Survival Rates from Fracture of Endodontically Treated Premolars Restored with Full-coverage Crowns or Direct Resin Composite Restorations: A Retrospective Study

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Abstract

Introduction: The aim of the present study was to compare the survival rates against fracture of premolar endodontically treated teeth (ETT) restored with resin composite or crowns and to identify risk factors associated with the fracture. **Methods:** Data from dental records and radiographs of premolar ETT with postendodontic restorations (ie, resin composite or crowns) were collected between 2012 and 2016 and selected following selected inclusion and exclusion criteria. Tooth location, type of restoration, number of proximal contacts, and amount of tooth surface loss were recorded. The incidence and restorability of postendodontic fractures were identified. Survival rates against fracture of the 2 restoration types were calculated using Kaplan-Meier survival analysis. Any potential factors associated with fractures were identified using Cox proportional hazards models. **Results:** The survival rate against fracture of ETT restored with crowns (95.1%) was higher than resin composite (77.0%). ETT restored with resin composite with 1 or 2 tooth surface losses and 2 proximal contacts had a high survival rate of 88.5% that was not significantly different from ETT with crowns. A higher incidence of restorability after fracture was observed in teeth restored with resin composite than crowns. The type of restoration and number of proximal contacts were identified as potential risk factors associated with fracture incidence. **Conclusions:** The survival rate against fracture of ETT restored with crowns was higher than resin composite. However, ETT with 1 or 2 tooth surface losses and 2 proximal contacts and restored with resin composite showed a high survival rate that was comparable with ETT restored with crowns. *(J Endod 2018;44:233–238)*

Key Words

Endodontically treated teeth, full-coverage crown, resin composite, survival rate, tooth fracture

Significance

For survival from fracture, endodontically treated premolars with no more than 2 surface coronal structure losses and 2 adjacent teeth can be restored successfully with either a crown or resin composite as determined at the 5-year recall.

Fracture of tooth structure is a concern for endodontically treated teeth (ETT), especially in the posterior region. ETT are weakened from carious lesions, preexisting large restorations, or improper restorative procedures (1, 2). Tooth fracture usually occurs when ETT are not immediately restored, which can lead to coronal bacteria leakage or an unrestorable fracture (3, 4). The success rate of ETT with permanent restorations was significantly higher than those with temporary restorations (5, 6). For this reason, a permanent restoration should be placed as soon as possible after the completion of endodontic treatment.

As a protective concept, posterior ETT should receive a cuspal-coverage crown restoration to protect the tooth from fracture (7, 8). Several clinical studies reported that cuspal-coverage restorations significantly improved the success rate of posterior ETT by reducing the chance of postendodontic fracture (8–10).

As a conservative concept, posterior ETT with minimal to moderate loss of tooth structure can be restored with direct resin composite as the final restoration (7). *In vitro*, a high fracture resistance of ETT restored with resin composite was reported (11, 12). This concept is supported by the result of a randomized controlled trial. In this clinical study, the success rate of the premolar ETT at 3 years with 1 or 2 proximal surface losses and restored with fiber posts and resin composite was as high as those restored with crowns (13). However, the longevity of resin composite restorations in ETT with moderate to severe loss of tooth structure is questionable (14). The concepts of suitable postendodontic restoration in posterior ETT (conservative or protective approach) (15) are still controversial.

Therefore, the purpose of this study was to compare the survival rates against fracture of premolar ETT restored with either non–cuspal-coverage resin composite or cuspal-coverage crowns using a retrospective cohort design. In addition, the potential risk factors associated with the fracture were identified.

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Materials and Methods

The protocol was approved by the institutional review board of the Faculty of Dentistry/Faculty of Pharmacy, Mahidol University (MU-DT/PY-IRB 2016/032.0508), Bangkok, Thailand. Dental records were searched from the patients' charts who attended the Endodontics Clinic, Faculty of Dentistry, Mahidol University. Dental records of patients who received complete nonsurgical endodontic treatment in premolars by undergraduate or postgraduate dental students and attended recalls between 2012 and 2016 were selected. Postendodontic restorations with direct resin composite or full-coverage crowns were provided for these ETT. All restorations were performed by undergraduate or postgraduate students, general dentists, or prosthodontists.

Endodontic and Restorative Procedures

In brief, endodontic treatment was performed using the following procedures. Rubber dam isolation was mandatory for root canal treatments. Coronal access and working length determination were performed. Root canals were cleaned and shaped with the crown-down technique using stainless steel hand files and/or rotary nickel-titanium instruments. Sodium hypochlorite at 2.5% and 17% EDTA solution (EndoClean; M Dent, Bangkok, Thailand) were used as root canal irrigants. Root canals were obturated with gutta-percha cones with zinc oxide–eugenol sealer (MU Sealer, M Dent) or epoxy resin–based sealer (AH Plus; Dentsply Maillefer, Tulsa, OK) using lateral or vertical compaction to the level of 1–2 mm below the orifices. Access cavities were cleaned using alcohol-soaked cotton pellets, washed with air/water spray, and dried before the restorative procedures.

Light-cured resin composite (Z250 or Z350; 3M ESPE, St Paul, MN) bonded with resin-based adhesive (etch-and-rinse adhesive [Adper Single Bond 2, 3M ESPE] or Excite F [Ivoclar Vivadent AG, Schaan, Liechtenstein] or 2-step self-etch adhesive [Clearfil SE Bond; Kuraray Noritake Dental, Tokyo, Japan) were placed. For the patients who declined a crown restoration or could not afford the cost of a crown or in ETT with only coronal access, resin composite restorations were placed as final restorations. In some cases, dual-cured resin core built-up material (MultiCore Flow; Ivoclar Vivadent Inc, Amherst, NY) bonded with resin-based adhesive (Excite DSC, Ivoclar Vivadent AG) was initially placed and covered with resin composite. Before placement of the resin-based material, the cavities were based with GIC (Vitrebond [3M ESPE] or GC Fuji VII [GC Corp, Tokyo, Japan]) at 1- to 2-mm thickness. For all ETT restored with resin composite restorations, a post was not placed.

For ETT planned to receive full-coverage crown restorations, the restored teeth were prepared for full metal, porcelain fused to metal, or all-ceramic crowns. If intraradicular posts were indicated, cast metal posts or prefabricated fiber posts (D.T. LIGHT-POSTS [Bisco Inc, Schaumburg, IL] or FRC Postec Plus [Ivoclar Vivadent AG]) were used and cemented into root canals with a resin-based core built-up material (MultiCore Flow) using the adhesive. The crowns were cemented with a resin-based cement (Rely X Unicem [3M ESPE] or Panavia F 2.0 [Kuraray Noritake Dental, Tokyo, Japan]).

Case Selection and Data Collection

Details of clinical and radiographic examinations were recorded at the recall visit. From the data, ETT were selected based on the following inclusion and exclusion criteria.

The inclusion criteria were as follows:

1. Premolar ETT, either nonsurgical root canal treatment or retreatment, with mature root formation
2. ETT restored with single crowns or direct resin composite
3. ETT with at least 1 opposing tooth with occlusal contact. The occluded tooth had to be a natural tooth or a fixed dental prosthesis. If the opposing tooth was a removable prosthesis, the tooth was not included.
4. Patients had to participate in the recall programs at least once.

The exclusion criteria were as follows:

1. ETT that were extracted for endodontic or periodontal reasons
2. ETT with chronic marginal periodontitis exhibiting bone loss in more than half of the root length
3. A history of previous cracks on a coronal or radicular tooth structure or a vertical root fracture was suspected
4. ETT with orthodontic appliances except those with orthodontic retainers were included

In addition, sex, tooth location, restoration type, the number of adjacent teeth, and the number of tooth surface losses were recorded. The incidence and restorability of postendodontic fractures were identified.

Criteria for Survival from Fracture Assessment

An overview of the methodology and fracture assessment is presented in Figure 1. The fracture assessment criteria are presented in Table 1. The fracture group was classified into 3 subgroups based on the type of fracture: a natural tooth, a restoration, or a combination of a natural tooth and a restoration. Fracture in a natural tooth, a restoration, or the combination group was further classified into 2 types: restorable and nonrestorable fractures.

Statistical Analysis

Kaplan-Meier survival analysis was used to calculate the survival time of teeth without fracture. The survival rate against fracture and subanalysis in the combination of tooth structure loss and contact surfaces of the premolar ETT restored with the 2 types of restorations were calculated and compared using the log-rank test.

To evaluate the potential factors related to the survival rate from fracture, statistical analysis was performed in 2 parts:

1. Univariate analysis for initially identifying the associations between the survival rate against fracture and any other potential factors
2. Multivariate analysis for finally concluding the potential risk(s) among the selected factors at the cutoff point P value ($\leq .25$ in the univariate analysis) (16).

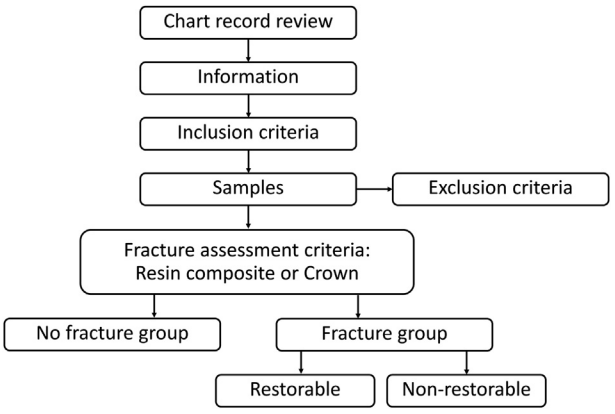

Figure 1. An overview of the methodology and fracture assessment.

TABLE 1. Criteria and Definitions of Fracture Type and Restorability

Fracture assessment criteria	Definitions
Fracture type	
Natural tooth	• Fracture located at any portion of tooth structure (crown or root or crown/root)
Restoration	
Resin composite	• Fracture of direct restoration without loss of tooth structure
Crown	• Fracture of crown restoration without loss of tooth structure
Combination	• Fracture of direct restoration or crown restoration combined with fracture of natural tooth structure
Restorable fracture	• Fracture could be repaired or replaced with a new restoration
Nonrestorable fracture	• Fracture with extensive destruction of natural tooth/root structure leading to ◦ Insufficient ferrule height/width that a new restoration was not appropriate ◦ Subgingival fracture that crown lengthening was not possible • Fracture as vertical root fracture

Cox proportional hazards models were performed to evaluate the potential risk factors at a significance level of .05.

Results

Data Distribution and Survival Analysis

Data distribution and survival rates are shown in Table 2. One half of the premolar ETT were restored with resin composite ($n = 61$), and the other half were restored with full-coverage crowns ($n = 61$). The distribution of restored premolar teeth was 71 (58.2%) in the maxilla and 51 (41.8%) in the mandible. The overall survival rate against fracture was 86.1%. Based on the restoration type, the survival rate of the premolar ETT restored with resin composite was 77%, and for premolar ETT restored with full-coverage crowns, it was 95.1%.

Kaplan-Meier survival graphs presenting cumulative survival rates at each studied time point according to the restoration type and the number of contacts are shown in Figures 2 and 3. Using univariate log-rank analysis, all factors that potentially affect the survival against fracture were initially identified.

Using the multivariate Cox proportional hazards model, the variables that affected the survival rate against fracture of the premolars are presented in Table 3. The restoration type, the number of proximal contacts (adjacent teeth), and sex were factors that affected the 5-year survival rate against fracture of premolar ETT ($P < .05$). Premolar ETT restored with resin composite had a 13 times higher chance of fracture than teeth restored with full-coverage crowns (hazard ratio [HR] = 13.01; 95% confidence interval [CI], 3.22–52.65; $P < .05$). Teeth with 1 and no contact had an 8.7 times greater chance of fracture than those with 2 contacts (HR = 8.69; 95% CI, 2.75–27.44). Restored teeth in males had a 5.3 times higher risk of tooth fracture than those in females (HR = 5.25; 95% CI, 1.81–15.29; $P < .05$).

Survival Rate against Fracture of ETT Restored with Resin Composite Restorations: The Combination Effect of Restoration Type, Number of Tooth Structure Losses, and Contacts

The percentages of teeth that had lost between 1 and 4 surfaces of tooth structure were 8.2% (5 teeth), 50.8% (31 teeth), 32.8% (20 teeth), and 8.2% (5 teeth), respectively. Because the sample sizes of the groups of 1 and 4 surfaces were small, ETT were pooled in 2 categories (1–2 surface losses and 3–4 surface losses). The survival rate for ETT fracture with 1 to 2 surface losses was 83.3%, and for ETT with 3 to 4 surface losses, it was 68%.

The analysis of ETT with a combination of factors (ie, the number of tooth surfaces lost and the contacts) is presented in Table 4. The survival rate against fracture of the ETT restored with resin composite ranged between 28.6% and 88.5%. In the resin composite subgroups, the presence of 2 contacts (adjacent teeth) increased the survival rates. The highest survival rate was observed in teeth with 1 to 2 surface losses with 2 proximal contacts. The survival rate was not significantly different from that of the crown group.

Types of Fracture in Relation to Restoration Types

According to the restoration type, the percentages of fractured teeth in premolar ETT restored with resin composite were as follows: 42.9% with a tooth structure fracture, 28.6% with a restoration fracture, and 28.6% with a combination. For the full-coverage crowns, the

TABLE 2. Data Distribution and Univariate Log-rank Analysis of Premolar Endodontically Treated Teeth ($N = 122$)

Variables	Number of teeth	Number of teeth with fracture	Number of teeth survived from fracture	*P* value
Sex				.078
Female	91	8 (8.8)*	83 (91.2)	
Male	31	9 (29.0)	22 (71.0)	
Location				.159
Maxilla	71	8 (11.3)	63 (88.7)	
Mandible	51	9 (17.6)	42 (82.4)	
Restoration				.004†
Crown	61	3 (4.9)	58 (95.1)	
Resin composite	61	14 (23.0)	47 (77.0)	
Contact				.001†
2	90	7 (7.8)	83 (92.2)	
0/1	32	10 (31.3)	22 (68.8)	

*Percentages of teeth are in parentheses.

†A significant difference is indicated by log-rank test ($\alpha = 0.05$): compared the survival rate within each factor. Factors with *P* value ≤.25 were further analyzed using the multivariate model.

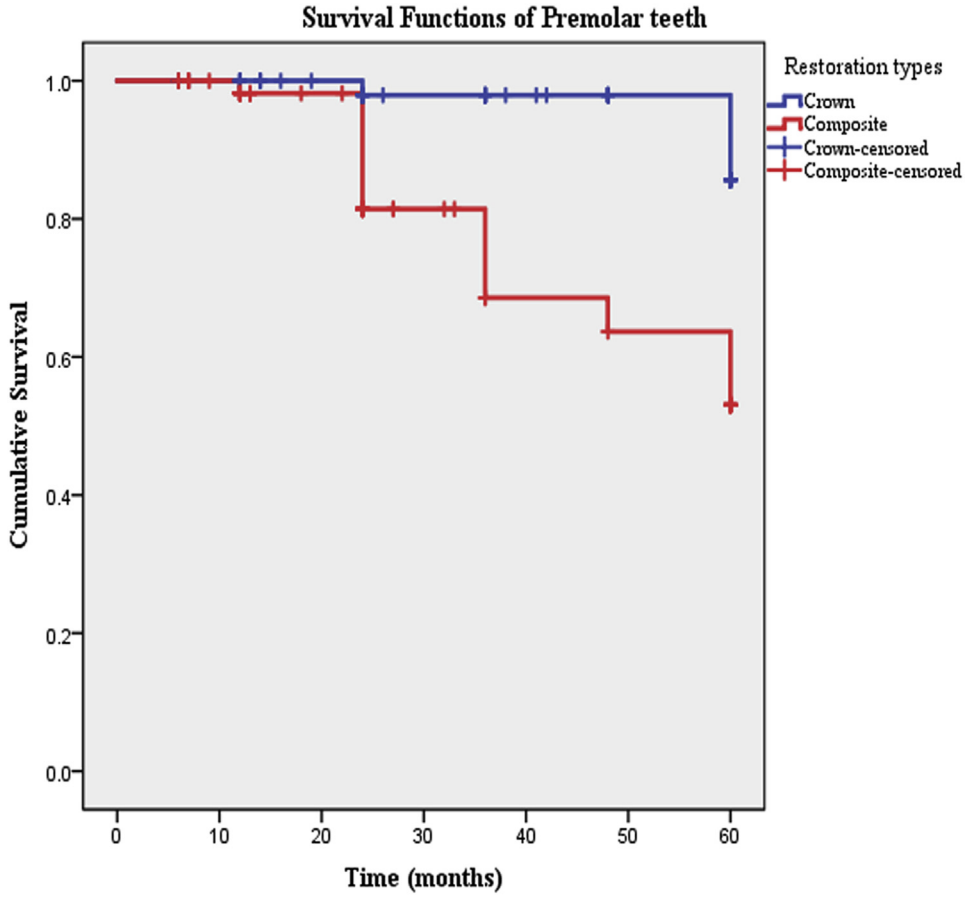

Figure 2. The Kaplan-Meier cumulative survival curve of premolar ETT according to the restoration types.

fractured teeth types were 66.7% with a tooth structure fracture and 33.3% with a combination. For resin composite and full-coverage crowns, the highest frequency of fracture was observed in the tooth structure.

The percentages of teeth with/without post placement in the ETT restored with crowns were as follows: 6.6% (4 teeth) without a post, 39.3% (24 teeth) with prefabricated fiber posts, and 54.1% (33 teeth) with cast metal posts. The incidence of fracture in the premolar ETT with crowns was only 3 teeth, 1 tooth in each group.

Restorability of Fractured Premolar ETT in Relation to the Restoration Types

From 14 fractured teeth restored with resin composite, 71.4% (10 teeth) were defined as restorable, and 28.6% (4 teeth) were defined as nonrestorable. All fractures in the full-coverage crown group were observed as nonrestorable (100%, 3 teeth). Teeth restored with resin composite had a greater restorability rate than those restored with crowns.

Discussion

According to our results, full-coverage crowns tended to achieve more desirable outcomes than direct resin composite restorations. This is consistent with the general recommendation for postendodontic restoration in posterior teeth (7). However, premolar ETT with 1 to 2 surface losses of tooth structure and the presence of 2 proximal contacts (adjacent teeth) were successfully restored with resin composite in this study. Our finding challenges the concept that postendodontic restoration should generally be a cuspal-coverage crown. The benefit of this finding is that direct resin composite can be used as a final restoration in some ETT when a substantial tooth structure remains. This conservative protocol can reduce treatment times as well as being more economic for the patient.

The survival rate increased because of the favorable conditions of those teeth. The more tooth structure that remains, the higher the expected survival rate (9, 14). Moreover, having 2 adjacent teeth might help in the distribution of occlusal forces and decrease occlusal stresses on the ETT (10, 17). Nevertheless, a cuspal coverage restoration is still recommended in premolar ETT with 3 to 4 surface tooth losses.

The remaining tooth structure is considered as a significant factor to resist fracture for ETT (9, 14). The result of the resin composite group in the present study was consistent with previous studies that reported the influence of the remaining tooth structure on fracture resistance of ETT (9, 14, 18). Premolars restored with resin composite restorations with 3 or more surface losses had a higher incidence of fracture than teeth with 1 or 2 surface losses. In the current study, the data of 1 and 2 surface losses and 3 and 4 surface losses were combined because of the small sample sizes in the groups for 1 and 4 surfaces. Nevertheless, the pooled data may not completely represent individual results. Increasing the sample sizes in future studies is recommended. The remaining walls were not defined for the crown group because such details were not recorded in the patient charts.

The number of proximal contacts (adjacent teeth) seems to be another positive factor for the survival rate against fracture; this also

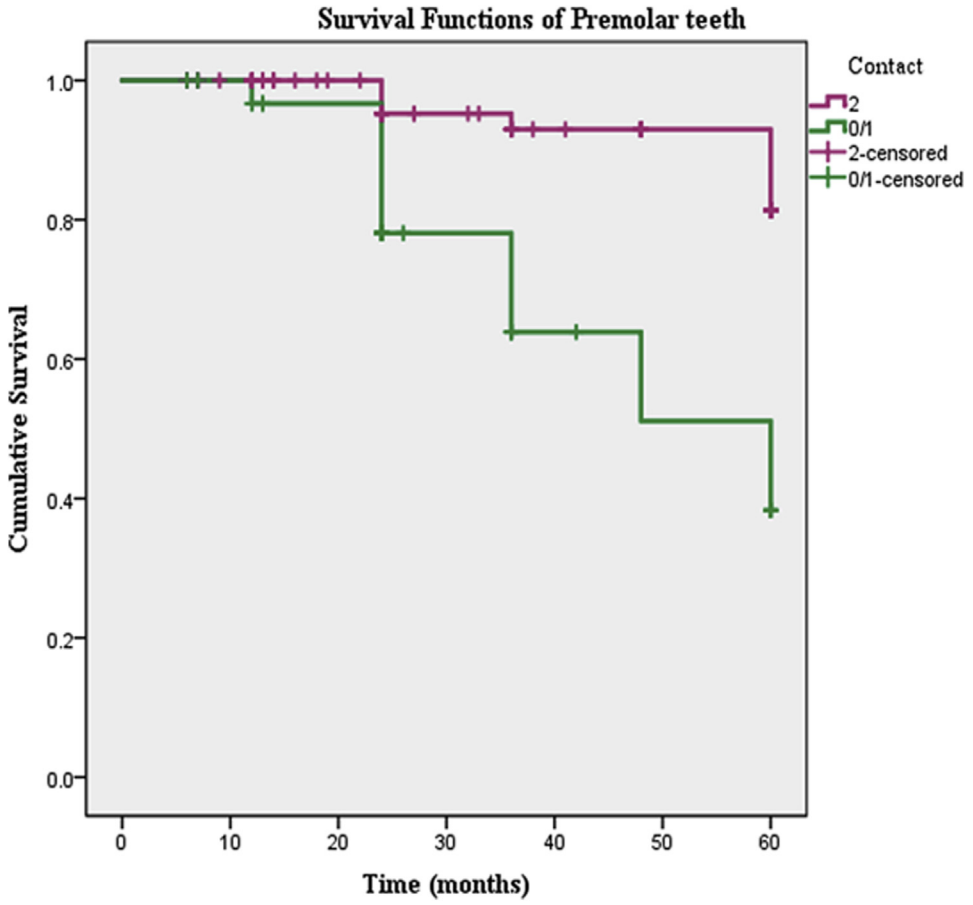

Figure 3. The Kaplan-Meier cumulative survival curve of premolar ETT according to the number of contacts.

agrees with the results of previous studies (10, 17, 19). The adjacent teeth distribute occlusal forces and decrease the stress on ETT. This can explain the high survival rate of resin composite restorations in ETT with 1 to 2 surface losses and 2 adjacent teeth, which was similar to the survival rate of crown restorations. According to another clinical study, 58% of ETT extracted because of fracture had 1 or no proximal contacts (19). Hence, the survival rate of fractured ETT with 2 proximal contacts tends to be better than the teeth with 1 or no contacts.

For the fracture pattern and restorability of ETT, a high incidence of tooth fracture was observed in this study. Fracture of tooth structure (or in combination with a restoration) is a major concern, resulting in less remaining tooth structure for a new restoration or leading to an unrestorable condition. In contrast, restoration fracture is usually restorable and can be repaired or replaced. A greater number of restorable teeth was observed in those ETT restored with resin composite compared with full-coverage crowns. This is consistent with the fracture pattern of resin composite that was typically presented with tooth structure and/or restoration fracture. In contrast, the majority of fractures in the crowns were root fractures that were nonrestorable. The high restorability rate after fracture of resin composite–restored teeth may be explained by the fact that ETT are more likely to fracture in the coronal portion because of adhesive failure between the restoration and tooth structure (20). This leads to a fracture of the coronal tooth structure and/or resin composite, rather than a radicular fracture. In contrast, the fracture pattern of full-coverage crowns typically presented as vertical root fractures. This might be caused by the high vertical/lateral forces being distributed onto the root portion of the tooth via the crown (21, 22). Improper post placement weakens the roots and promotes fracture and is another factor that needs further study (3, 22).

TABLE 3. Multivariate Cox Proportion Hazards Model Analysis of Premolar Endodontically Treated Teeth

Variables	Hazard ratio* (95% CI)	*P* value
Sex		
Male vs female	5.253 (1.805–15.288)	**.002**†
Location		
Mandible vs maxilla	1.667 (0.611–4.545)	.318
Restoration		
Composite vs crown	13.011 (3.215–52.651)	**.000**†
Contact		
0/1 vs 2	8.690 (2.753–27.437)	**.000**†

*Hazard survival analysis was used to evaluate the effect of factors on the survival rate from fracture. The hazard ratio describes the relative risk of the factors based on a comparison of survival rates from fracture.

†A significant difference is indicated by Cox regression analysis ($\alpha = 0.05$).

In this study, sex was also a significant factor associated with the survival rate against fracture. A high incidence of fracture in premolar ETT was observed in male patients, which may be related to sex-related risk factors such as a stronger masticatory force or a tendency to consume harder food (23, 24).

The number of fractured teeth in this study was not high (14 teeth for resin composite and 3 teeth for crowns). The ability to identify risk factor(s) is limited because of the small numbers observed. Therefore, increasing the overall number of subjects is planned for a further study.

TABLE 4. A Comparison of Survival Rates from Fracture of the Premolar Endodontically Treated Teeth Restored with Resin Composite and Crowns according to the Different Tooth Structure Loss and the Number of Contacts

Restoration type	Proportion of tooth fracture (fracture/all teeth)	Survival rate (%)	*P* value
Crown	3/61	95.1	
Resin composite with 1-2 surface losses vs crown			
0/1 contact	3/10	70.0	**.000***
2 contacts	3/26	88.5	.278
Resin composite with 3-4 surface losses vs crown			
0/1 contact	5/7	28.6	**.000***
2 contacts	3/18	83.3	**.033***

*A significant difference is indicated by log-rank test ($\alpha = 0.05$): compared the survival rate from fracture between the types of restorations.

In summary, the survival rates of full-coverage crowns in relation to fracture were higher than those for direct resin composite restorations in premolar ETT. However, premolar ETT might be successfully restored with resin composite as a final restoration under specific conditions. Premolar ETT with no more than 1 to 2 surface losses of tooth structure and with 2 proximal contacts from adjacent teeth had an acceptable survival rate from fracture that was similar to premolar ETT restored with full-coverage crowns (88.5% vs 95%, respectively). However, degradation of adhesion between resin composite and the tooth structure leading to coronal leakage remains a long-term concern. A randomized controlled clinical trial of postendodontic restorations in ETT should be conducted to confirm the benefits of these clinical findings.

Conclusions

The present study showed a higher fracture survival rate of premolar ETT restored with full-coverage crowns than resin composite. However, ETT restored with resin composite with 1 to 2 tooth surface losses and 2 proximal contacts showed survival rates comparable with teeth restored with crowns.

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

References

1. Panitvisai P, Messer HH. Cuspal deflection in molars in relation to endodontic and restorative procedures. J Endod 1995;21:57–61.
2. Reeh ES, Douglas WH, Messer HH. Stiffness of endodontically-treated teeth related to restoration technique. J Dent Res 1989;68:1540–4.
3. Fuss Z, Lustig J, Tamse A. Prevalence of vertical root fractures in extracted endodontically treated teeth. Int Endod J 1999;32:283–6.
4. Vire DE. Failure of endodontically treated teeth: classification and evaluation. J Endod 1991;17:338–42.
5. Safavi KE, Dowden WE, Langeland K. Influence of delayed coronal permanent restoration on endodontic prognosis. Endod Dent Traumatol 1987;3:187–91.
6. Uranga A, Blum JY, Esber S, et al. A comparative study of four coronal obturation materials in endodontic treatment. J Endod 1999;25:178–80.
7. American Association for Endodontists. Restoration of endodontically treated teeth: the endodontist's perspective: part I. 2004. Available at: http://www.aae.org/uploadedfiles/publications_and_research/endodontics_colleagues_for_excellence_newsletter/ss04ecfeforweb.pdf. Accessed November 29, 2017.
8. Sorensen JA, Martinoff JT. Intracoronal reinforcement and coronal coverage: a study of endodontically treated teeth. J Prosthet Dent 1984;51:780–4.
9. Nagasiri R, Chitmongkolsuk S. Long-term survival of endodontically treated molars without crown coverage: a retrospective cohort study. J Prosthet Dent 2005;93:164–70.
10. Aquilino SA, Caplan DJ. Relationship between crown placement and the survival of endodontically treated teeth. J Prosthet Dent 2002;87:256–63.
11. Xie KX, Wang XY, Gao XJ, et al. Fracture resistance of root filled premolar teeth restored with direct composite resin with or without cusp coverage. Int Endod J 2012;45:524–9.
12. Mincik J, Urban D, Timkova S, Urban R. Fracture resistance of endodontically treated maxillary premolars restored by various direct filling materials: an *in vitro* study. Int J Biomater 2016;2016:9138945.
13. Mannocci F, Bertelli E, Sherriff M, et al. Three-year clinical comparison of survival of endodontically treated teeth restored with either full cast coverage or with direct composite restoration. J Prosthet Dent 2002;88:297–301.
14. Dammaschke T, Nykiel K, Sagheri D, Schafer E. Influence of coronal restorations on the fracture resistance of root canal-treated premolar and molar teeth: a retrospective study. Aust Endod J 2013;39:48–56.
15. Dietschi D, Bouillaguet S, Sadan A. Restoration of the endodontically treated tooth. In: Dietschi D, Bouillaguet S, Sadan A, eds. *Cohen's Pathways of the Pulp*, 10th ed.; 2011:777–807.
16. Bursac Z, Gauss CH, Williams DK, Hosmer DW. Purposeful selection of variables in logistic regression. Source Code Biol Med 2008;3:17.
17. Caplan DJ, Weintraub JA. Factors related to loss of root canal filled teeth. J Public Health Dent 1997;57:31–9.
18. Reeh ES, Messer HH, Douglas WH. Reduction in tooth stiffness as a result of endodontic and restorative procedures. J Endod 1989;15:512–6.
19. Ng YL, Mann V, Gulabivala K. A prospective study of the factors affecting outcomes of non-surgical root canal treatment: part 2: tooth survival. Int Endod J 2011;44:610–25.
20. De Munck J, Van Landuyt K, Peumans M, et al. A critical review of the durability of adhesion to tooth tissue: methods and results. J Dent Res 2005;84:118–32.
21. Chan CP, Lin CP, Tseng SC, Jeng JH. Vertical root fracture in endodontically versus nonendodontically treated teeth: a survey of 315 cases in Chinese patients. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1999;87:504–7.
22. Tamse A. Vertical root fractures in endodontically treated teeth: diagnostic signs and clinical management. Endod Topics 2006;13:84–94.
23. Chan CP, Tseng SC, Lin CP, et al. Vertical root fracture in nonendodontically treated teeth–a clinical report of 64 cases in Chinese patients. J Endod 1998;24:678–81.
24. Yang SF, Rivera EM, Walton RE. Vertical root fracture in nonendodontically treated teeth. J Endod 1995;21:337–9.