The 8-year survival rate after root canal treatment was 84% with full coverage crowns (full crown group). For ETT that received core buildup restorations (Composite group), 8-year survival rate was 71%. Teeth that did not receive a permanent restoration after RCT (None group) showed the lowest 8-year survival rate of 58%. Type of restoration significantly affected survival rate of ETT (P = .001). Cum, Cumulative.

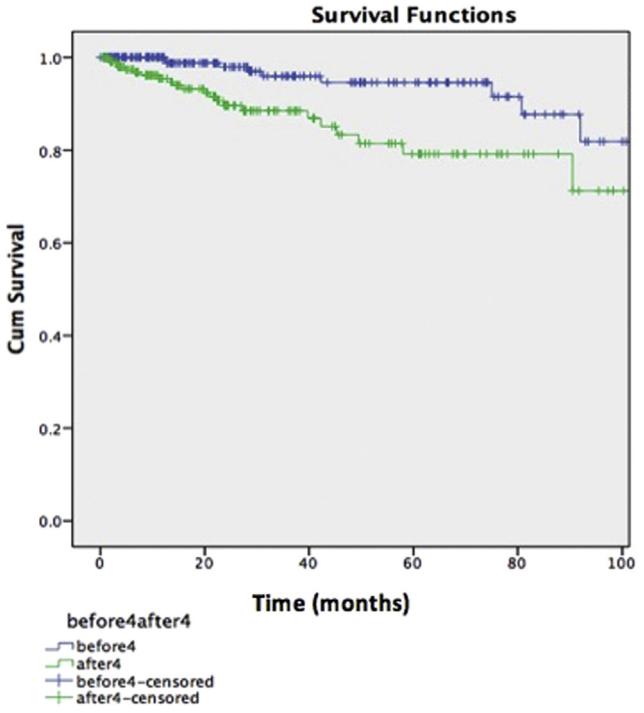

Figure 2. Kaplan-Meier survival curve as a function of time of crown placement. The 8-year survival rates of ETT that received crown within 4 months (before group) and after 4 months (after group) of RCT were 85% and 68%, respectively. Cum, Cumulative.

age affected the survival rate of ETT, which is consistent with previous studies (14, 15). Also, tooth-related factors such as dental arch and the type of posterior tooth showed no effect on the ETT survival rate, which is in agreement with previous findings (16, 17). However, this is contrary to Lee et al (18), who found "age, tooth type, pre-operative periapical status, occlusion, type of final restoration, and condition of the tooth/restoration margin were significant factors affecting both periapical healing and tooth survival". Furthermore, in this study, the presence and type of opposing dentition showed no significant effect on the survival rate. This finding is not in agreement with studies that related the survival of root canal treated teeth to opposing dentition (15, 19). This contradictory result may be due to occlusal reduction after RCT or after permanent restoration of the ETT.

The authors reported that there is no significant relation between the number of RCT visits and survival rate. Vera et al (20) reported that 2-visit RCT by using calcium hydroxide as an intracanal medication can result in an "improved microbiological status of the root canal system compared to the single visit protocol". However, the results of the present study and others indicate that the outcome of RCT is independent from the number of appointments required to finish RCT (21). These findings might highlight the need for further studies to evaluate the effect of additional microbial load reduction, which is gained by intracanal medications such as calcium hydroxide, on outcome of RCT.

The authors investigated the effect of the type of restoration after RCT on the survival rate of ETT. The 8-year survival rate after RCT was 84% with full coverage crowns. For ETT with core buildup restorations without receiving a full coverage crown, the 8-year survival rate after RCT was 71%. Also, root canal treated teeth that did not subsequently receive any permanent restorations had the lowest 8-year survival rate of 58%. Authors of the present study reported that the type of restoration can significantly affect the survival of posterior ETT. This finding further confirms previous studies that reported restoring the ETT with a full coverage crown could improve its survival rate. These results could be related and possibly explain our findings for the reason of extraction of ETT in this study. The majority of extractions were carried out because of crown fractures (60%), which could probably have been prevented by the timely placement of a crown after RCT. Also, a well-sealed restoration such as full coverage crown could prevent potential microleakage, which has long been considered a major cause of endodontic failure and tooth loss after RCT (22). However, it is not clear whether the longevity of ETT after crown placement is mainly due to prevention of microleakage or supporting the tooth structure against occlusal load and fractures. The retrospective nature of this study cannot reveal a cause-effect relationship between restorative modalities and survival rate (23).

There was a favorable effect for the placement of a crown on posterior teeth after RCT. The adjusted HR showed that ETT with temporary restorations are 4 times more likely to get extracted compared with

TABLE 4. Tooth Loss HR in Different Time Intervals

Time interval (mo)*	HR (CI)†
4–6	4.72 (1.32–16.89)
7–12	2.97 (1.7–11.98)
12–18	5.8 (1.6–19.9)
18–24	10.79 (3.4–34.2)

*Time lapse between RCT and receiving crown.

†HR has been reported compared with 0–4 months as a reference point.

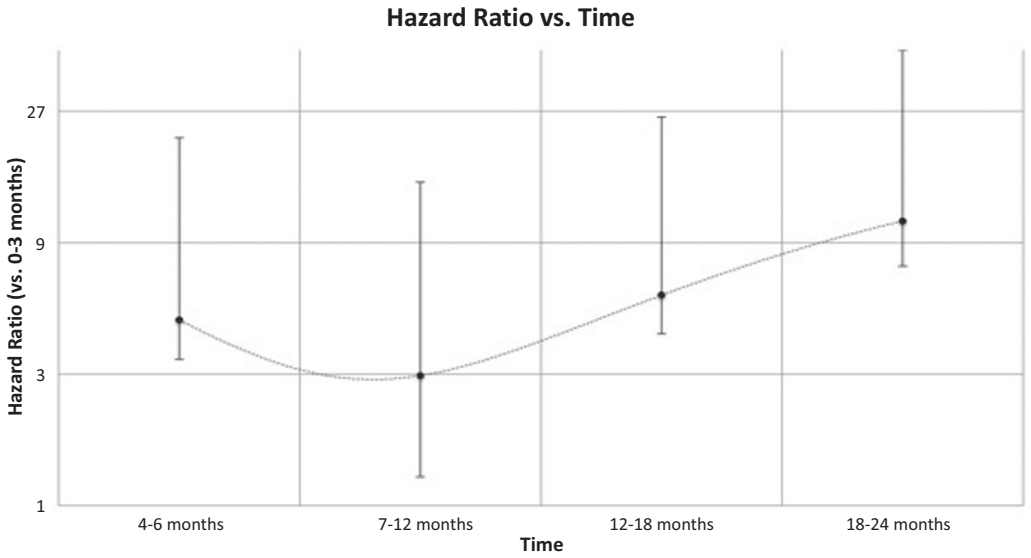

Figure 3. Tooth loss hazard model in different time intervals. After 18 months, HR of tooth loss experienced a sharp rise compared with ETT that received crown within 4 months of RCT.

those that received crowns. However, 27% of the teeth in this study never received any type of permanent restoration during the 8-year observation period. This finding suggests that a more proactive collaboration between the triad of endodontist, general dentist, and patient is required to ensure continuity of care to address the importance of post-endodontic restorative factors that can affect the prognosis of treatment.

The presence of post did not influence the survival of the ETT in this study, which is in agreement with previous studies (9, 12, 24). This may be due to the ubiquitous selection of fiber post for the retention of the core material in the study setting. It has been shown that a tooth with post that has a lower modulus of elasticity (eg, fiber post) shows higher fracture resistance compared with a tooth restored with cast post (25). This contrasts the results of a meta-analysis from Zhou and Wang (26), which found that ETT restored with cast post displayed significantly higher fracture resistance than teeth restored with fiber post. Survival of ETT restored with post-retained restorations depends on various post-related and tooth-related factors such as the existence of ferrule and quality of post placement (27). It was speculated that differences with these parameters and also in the type of included ETT in various studies might explain these contrary results.

One factor that has not been assessed widely is the possible role of the timing of crown placement on the survival of ETT. For the first time, the effect of the time lapse between endodontic intervention and crown placement after RCT was assessed in the present study to form a tooth loss hazard model. It was shown that ETT that received a crown 4 months after RCT were extracted at 3 times the rate of teeth that received a crown within 4 months after RCT. According to the tooth loss hazard model (Fig. 3), the overall probability of the survival of ETT remained relatively constant for ETT that received crown from 4 to 18 months after RCT. However, at 18 months, the HR of tooth loss experienced a sudden rise. One suggested explanation for this inconsistent, sudden increase in the HR could be that this time interval represents the time subsequent to a clinical presentation or occurrence of most crown or root fractures. It should be explained that the delay in the crown placement in the present study might be due to the study being conducted in a school setting. Also, socioeconomic status of patients might affect the timing of the crown placement, which should be considered in future studies. However, the fact that the delayed crown placement significantly jeopardizes the survival rate of ETT cannot be denied.

Practitioners might recommend tooth extraction and implant placement for teeth that could be preserved or maintained with endodontic intervention (28). However, they may be neglecting the fact that dental implants are susceptible to technical complications and diseases, leading to further removal and rehabilitation, which could result in high maintenance costs in a large number of cases (29, 30). This study confirmed that the timely placement of a full coverage crown after RCT can enhance the serviceability of ETT and present RCT as a treatment option with an acceptable survival rate. It is worth mentioning that ETT are functioning as a dynamic unit in the oral cavity, and different uncontrollable factors might affect their survival rate. Also, there are other confounding variables such as preoperative pulp and periapical status that could affect the overall survival rate of our study (3). However, the present study highlighted the significant effect of timing of the crown placement on the survival rate of ETT. Therefore, the effect of postoperative restoration in conjunction with other variables on the survival of ETT could be further evaluated in future prospective randomized controlled trials.

Acknowledgments

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

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