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ORIGINAL ARTICLE

Endodontically posterior crown fracture

Endodontically treated posterior teeth restored with or without crown restorations: A 5-year retrospective study of survival rates from fracture

Titalee Jirathanyanatt[1] | Warattama Suksaphar[1,2] | Danuchit Banomyong[1] | Yaowaluk Ngoenwiwatkul[3]

[1]Department of Operative Dentistry and Endodontics, Faculty of Dentistry, Mahidol University, Bangkok, Thailand

[2]Department of Endodontics, Faculty of Dentistry, Rangsit University, Pathum Thani, Thailand

[3]Department of Community Dentistry, Faculty of Dentistry, Mahidol University, Bangkok, Thailand

Correspondence
Danuchit Banomyong, Department of Operative Dentistry and Endodontics, Faculty of Dentistry, Mahidol University, Bangkok, Thailand.
Email: danuchit.ban@mahidol.ac.th

Funding information
Faculty of Dentistry, Mahidol University, Thailand.

Abstract

Aim: The aim of the present study was to investigate survival rates from fracture of endodontically treated posterior teeth (ETT) restored with or without crowns with recall periods of up to 5 years.

Methods: ETT with single-unit crown or resin composite restorations were studied based on the inclusion criteria. Restoration, tooth structure loss, adjacent teeth, fracture, and restorability were recorded. Survival rates from fracture were calculated, and risk factors were identified.

Results: Overall, survival rate of ETT with crowns (92.2%) was significantly higher than resin composites (77.4%) ($P < 0.05$). ETT with one or two surface loss/es and two adjacent teeth had a high survival rate of 86.9%, which was not significantly different to ETT with crowns ($P \geq 0.05$). Restoration and adjacent teeth were identified as significant factors. The majority of fractured ETT with resin composites were restorable, whereas those with crowns were unrestorable. Survival rates from unrestorable fracture were not significantly different between the crown (93.1%) and resin composite (96%) ($P \geq 0.05$).

Conclusions: The survival rate from the fracture of ETT restored with crowns was significantly higher than ETT restored with resin composites, but was not significantly different to ETT with one or two ETT with one or two surface loss/es and two adjacent teeth. ETT restored with resin composites had mostly restorable fracture, whereas ETT with unrestorable fracture were similar between the two restorations.

KEYWORDS

crown, endodontically treated posterior teeth, resin composite, survival rate, tooth fracture

1 | INTRODUCTION

Fracture of endodontically treated posterior teeth (ETT) is associated with the amount of remaining tooth structure.[1,2] ETT are weakened by the loss of tooth structure from dental caries, tooth fracture, or pre-existing restoration, but not from endodontic procedures.[3] With a significant loss of tooth structure, ETT should receive a cuspal-coverage restoration to prevent unrestorable fracture.[4,5] ETT restored with crowns within 4 months had a significantly higher survival rate than ETT with delayed restoration placement.[5]

A recent systematic review found that ETT with minimal-to-moderate loss of tooth structure can be restored with direct resin composite restorations,[6] with the survival rate against fracture found to be as high as ETT restored with crowns. According to a randomized

control trial at 3-year recall, the clinical success of ETT with one or two proximal surface loss/es and restored with fiber post/resin composite was similar to teeth restored with crowns.[7]However, the results from the trial were limited to premolars.[7] Survival from fracture in molars or teeth with moderate-to-severe loss of tooth structure has been questioned.[2] As noted in the Cochrane Database Systematic Reviews, the benefit of crown placement remains unclear and requires more clinical evidence.[8]

The incidence of fracture of ETT is most likely associated with risk factors, such as tooth type/location, remaining tooth structure (tooth loss), adjacent teeth (contact), restoration type, and use of a post.[1,2,4,9,10] If restored with posts and crowns, ETT with circumferential or partial ferrule tend to better resist lateral force and are less likely to be fractured than those without ferrule.[1,11] Ferrule at a height of 1-2 mm, either complete or partial, has a positive effect on fracture strength of ETT.[11] ETT have a higher risk of tooth fracture with a lower remaining coronal structure.[12] If restored with resin composites, ETT with more surrounding tooth structure to support the restoration tend to be less fractured.[2,6]

The fracture of ETT can be categorized as restorable and unrestorable.[6] ETT with restorable fracture can be repaired or replaced with a restoration; either a resin composite or crown. In contrast, ETT with unrestorable fracture requiring tooth extraction are more critical and should be prevented. The impact of these two fracture types is markedly different and should be carefully considered.

Therefore, the purpose of the present retrospective study was to compare survival rates from the overall (restorable and unrestorable) fracture of ETT restored with either direct resin composite restorations or full-coverage crowns at a recall period of up to 5 years. Survival rates from unrestorable fracture were also compared between the two restorations. For ETT with resin composites, tooth structure loss could be categorized and further analyzed. In addition, risk factors associated with survival from fracture were identified.

2 | MATERIALS AND METHODS

The present retrospective study was approved by the Institutional Review Board of the Faculty of Dentistry/Faculty of Pharmacy, Mahidol University, Bangkok, Thailand (MU-DT/PY-IRB 2016/032.0508).

Data were searched and collected from the dental records of patients from the postgraduate clinic during 2012-2016. ETT with single-unit restorations were selected based on the inclusion criteria: (a) with mature root formation; (b) restored with direct resin composite or crown; and (c) had at least one opposing tooth. The exclusion criteria were: (a) extracted for endodontic or periodontal reasons; (b) with alveolar bone loss greater than half the root length; and (c) a history of cracks or root fracture.

Operators and endodontic and restorative protocols were identified from the dental records. In brief, endodontic treatments were performed under rubber dam isolation by undergraduate students supervised by instructors who were specialist endodontists. After access opening, root canals were shaped using stainless steel hand files with a crown-down technique, and irrigated with 2.5% sodium hypochlorite and 17% ethylenediaminetetraacetic acid. The root canals were medicated with calcium hydroxide paste before being obturated with gutta percha cones and zinc oxide eugenol sealer using the lateral compaction technique up to 1-2 mm below the canal orifices.

Coronal restorations were either direct resin composite restorations or full-coverage crowns. If the prognosis was favorable and the patients could afford the cost, crown restorations were placed. If the prognosis was questionable or the patients could not afford the cost, resin composite restorations were placed, and the patients were informed risk of fracture. The majority of coronal restorations were provided by undergraduate students supervised by instructors who were specialist prosthodontists.

For resin composite restorations, the resin composite was placed without a post. Most of the cavities were based with a glass ionomer cement liner (GC Fuji VII; GC, Tokyo, Japan) at a thickness of 1-2 mm. In the majority of cases, a light-cured resin composite (Z250; 3M ESPE, St Paul, MN, USA) was bonded with an etch-and-rinse adhesive (Adper Single Bond 2; 3M ESPE, USA).

For full-coverage crown restorations, the restored teeth were prepared and an impression was taken for crown fabrication. Crowns (porcelain fused to metal for the majority) were inserted and cemented with a resin-based cement. If indicated, cast metal or prefabricated fiber posts (DT Light Post; BISCO, Schaumburg, IL, USA) were used and cemented with a resin-based cement.

Information and potential predisposing factors were collected, including sex, tooth type (premolar or molar), tooth location (upper or lower), restoration type, and number of adjacent teeth (contact). For the resin composite group, the amount of tooth structure loss was identified from dental records and/or radiographs, and categorized into 1-4 of the surfaces lost. For the crown group, the amount of tooth structure loss was not recorded in the majority of dental charts and could not be accurately identified from radiographs. If a post was present, the type of post was recorded. The incidence of recurrent caries formation at the restorative margins of resin composites or crowns were identified from dental records and/or radiographs.

The incidence of fracture, fracture type, and restorability were identified. Fracture types were tooth structure (coronal and/or radicular), restoration, or combination fracture. Restorability after fracture was classified as restorable or unrestorable.

2.1 | Statistical analysis

The survival times of ETT without the incidence of overall (restorable and unrestorable) and only unrestorable fracture were calculated using the Kaplan-Meier survival analysis. The survival rates of ETT restored with or without crown restorations were compared using the log-rank test. Univariate analysis was used to initially identify any potential risk factors, and multivariate analysis was then used to identify potential risk factors ($P \leq 0.25$).[13] Cox

proportional hazards models were used to evaluate the potential risk factors at a significance level of $P < 0.05$.

3 | RESULTS

3.1 | Data distribution and survival analysis

Data distribution of the 226 ETT studied are presented in Table 1. The data were obtained from 56 males and 170 females aged between 16 and 81 years. ETT restored with resin composites included 124 teeth in 61 premolars and 63 molars, and those with crowns included 102 teeth in 61 premolars and 41 molars. The follow-up period ranged from 6 to 60 months, with a mean recall of 32 months.

ETT restored with resin composite restorations were categorized following the tooth surface loss into one (N = 12 teeth), two (N = 69 teeth), three (N = 32 teeth), and four surfaces (N = 11 teeth). ETT with crowns were without post (N = 17 teeth), with prefabricated fiber posts (N = 36 teeth), and with cast metal posts (N = 49 teeth). The number of teeth with recurrent caries at the restorative margins were similar between the two groups: three teeth (3/124, 2.42%) in the resin composite group and two teeth (2/102, 1.96%) in the crown group.

Overall, the survival rate from fracture in ETT was 190/226 ETT (84.1% survival) (Table 1). Survival rates from fracture of ETT restored with resin composite restorations and crowns were 77.4% and 92.2%, respectively. For ETT with resin composite restorations, the numbers of fractured teeth were as follows: one surface (N = 1 tooth, 8.3%), two surfaces (N = 14 teeth, 20.3%), three surfaces (N = 11 teeth, 30.6%), and four surfaces (N = 2 teeth, 18.2%). The fracture rate of ETT with a loss of two marginal ridges at 37.5% was higher than those of ETT with no loss or a loss of one marginal ridge at 19.7%-31.3%.

3.2 | Associated risk factors of survival rate from fracture

The potential risk factors of survival rate from fracture are presented in Table 1. The restoration type and adjacent teeth were significant risk factors ($P < 0.05$). ETT restored with resin composite restorations had a higher risk of fracture; 3.9 times greater than ETT with crowns (hazard ratio [HR]: 3.91, 95% confidence interval [CI]: 1.76-8.68, $P < 0.05$). ETT with one adjacent tooth or no adjacent tooth had a 2.2 times higher risk of fracture than those with two adjacent teeth (HR: 2.22, 95% CI: 1.10-4.49, $P < 0.01$). Survival rates of premolars and molars were not significantly different ($P \geq 0.05$), so the teeth were considered and further analyzed as the same unit of ETT.

Kaplan-Meier survival curves of ETT according to the restoration type are presented in Figure 1A. As seen in the survival analysis at each time interval, the survival rates at 6 and 12 months were similar between the two restoration types ($P \geq 0.05$) (Table 2). At 24, 36, and 48 months, the resin composite group showed significantly lower survival rates than the crown group ($P < 0.05$). However, the survival rates were not significantly different at 60 months ($P \geq 0.05$).

TABLE 1 Data distribution of the 226 recruited endodontically treated posterior teeth according to the possible predisposing factors: number of teeth with or without fracture, *P*-values, and hazard ratios from the univariate and multivariate analyses

				Univariate analysis	Multivariate analysis	
Variables	No. teeth (%)	Teeth with fracture	Teeth without fracture	*P*-value*	Hazard ratio[a] (95% CI)	*P*-value[b]
Sex						
Female	170 (75.2)	21 (12.4)	149 (87.6)	0.246	1.414 (0.69, 2.87)	0.339
Male	56 (24.8)	15 (26.8)	41 (73.2)			
Tooth type						
Premolar	122 (54.0)	17 (13.9)	105 (86.1)	0.372	—	—
Molar	104 (46.0)	19 (18.3)	85 (81.7)			
Location						
Maxilla	101 (44.7)	11 (10.9)	90 (89.1)	0.045	1.671 (0.79, 3.52)	0.178
Mandible	125 (55.3)	25 (20.0)	100 (80.0)			
Restoration type						
Crown	102 (45.1)	8 (7.8)	94 (92.2)	0.002	3.917 (1.76, 8.68)	<0.01
Resin composite	124 (54.9)	28 (22.6)	96 (77.4)			
Contact (adjacent teeth)						
2	160 (70.8)	18 (11.3)	142 (88.8)	0.007	2.224 (1.10, 4.49)	0.026
0/1	66 (29.2)	18 (27.3)	48 (72.7)			

[a]Hazard survival analysis was used to evaluate the relative risk of the factors, based on comparison of fracture survival rates.
[b]Log-rank test compared survival rates between the factors; variables with $P < 0.25$ in the univariate model were further analyzed in the multivariate model.

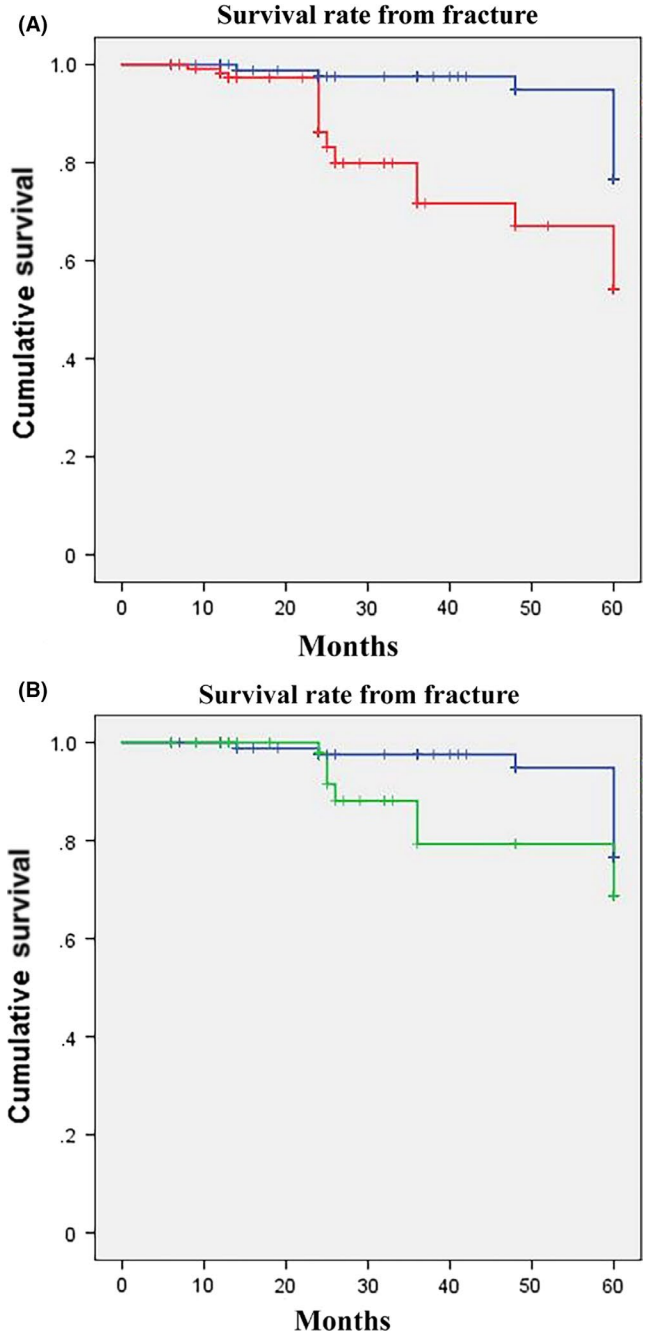

FIGURE 1 (A) Kaplan-Meier survival curves of endodontically treated posterior teeth (ETT) from overall (restorable and unrestorable) fracture according to the two restorative groups. At the 5-year recall period, the cumulative survival rates from fracture of ETT restored with resin composite restorations and full-coverage crowns were 77.4% and 92.2%, respectively, which were significantly different ($P < 0.05$). , ETT with crown; , ETT with composite. (B) Kaplan-Meier survival curves of ETT restored with resin composite restorations, with one or two surface losses and two adjacent teeth, and ETT restored with crowns. At the 5-year recall period, the cumulative survival rates from fracture (86.9% and 92.2%, respectively) were not significantly different between the two groups ($P \geq 0.05$). , ETT with crown; , ETT (1-2 surface loss and 2 adjacent teeth) with composite

3.3 | Subgroup analysis of endodontically treated posterior teeth restored with resin composite restorations

ETT restored with resin composite restorations were further analyzed according to tooth structure loss and adjacent teeth, as shown in Table 3. The survival rate for the ETT with one or two surface loss/es and two adjacent teeth was highest and not significantly different to ETT with crowns ($P \geq 0.05$). With one adjacent tooth or no adjacent tooth, the survial rate of ETT with one or two surface loss/es significantly decreased ($P < 0.05$). Survival rates in ETT with three or four surface losses were significantly lower than ETT with crowns ($P < 0.05$), regardless of adjacent teeth. Kaplan-Meier survival curves of ETT with one or two surface loss/es and two adjacent teeth restored with resin composites and those restored with crowns are presented in Figure 1B.

The incidence of fracture, fracture type, and restorability after fracture are presented in Table 4. The highest fracture was tooth structure fracture at 75% and 42.9% in the crown group and the resin composite group, respectively. For restorability after fracture, 23 of 28 fractured ETT with resin composite restorations (82.1%) were restorable, whereas seven of eight fractured ETT with crowns (87.5%) were unrestorable. ETT restored with resin composite restorations had a higher restorability rate than those restored with crowns. As seen in the Kaplan-Meier survival curves plot (Figure 2), the cumulative survival rates from unrestorable fracture of ETT restored with resin composite restorations and full-coverage crowns were 96% and 93.1%, respectively, and were not significantly different ($P \geq 0.05$).

4 | DISCUSSION

In the present study, the survival rate from overall fracture in ETT restored with full-coverage crowns was higher than those restored with resin composite restorations. The outcome was consistent with the results of other studies that showed that ETT with a significant loss of tooth structure should be restored with crowns.[4,5]

Based on the subgroup analysis, our results indicated that ETT with one or two surface loss/es and with two adjacent teeth could be permanently restored with resin composite restorations. This result is in agreement with a randomized controlled trial of restored premolar ETT with two or three surface losses.[7] The more tooth structure that remains, the greater the expected survival rate from fracture.[2,7,14] Moreover, two adjacent teeth helps in stress distribution from occlusal forces on ETT.[15-17] In a retrospective study, ETT were found to be more frequently fractured when the teeth had only one adjacent tooth or no adjacent tooth.[18] Our study demonstrated that ETT with three surfaces or more resin composite restorations, regardless of adjacent teeth, had a high incidence of fracture and should be restored with crowns.

For the ETT restored with resin composite, the fracture rate of the teeth with a loss of two marginal ridges was higher than the teeth with no loss or a loss of one marginal ridge. The marginal ridge

TABLE 2 Endodontically treated posterior teeth (ETT) that survived fracture, and log-rank analysis at each time interval

Restoration	No. (%) ETT that survived fracture at each time interval (months)						
	6	12	24	36	48	60	Total
Crown	7 (100)	15 (93.8)	28 (96.6)	13 (100)	10 (90.0)	21 (80.8)	94 (92.2)
Composite	7 (87.5)	23 (92.0)	35 (71.4)	7 (63.6)	3 (60.0)	21 (80.8)	96 (77.4)
P-value[a]	0.35	0.84	<0.01	0.02	0.16	1.00	<0.01

[a]Log-rank test (with a level of significance at $P < 0.05$) compared survival rates at each time interval.

TABLE 3 Survival rates from fracture of endodontically treated posterior teeth (ETT) restored with resin composite restorations according to tooth structure loss and contact (adjacent teeth) compared with ETT restored with crowns

Restoration	Proportion of tooth fracture (fracture/all teeth)	Survival rate (%)	*P*-value[a]
Crown	8/102	92.2	—
Resin composite with 1-2 surfaces loss vs crown			
0/1 contact(s)	7/20	65.0	<0.01
2 contacts	8/61	86.9	0.20
Resin composite with 3-4 surfaces loss vs crown			
0/1 contact(s)	6/12	50.0	<0.01
2 contacts	7/31	77.4	<0.01

[a]Log-rank test ($P < 0.05$) compared survival rates from fracture between the resin composite subgroup and the crown group.

TABLE 4 Number and type of fracture and restorability after fracture of endodontically treated posterior teeth according to restoration type

Type of restoration	No. fracture	Type of fracture			Restorability	
		Tooth structure	Restoration	Combination	Restorable	Unrestorable
Crown	8	6 (75.0)	1 (12.5)	1 (33.3)	1 (12.5)	7 (87.5)
Composite	28	12 (42.9)	9 (32.1)	7 (25.0)	23 (82.1)	5 (17.9)

is crucial for the structural integrity to prevent cuspal deflection.[19,20] The loss of marginal ridges is strongly associated with the loss of strength in posterior teeth.[19,21] Our result demonstrated the importance of the amount, as well as the location, of tooth structure loss on survival from fracture.

The ferrule effect of remaining cervical dentin is important to increase the longevity of ETT with crown restorations.[1,22] Fracture resistance of ETT restored with resin composite restorations might be also affected by the ferrule.[23] In our study, the number and location of tooth surface losses were obtained in the resin composite group, but were not identified in the crown group. Therefore, a direct comparison between the two restoration types with a similar amount of remaining tooth structure (or ferrule) was not possible and should be further investigated.

The number of ETT with restorable fracture was higher in ETT restored with resin composite restorations compared with crowns. In our study, the fracture of ETT with resin composite restorations mostly presented as coronal fracture at or above the gingival area. The fracture is expected to occur at the adhesive interfaces between the restoration and tooth structure.[24] In contrast, the fracture of ETT with crowns mostly presented in the radicular portion as root fracture. With a rigid restoration, high occlusal forces are likely to distribute onto the roots,[25,26] and this might induce a formation of root fracture. In addition, post-space preparation might reduce root strength and increase the chance of root fracture.[26,27]

From a clinical point of view, we propose that ETT can be restored with resin composite restorations without further crown placement. ETT with or without crown restorations had a similar high survival rate at 5 years from unrestorable fracture at 93%-96%; only a few ETT required tooth extraction due to the fracture with a low annual failure rate of approximately 0.8%-1.4%. In addition, the chance of restorable fracture occurring was 18.5% in the ETT without cuspal coverage restoration, but fractured teeth could be still repaired or replaced with a new restoration.

ETT restored with crowns tends to present more tooth structure loss than ETT restored only with resin composite restorations. In the present study, the majority of ETT in the resin composite group presented with two or three surfaces losses. This confounding factor might reduce the chance of fracture in the resin composite group. This effect should be further investigated in a randomized control trial.

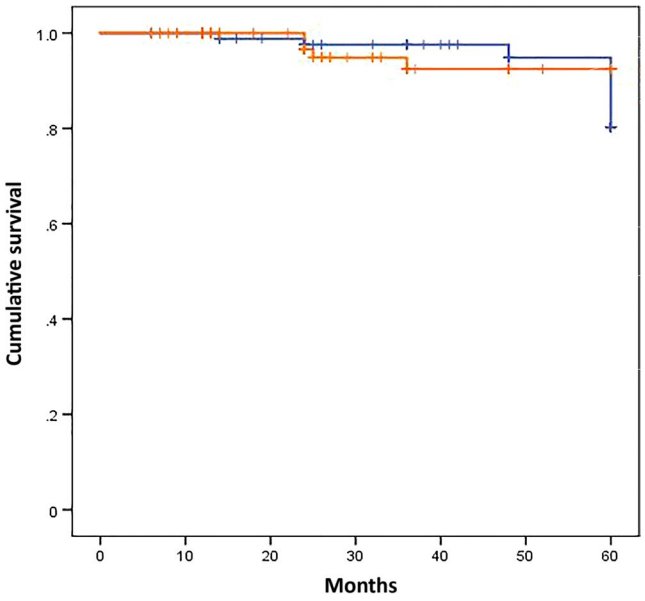

FIGURE 2 Kaplan-Meier survival curves of endodontically treated posterior teeth (ETT) from unrestorable fracture according to the two restorative groups. At the 5-year recall, the cumulative survival rates from unrestorable fracture of ETT restored with resin composite restorations and full-coverage crowns were 96% and 93.1%, respectively, which were not significantly different ($P \geq 0.05$). Restoration type: ⌐¬, Crown; ⌐¬, Composite; ⊣⊢, Crown censored; ⊣⊢, Composite censored

As seen in the survival analysis, the survival rate from the fracture of ETT with resin composite restorations and crowns was similar at the 1-year recall. However, the differences in the survival rates began at the 2-year recall. ETT with interim restorations should be permanently restored with cusp-coverage restorations within the first year to reduce the risk of fracture.

Resin composite restorations increase the fracture strength because of their ability to bond to the tooth structure,[28,29] which supports the remaining cusps and reduces cuspal deflection.[19] Fracture resistance after restoration is likely to increase back to the level of the intact tooth. However, the long-term degradation of adhesion remains a concern. Hashimoto et al reported that the resin-dentine bond was degraded after 1-3 years in vivo.[30] As a result, the fracture strength might be reduced. This might explain the increased incidence of fracture in ETT restored with resin composite restorations at 2-3 years in our study.

As well as tooth fracture, recurrent caries also causes failure of ETT. Mannocci et al reported that approximately 10% of ETT (premolars) restored with direct resin composite restorations failed due to the formation of recurrent caries at the restorative margins.[31] However, the incidence of recurrent caries formation in our study was lower at 2%-2.5%, and was similar between the resin composite and crown restorations. In the present study, the patients who attended the follow-up appointments tended to cooperate with periodical recalls for routine check-ups and oral hygiene maintenance. It can be expected that these patients maintain their oral hygiene, which decreases the chance of recurrent caries formation. Oral hygiene maintenance might be key to the long-term success of ETT.

5 | CONCLUSION

The present retrospective study showed that the survival rate from overall fracture in ETT restored with full-coverage crowns was higher than resin composite restorations. ETT with only one or two tooth surfaces lost and with two adjacent teeth restored with resin composite restorations showed an overall survival rate similar to that of ETT with crowns. In addition, restoration type and adjacent teeth were identified as the significant predisposing factors associated with the incidence of fracture. Fracture in ETT with resin composite restorations are usually restorable and only require repair or replacement of the restorations. The survival rates of ETT from unrestorable fracture, which resulted in tooth extraction, were not significantly different between the two restorations.

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ORCID

Danuchit Banomyong https://orcid.org/0000-0003-3612-3830

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