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Survival Outcomes of Crowns with and without Repaired Endodontic Access Cavities: A Retrospective Propensity Score Matching Study

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ABSTRACT

Objective: This retrospective study aimed to compare the survival outcomes between crowns with repaired endodontic access cavities and intact crowns and to identify factors that influence restoration longevity.

Methods: Clinical records of patients who underwent root canal treatment through existing crowns (crowns with repaired access cavities, CRA) or received crowns after root canal treatment (intact crowns, IC) between 2012 and 2023 were analysed. A 1:1 propensity score matching was applied based on age, sex, tooth type, and crown type. The outcomes of the matched cases were classified as survival or non-survival. Kaplan–Meier analysis and log-rank tests were used to compare outcomes between the two groups over time. For CRA, multivariable Cox proportional hazards regression analysis was conducted to identify potential predisposing factors.

Results: Among 608 eligible endodontically treated teeth, 120 CRA and 488 IC met the inclusion criteria. After matching, 120 samples per group were analysed. The survival rate was significantly lower for CRA (85.8%) than for IC (91.7%) (p=0.004). Occlusal parafunctional habits or interferences were the only significant factors affecting CRA survival.

Conclusion: CRA demonstrated lower survival rates than IC, with occlusal parafunctional habits or interferences as key factors influencing their longevity.

Keywords: Dental crowns, dental prosthesis repairs, endodontically treated teeth, outcomes, survival rates

HIGHLIGHTS

- The survival rate of crowns with repaired endodontic access cavities was lower than that of intact crowns in propensity score-matched cases.
- The presence of occlusal parafunctional habits and interferences significantly impacted the longevity of repaired crowns.
- Understanding survival differences and key influencing factors can aid clinical decision-making and enhance long-term outcomes for post-endodontic restorations.

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INTRODUCTION

Endodontic treatment is occasionally required as a consequence of restorative procedures, particularly tooth preparation, which can pose risks to the dental pulp. Approximately 10% of teeth require endodontic therapy following full-coverage restorations (1). The combination of mechanical irritation during tooth preparation and dentin removal facilitates bacterial invasion, increasing the risk of infection and inflammation, which may require endodontic treatment (2). The survival rate of vital pulp in crowned teeth is approximately 80–90% over 10–25 years (3, 4). A systematic review identified the loss of pulp vitality as a common biological complication associated with metal-ceramic and all-ceramic single crowns (5). In some cases, root-filled teeth may require endodontic retreatment, often necessitating access through the existing crown due to persistent interradicular infections (6).

Managing pulpal or root canal complications in crowned teeth requires either replacing the restoration after treatment or repairing the access cavity through the existing crown (6). Treating through the existing crown can delay the need for a new restoration, improving patient satisfaction and cost-effectiveness (6). However, it can cause unnecessary loss of tooth structure, difficulty in locating canals, missed detection of cracks or fractures, and potential damage to the restoration to some extent (7). An *in vitro* study has indicated that endodontic access may compromise crown integrity and retention, increasing the risk of fractures or dislodgement (8). Although composite repairs yield clinically satisfactory outcomes (9–12), the absence of standardised guidelines and limited evidence regarding the survival of crowns in endodontically treated teeth (ETT) with repaired access cavities pose challenges for clinical decision-making.

A retrospective study reported survival rates of full-coverage restorations with composite-repaired endodontic access cavities as 82.7%, 71.5%, 67.3%, and 48.8% at 2, 5, 7, and 10 years, respectively (9). Other studies on ETT with repaired crowns reported survival rates of 51–99%, reflecting variations in study criteria and observation periods (10–12). Although studies have evaluated the survival of intact crowns in ETT (crowns without repaired access cavities), their findings remain inconsistent (13–15). No clinical study has directly compared the survival of repaired and intact restorations under uniform evaluation criteria, limiting understanding of how damage to existing restorations affects crown longevity in ETT.

Propensity score matching is a statistical method that minimises selection bias by balancing confounding variables between treatment groups, particularly in non-randomised controlled studies. Estimating the probability of treatment assignment based on observed covariates facilitates the comparison of groups with balanced characteristics (16). To date, no clinical studies on post-endodontic restoration survival have applied propensity score matching.

Apart from survival rates, tooth-related variables such as the amount of remaining tooth structure and cavity type; factors related to occlusal forces, including tooth type, tooth location, opposing dentition, and presence of parafunctional habits; and crown type may influence the longevity of restorations. However, these factors have not been thoroughly analysed in current studies (9–12).

This study aimed to evaluate the survival outcomes of crowns with repaired access cavities (CRA) compared with those of intact crowns (IC) using propensity score matching and to investigate potential factors influencing restoration longevity.

MATERIALS AND METHODS

Study Design

This retrospective observational study investigated the survival rates of dental crowns in ETT, comparing CRA and IC. CRA referred to restorations damaged by endodontic access cavities and subsequently repaired with direct restorations, whereas IC included crowns in ETT without access cavities. Data were collected from patients who underwent non-surgical endodontic treatment performed by postgraduate students or endodontists at the Endodontic Clinic, Mahidol University, between January 2012 and December 2023. For CRA, patients received root canal treatment performed through existing crowns, which were later repaired with direct restorations, and attended recall appointments within the study period. In IC cases, patients received dental crowns following the completion of initial root canal treatment or retreatment at the Main Clinic, Advanced General Dentistry Clinic, or Prosthodontic Clinic. Treatment was performed by undergraduate students, postgraduate students, or specialists, and patients attended recall appointments within the same timeframe. This study adhered to the guidelines and checklist of the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement (17) and the Preferred Reporting Items for Observational Studies in Endodontics (PROBE) 2023 guidelines (18). The study protocol was approved by the Ethics Committees of the Faculty of Dentistry and the Faculty of Pharmacy, Mahidol University, Institutional Review Board (Number: MU-DT/PY-IRB 2024/DT017). The study was conducted in accordance with the Declaration of Helsinki.

Sample Size Calculation

The required sample size was determined using data from previous research (9). A significance level of 0.05 and a statistical power of 0.8 were used for the calculation. The effect size proportion for CRA was estimated at 0.827. An allocation ratio of 1:1 between CRA and IC was established, with 27 cases in each group following the propensity score matching process.

Case Selection

Patient records were reviewed to determine their eligibility.

Inclusion Criteria

1. Dental records with sufficiently detailed and complete clinical and radiographic examinations.
2. A minimum follow-up period of at least 1 year after the final restoration was required. For CRA, this period began after the repair of access cavities with direct restorative materials. For IC, the follow-up period started after crown placement.

Exclusion Criteria

1. For CRA, where the existing restoration exhibited marginal leakage, secondary caries, or was not intact before the root canal treatment or during the endodontic procedure.
2. Teeth diagnosed with root fractures, cracks, or severe periodontal conditions classified as stage III or IV periodontitis based on the 2017 classification of periodontal and peri-implant diseases and conditions (19).
3. Teeth with procedural errors that compromised the structural integrity of the coronal or radicular tooth structure, such as crown or root perforation.
4. Teeth with incomplete root formation or root resorption.

Endodontic and Restorative Procedures

Endodontic and restorative procedures were performed under a dental operating microscope (Zeiss Surgical and Dental Microscopes, Carl Zeiss Meditec AG, Jena, Germany), following standard institute protocols as detailed in previous studies (13–15). The selection of direct restorative materials for CRA access cavity repair, including direct resin composite, glass

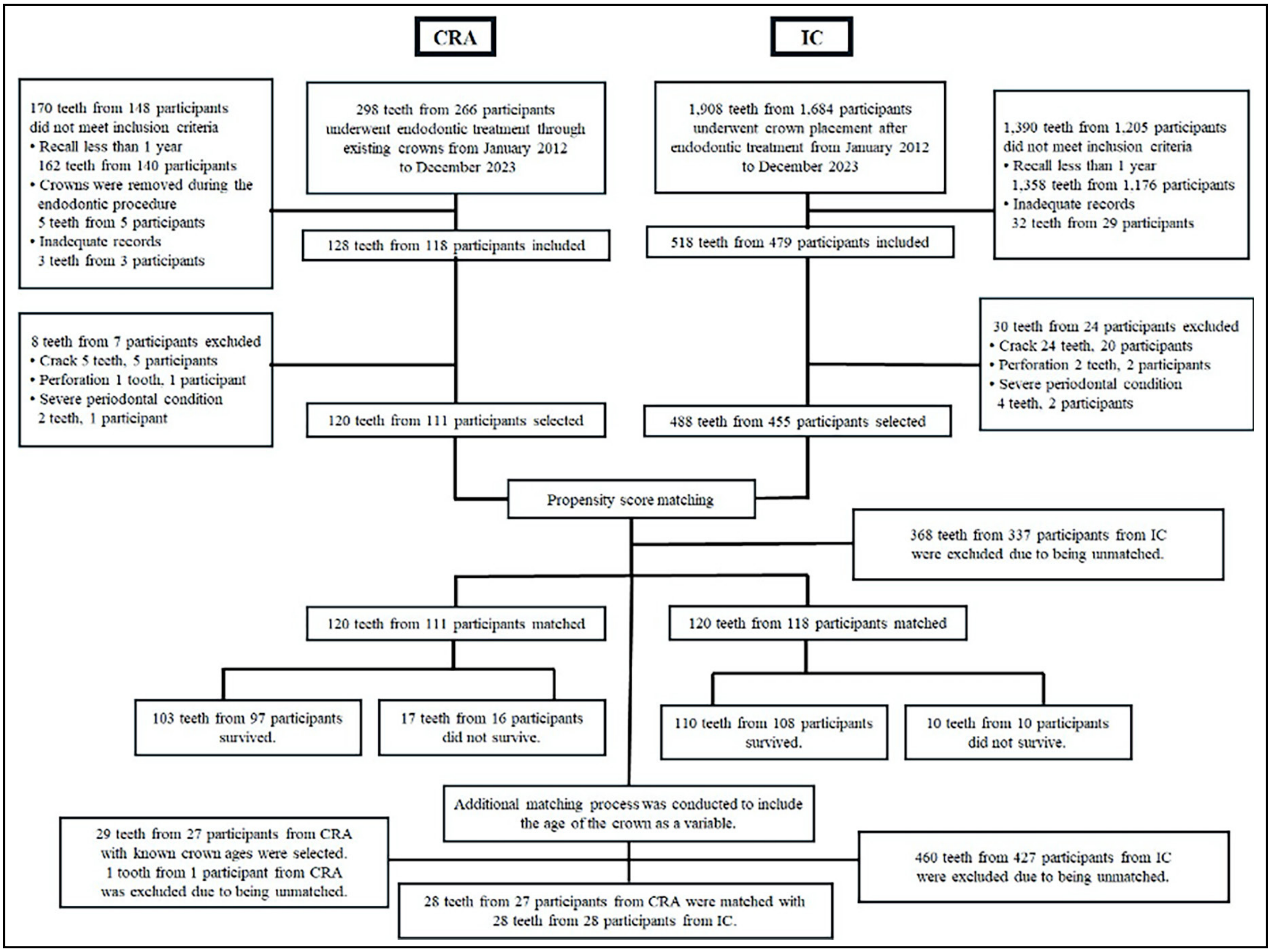

Figure 1. Flowchart illustrating sample inclusion and exclusion criteria.

CRA: Crowns with repaired access cavities, IC: Intact crowns.

ionomer cement combined with resin composite, core build-up, or post and core, was determined based on the operator's clinical judgment and case-specific considerations.

Data Collection

The following data were collected:

Demographic information including sex (male/female), age (years), crown placement date for IC and CRA (if available), and duration (months) following the repair of access cavities after endodontic treatment for CRA.

Clinical and radiographic information including tooth type (anterior/premolar/molar), tooth location (maxillary/mandibular), type of non-surgical root canal treatment (initial root canal treatment/root canal retreatment), crown type (full metal/porcelain-fused-to-metal [PFM]/ceramic), opposing dentition (natural tooth/fixed prosthesis/removable prosthesis), function as an abutment for prosthesis (none/dental bridge/removable prosthesis), presence of adjacent teeth (none/one side/two sides), occlusal parafunctional habits or occlusal interferences (yes/no), operator (postgraduate student/qualified endodontist), and direct restorative material for repairing access cavities in CRA (amalgam/resin composite/core/post and core).

Outcome Assessment

Outcomes were classified as survival or non-survival as follows: Survival was defined as the retention of the crown with an intact substructure, no signs of loosening or fracture, and no fractures in the natural teeth or root structure. Teeth with porcelain chipping or marginal leakage due to dental caries were classified as surviving cases.

Non-survival included cases where the crown became loose, dislodged, or structurally compromised due to fracture. This category also encompassed instances where a fracture resulted in the destruction of the natural teeth or root structure. For non-surviving cases, additional information was gathered, including the fracture pattern (restoration dislodgement/restoration fracture/tooth fracture/restoration-tooth fracture), restorability (restorable/non-restorable), and the treatment provided (e.g., crown replacement/extraction).

Statistical Analysis

Data analysis was conducted using SPSS v.22 for Windows (SPSS Inc., Chicago, IL, USA) and STATA 17 (StataCorp LLC, College Station, TX, USA). Statistical significance was set at $p<0.05$. Numerical data are presented as means and standard deviations (SDs)

TABLE 1. Characteristics and distribution of ETT before and after propensity score matching

Factors	Total population				Propensity score-matched pairs			
	CRA (n=120)	**IC (n=488)**	**p value**	**ASD**	**CRA (n=120)**	**IC (n=120)**	**p value**	**ASD**
Age (years) (mean±SD, median [IQR])	61.4±13.0 63 [54–71]	56.2±13.0 59 [49–65]	**<0.001**†	0.403	61.4±13.0 63 [54–71]	61.2±12.2 63.5 [56.5–69]	0.894†	0.017
Sex, n (%)			0.500ʃ	0.068			0.896ʃ	0.017
Male	52 (43.3)	195 (38.6)			52 (43.3)	51 (42.5)		
Female	68 (56.7)	293 (61.4)			68 (56.7)	69 (57.5)		
Tooth type, n (%)			**0.032**ʃ	0.255			0.957ʃ	0.024
Anterior	15 (12.5)	87 (17.8)			15 (12.5)	15 (12.5)		
Premolar	33 (27.5)	173 (35.5)			33 (27.5)	35 (29.2)		
Molar	72 (60.0)	228 (46.7)			72 (60.0)	70 (58.3)		
Crown type, n (%)			**<0.001**ʃ	0.447			0.959ʃ	0.036
Full metal	35 (29.2)	84 (17.2)			35 (29.2)	33 (27.5)		
PFM	82 (68.3)	344 (70.5)			82 (68.3)	84 (70.0)		
All-ceramic	3 (2.5)	60 (12.3)			3 (2.5)	3 (2.5)		
	CRA (n=29)	**IC (n=488)**	**p value**	**ASD**	**CRA (n=28)**	**IC (n=28)**	**p value**	**ASD**
Crown age (months) (mean±SD, median [IQR])	86.7±43.5 80 [53–115.5]	41.9±31.5 30.5 [19–55]	**<0.001**†	1.179	84.8±43.0 78.5 [53–106]	82.6±49.9 70 [55–134.5]	0.860†	0.048
Age (years) (mean±SD, median [IQR])	63.2±8.0 62 [57–69.5]	56.2±13.0 59 [49–65]	**0.004**†	0.651	63.1±8.1 62 [57–69.75]	62.3±10.2 63 [55–69.5]	0.719†	0.097
Sex, n (%)			0.879ʃ	0.029			0.783ʃ	0.072
Male	12 (41.4)	195 (38.6)			11 (39.3)	10 (35.7)		
Female	17 (58.6)	293 (61.4)			17 (60.7)	18 (64.3)		
Tooth type, n (%)			0.522ʃ	0.222			0.370ʃ	0.050
Anterior	3 (10.3)	87 (17.8)			3 (10.7)	4 (14.3)		
Premolar	10 (34.5)	173 (35.5)			10 (35.7)	9 (32.1)		
Molar	16 (55.2)	228 (46.7)			15 (53.6)	15 (53.6)		
Crown type, n (%)			0.629ʃ	0.158			0.943ʃ	0.065
Full metal	7 (24.2)	84 (17.2)			6 (21.4)	5 (17.9)		
PFM	19 (65.5)	344 (70.5)			19 (67.9)	20 (71.4)		
All-ceramic	3 (10.3)	60 (12.3)			3 (10.7)	3 (10.7)		

Bold values indicate statistical significance (p<0.05). †: Independent samples t-test, ʃ: Two-sided Pearson's chi-square test or Fisher's exact test. ETT: Endodontically treated teeth, CRA: Crowns with repaired access cavities, IC: Intact crowns, ASD: Absolute standardised difference, SD: Standard deviation, IQR: Interquartile range, PFM: Porcelain-fused-to-metal

or as medians and interquartile ranges (IQRs). Categorical data are summarised using frequencies and percentages.

Survival rates of restorations in matched CRA and IC were assessed and compared using Kaplan–Meier survival analysis. Log-rank tests were conducted to evaluate the univariable effect of potential predisposing factors in CRA. Variables with a p<0.25 were further analysed using the multivariable Cox proportional hazards model.

Propensity Score Matching

A 1:1 propensity score matching was performed for both CRA and IC using four variables: age, sex, tooth type, and crown type. The balance between groups was assessed by calculating absolute standardised differences (ASD) before and after matching. An ASD<0.1 indicated an acceptable balance.

For CRA with available crown placement dates, an additional matching process was conducted separately from the primary matching process. This analysis incorporated crown age, defined as the duration since crown placement, as an additional variable to enhance matching precision.

RESULTS

The initial screening included 298 CRA and 1,908 IC. After applying the inclusion and exclusion criteria, 608 ETT were eligible for analysis, consisting of 120 CRA and 488 IC. A 1:1 propensity score matching was conducted based on four variables, resulting in 120 IC being matched with CRA. Among CRA, crown placement dates were available for only 29 teeth (age in months: mean=86.7±43.5; median=80.0; IQR=53.0–115.5), as most crowns had been placed at external clinics. Consequently, an additional matching process incorporating crown age as a variable resulted in 28 samples per group (Fig. 1).

Following matching, no significant differences were observed between the two groups (Table 1). Across all variables, ASD decreased from >0.1 before matching to <0.1 after matching, indicating a successful balance between the groups (Fig. 2).

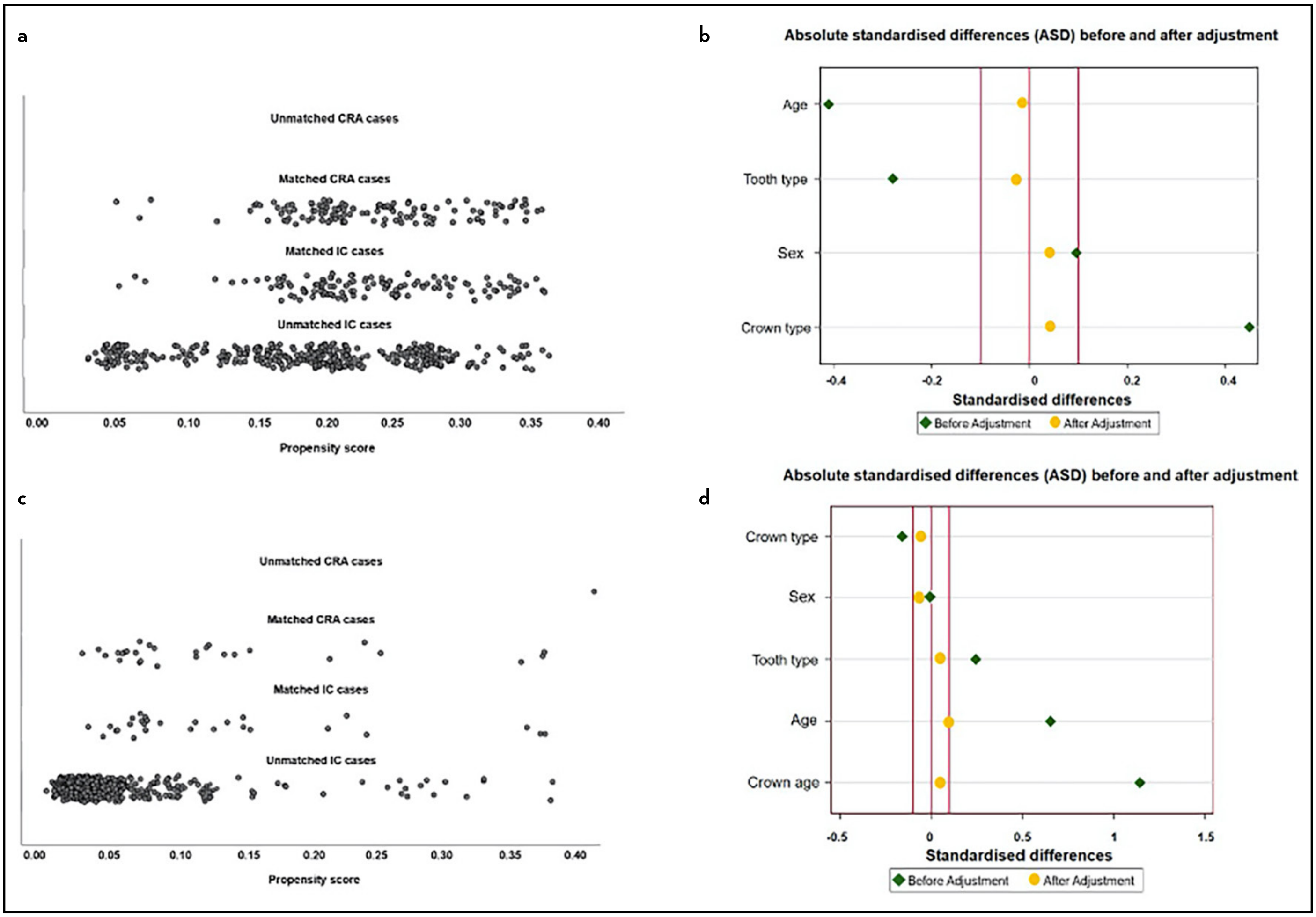

Figure 2. Results of propensity score matching for CRA and IC. (a) Distributions of propensity scores for matched and unmatched cases. (b) Standardised differences for covariates between the two groups before and after matching. (c) Distributions of propensity scores for matched and unmatched cases, with additional analysis accounting for controlled crown age. (d) Standardised differences for covariates between the two groups before and after matching, with additional analysis accounting for controlled crown age.

CRA: Crowns with repaired access cavities, IC: Intact crowns.

Survival Rates of Crowns with and without Repaired Access Cavities

Based on matching age, sex, tooth type, and crown type, with a recall period ranging from 12 to 167 months, the overall survival rates of CRA (mean recall period of 38.13 months) and IC (mean recall period of 45.15 months) (n=120) were 85.8% (103/120 teeth) and 91.7% (110/120 teeth). The mean survival times for CRA and IC were 84.62 and 129.87 months. Log-rank tests revealed significant differences in overall survival between CRA and IC (p=0.004). Within the first two years, CRA showed comparable survival rates to IC (p=0.175). The cumulative survival rate of CRA was 97.19% at 24 months, gradually decreasing to 78.40% and 53.06% at 60 and 96 months. However, IC survival rates were 100%, 92.98%, and 77.61% at 24, 60, and 96 months (Fig. 3a).

Among non-surviving CRA, non-restorable fractures affecting only the tooth structure accounted for the majority of failures (13/17 teeth). Restoration-tooth fractures led to extractions in 2/17 teeth. Crown dislodgement occurred in 2/17 teeth, both of which were subsequently managed with crown recementation and crown replacement (Table 2).

After crown age matching, log-rank tests indicated no significant differences in overall survival rates (p=0.749). The mean survival time was 151.81 months for CRA and 154.75 months for IC, with an 85.70% overall survival rate in both groups (Fig. 3b).

Potential Predisposing Factors Affecting the Survival of Crowns with Repaired Access Cavities

Univariable analysis identified occlusal parafunctional habits or interferences as the only significant factor influencing the survival rate (p<0.001) (Table 3, Fig. 4c). No statistically significant differences in longevity were observed across different crown types (p=0.223) or among the direct restorative materials used for repairs (p=0.336), although slight variations in survival curves appeared in the Kaplan–Meier survival graphs (Fig. 4a, b). The Cox proportional hazards regression analysis identified occlusal parafunctional habits or interferences as a significant factor affecting the survival rate. The hazard ratio (HR) revealed that ETT with occlusal parafunctional habits or interferences were 7.186 times less likely to survive compared to those without (95% confidence interval, 2.265–22.798; p=0.001) (Table 4). Crown type was excluded from the model due to no recorded fractures in all-ceramic crowns.

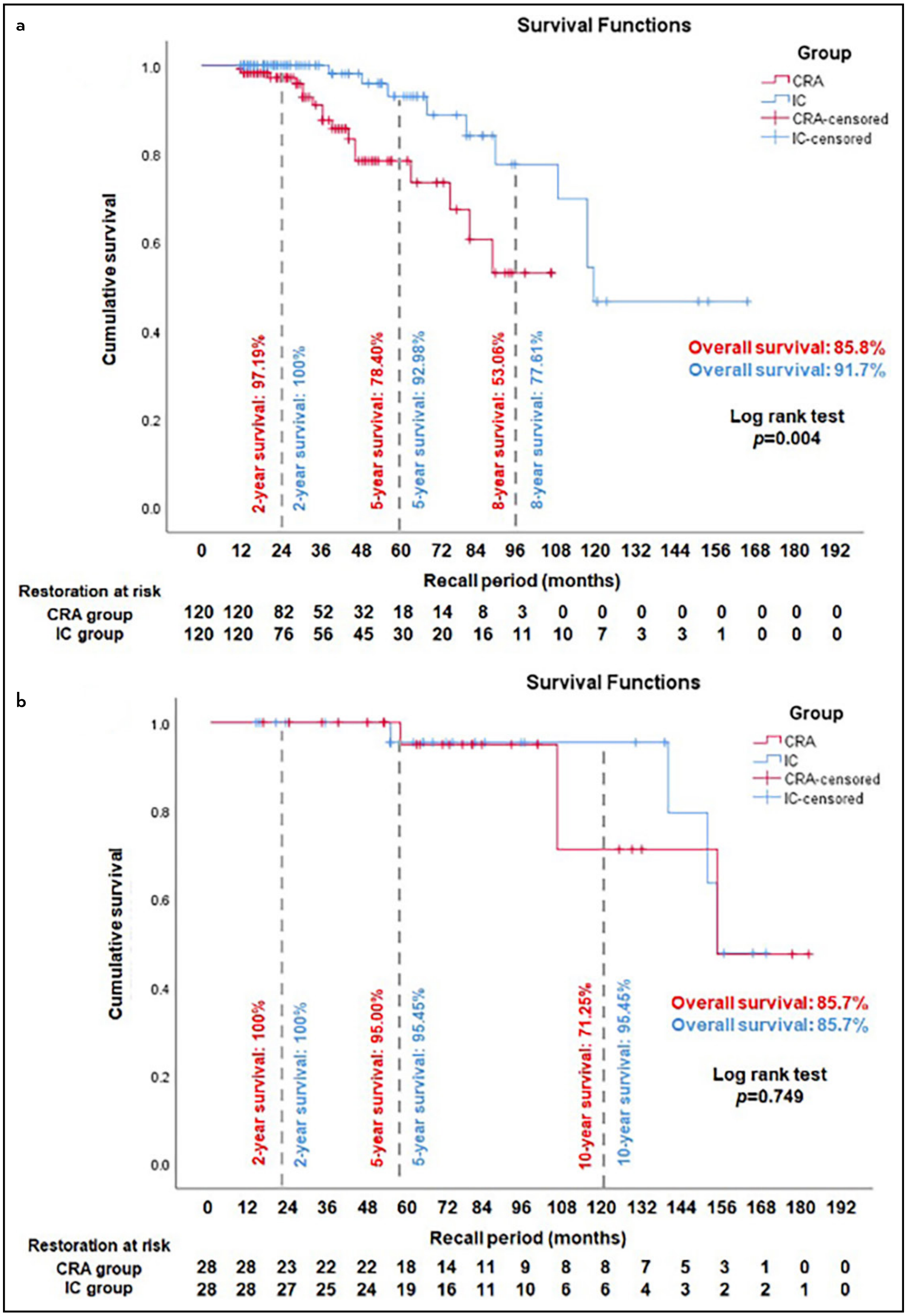

Figure 3. Kaplan–Meier survival curves depicting the cumulative survival rates of CRA and IC. Red annotations indicate the survival rates of CRA, whereas blue annotations represent the survival rates of IC. (a) Kaplan–Meier survival curve for matched CRA and IC (n=120). (b) Kaplan–Meier survival curve for matched CRA and IC (n=28), with additional analysis accounting for controlled crown age.

CRA: Crowns with repaired access cavities, IC: Intact crowns.

DISCUSSION

In this study, CRA exhibited a lower overall survival rate than IC. Within the first two years, CRA showed a high survival rate of 97.19%, comparable to the 100% observed in IC. The survival rate of CRA declined more than that of IC after 2 years, with 5- and 8-year survival rates of 78.40% and 53.06%, which are comparable to the 5- and 10-year survival rates of repaired restorations reported at 71.5% and 48.8% in a previous study

TABLE 2. Demographic data of non-surviving CRA (n=17)

Case	Sex	Tooth type	Crown type	Fracture pattern	Restorability after fracture	Type of treatment provided
1	M	Molar	Full metal	Crown dislodgement	R	Crown recementation
2	F	Molar	PFM	Crown dislodgement	R	Crown replacement
3	M	Molar	PFM	Tooth fracture	NR	Extraction
4	F	Molar	Full metal	Tooth fracture	NR	Extraction
5	F	Premolar	PFM	Tooth fracture	NR	Extraction
6	F	Premolar	PFM	Tooth fracture	NR	Extraction
7	F	Premolar	PFM	Tooth fracture	NR	Extraction
8	F	Premolar	PFM	Tooth fracture	NR	Extraction
9	F	Molar	PFM	Tooth fracture	NR	Extraction
10	F	Molar	PFM	Tooth fracture	NR	Extraction
11	F	Molar	PFM	Tooth fracture	NR	Extraction
12	F	Molar	PFM	Tooth fracture	NR	Extraction
13	F	Molar	PFM	Tooth fracture	NR	Extraction
14	F	Molar	PFM	Tooth fracture	NR	Extraction
15	F	Molar	PFM	Tooth fracture	NR	Extraction
16	M	Premolar	PFM	Restoration-tooth fracture	NR	Extraction
17	M	Molar	PFM	Restoration-tooth fracture	NR	Extraction

CRA: Crowns with repaired access cavities, M: Male, F: Female, PFM: Porcelain-fused-to-metal, R: Restorable, NR: Non-restorable

(9). Although definitions vary, survival is generally based on the clinical functionality and long-term prognosis of a crown (9, 11). We adopted this definition, considering porcelain chipping as a survival outcome, as it typically does not compromise the restoration's integrity and can be managed with minor repairs. Therefore, differences in failure definitions may influence variations in reported survival outcomes (9–12).

The reduced longevity of CRA compared to that of IC may be attributed to the risks associated with performing endodontic treatment through existing crowns, which can compromise the integrity and retention of the restoration and the underlying abutment, potentially causing fractures or dislodgement (8). However, this comparison was limited by the inability to control for crown age. In many CRA cases, the date of crown placement was unknown, and some crowns in the CRA group may have been placed earlier than those in the IC group, affecting the accurate assessment of restoration longevity. An additional propensity score matching analysis was performed to control for crown age. This supplementary analysis revealed no significant difference in survival between CRA and IC, different from the primary findings. The time from crown cementation was not consistently available for most CRA, resulting in a small sample size (28 teeth) in the crown age–matched analysis, thereby limiting the generalisability of these findings.

For non-surviving ETT, approximately 88% (15/17 teeth) exhibited unrestorable fractures involving the crown and/or tooth structure. This finding is consistent with failure patterns observed in non-surviving IC, where fractures represented the primary cause of failure, aligning with the findings of previous studies (20, 21). Notably, crown restorations affected by access cavities rarely failed due to loss of retention (loosening or dislodgement). Instead, fractures were the predominant failure mechanism, emphasising the importance of preserving the remaining tooth structure and minimising damage to the crown during access cavity preparation to maintain restorability and overall tooth survival.

This study identified occlusal parafunctional habits or interferences as significant factors influencing restoration outcomes (HR=7.186). Excessive forces on ETT may increase the risk of fractures in both the tooth and restoration compared to normal forces (22). Patients without occlusal parafunctional habits or interferences seem to experience better crown survival than those with such conditions. However, the limited number of restorations exhibiting parafunctional habits constrains the overall reliability of this finding. Additionally, no significant differences in survival outcomes were observed for other occlusal force-related factors, including opposing dentition type, prosthetic abutment function, or the number of adjacent teeth. These findings contrast with the results of previous studies that reported reduced survival rates for telescopic crowns or fixed dental prostheses compared to those for single crowns (9, 11). Although there is limited data on the impact of these factors on the survival of repaired crowns, this study highlights the importance of effectively managing occlusal forces to enhance the long-term restoration success.

Univariable analyses revealed no significant effect of tooth type, tooth location, or crown type on survival, aligning with previous studies (9, 10, 23, 24). The variations in survival rates among different crown types may be attributed to the differing definitions of failure used across studies (20, 25). Although the sample primarily consisted of molars with PFM crowns, potentially limiting generalisability, the findings likely reflect outcomes observed in most clinical cases. Approximately 90% of CRA cases were repaired using resin composite or core material without posts, with no significant impact on survival rates. These materials exhibit adhesive properties and a modulus of elasticity comparable to that of dentin, contributing to enhanced fracture resistance of the

TABLE 3. Univariable analysis of potential predisposing factors for CRA (n=120)

Factors	Total (n=120)		Non-survival (n=17)		Survival (n=103)		p value
	n	%	n	%	n	%	
Sex							0.134
Male	52	43.3	4	7.7	48	92.3	
Female	68	56.7	13	19.1	55	80.9	
Tooth type							0.542
Anterior	15	12.5	0	0.0	15	100.0	
Premolar	33	27.5	5	15.2	28	84.8	
Molar	72	60.0	12	16.7	60	83.3	
Tooth location							0.829
Maxillary	51	42.5	6	11.8	45	88.2	
Mandibular	69	57.5	11	15.9	58	84.1	
Type of root canal treatment							0.850
Initial root canal treatment	98	81.7	14	14.3	84	85.7	
Root canal retreatment	22	18.3	3	13.6	19	86.4	
Crown type							0.223
Full metal	35	29.2	2	5.7	33	94.3	
PFM	82	68.3	15	18.3	67	81.7	
All-ceramic	3	2.5	0	0.0	3	100.0	
Opposing dentition							0.564
Natural tooth	62	51.7	6	9.7	56	90.3	
Fixed prosthesis	48	40.0	10	20.8	38	79.2	
Removable prosthesis	10	8.3	1	10.0	9	90.0	
Function as an abutment for prosthesis							0.547
No	79	65.8	9	11.4	70	88.6	
Bridge	30	25.0	7	23.3	23	76.7	
Removable prosthesis	11	9.2	1	9.1	10	90.9	
Presence of adjacent teeth							0.778
0 sides	9	7.5	3	33.3	6	66.7	
1 side	48	40.0	6	12.5	42	87.5	
2 sides	63	52.5	8	12.7	55	87.3	
Occlusal parafunctional habits or occlusal interferences							**<0.001**
No	110	91.7	11	10.0	99	90.0	
Yes	10	8.3	6	60.0	4	40.0	
Direct restorative used for repair							0.336
Amalgam	2	1.7	0	0.0	2	100.0	
Resin composite	48	40.0	6	12.5	42	87.5	
Core	61	50.8	11	18.0	50	82.0	
Post and core	9	7.5	0	0.0	9	100.0	
Operator							0.988
Postgraduate student	106	88.3	14	13.2	92	86.8	
Qualified endodontist	14	11.7	3	21.4	11	78.6	

Bold values indicate statistical significance (p<0.05). All p-values were derived from the log-rank test. CRA: Crowns with repaired access cavities, PFM: Porcelain-fused-to-metal

TABLE 4. Multivariable Cox regression analysis of variables significant in univariable analyses

Factors	Hazard ratio (95% CI)	p value
Sex		0.586
Male	1	
Female	1.408 (0.411–4.822)	
Occlusal parafunctional habits or occlusal interferences		
No	1	
Yes	7.186 (2.265–22.798)	**0.001**

Bold values indicate statistical significance (p<0.05). All p-values were derived from the multivariable Cox regression model. CI: Confidence interval

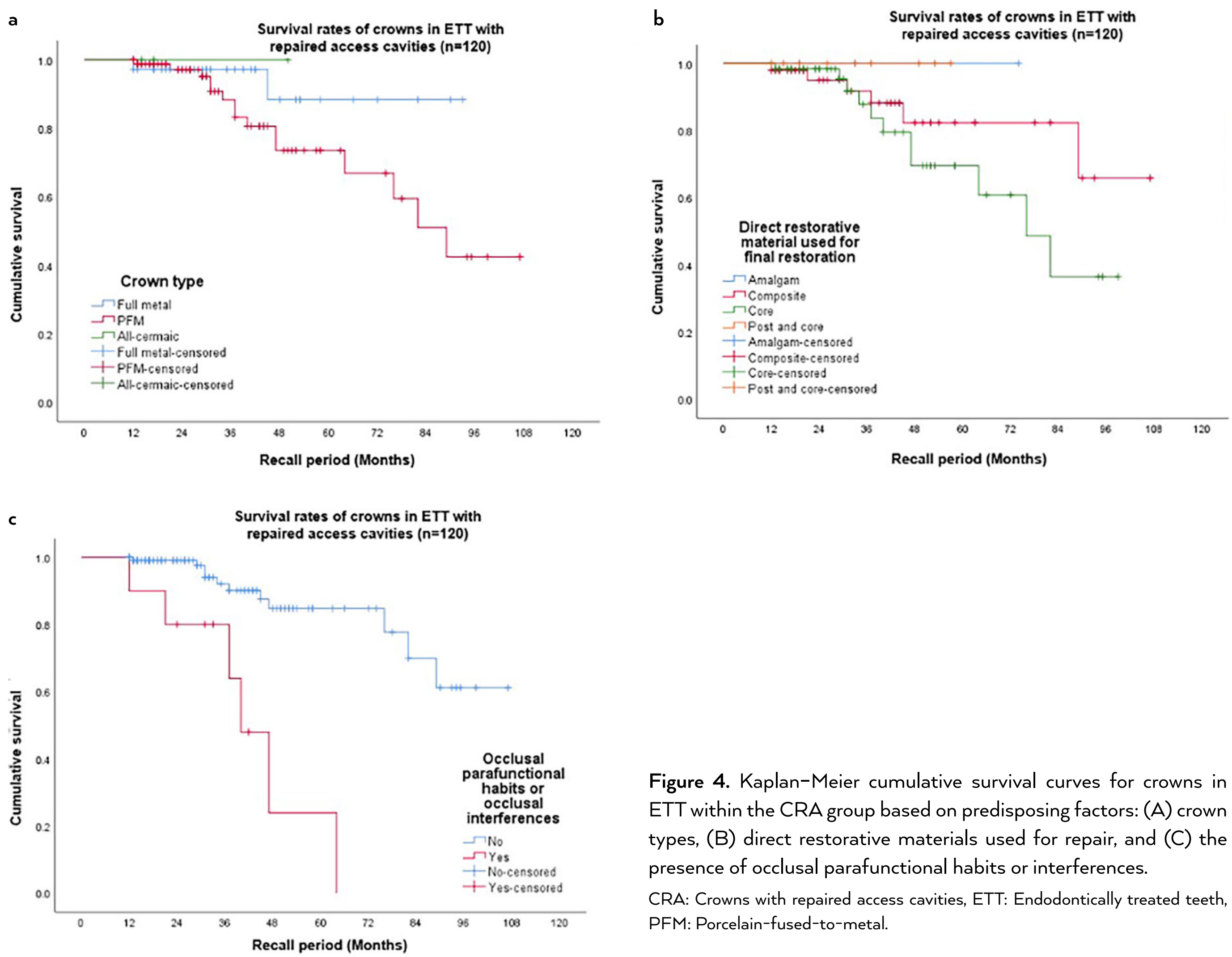

Figure 4. Kaplan–Meier cumulative survival curves for crowns in ETT within the CRA group based on predisposing factors: (A) crown types, (B) direct restorative materials used for repair, and (C) the presence of occlusal parafunctional habits or interferences.

CRA: Crowns with repaired access cavities, ETT: Endodontically treated teeth, PFM: Porcelain-fused-to-metal.

remaining tooth structure (26). Notably, survival curves beyond 5 years (Fig. 4b) indicated a greater decline for core material repairs compared to resin composite repairs. This trend may be influenced by a selection bias, as clinicians may prefer core materials for deeper or larger cavities, potentially affecting long-term outcomes. However, this study lacked data on surface conditioning methods, such as silica coating or primers, which have been associated with improved survival and bond strength in previous research (27, 28).

No non-surviving case of CRA repaired with a post and core was identified in this study. Typically, the use of a post is associated with intraradicular retention of the core material and reinforcement of the root structure, which may help prevent tooth fractures (29). However, unnecessary post placement can significantly weaken the tooth structure (30). Here, the rationale for post placement remains unclear, as only limited information was available regarding the amount of remaining tooth structure, including cavity type, dentin wall thickness, and the number of remaining walls. This limitation may introduce potential bias in the survival comparisons, as post placement was more frequently observed in IC than in CRA (Tables 3, 5).

To evaluate the longevity of repaired versus intact crowns, propensity score matching was used to balance potential confounding factors and enhance comparability between groups (16). In general, crown longevity is influenced by multiple factors, including patient-related, tooth-related, occlusal, and restoration-related factors. However, due to the variability of clinical cases, increasing the number of matching variables in the model reduces the number of matched pairs, as more cases are excluded due to mismatches, leading to a smaller sample size for comparison.

Since information on cavity type and amount of remaining tooth structure was available for only a limited number of cases, we included as many other relevant variables as possible in the matching process to account for potential confounding factors, while ensuring adequate representation of each group for meaningful comparison. The selected variables included age, sex, tooth type, and crown type, all of which have been previously reported to influence survival outcomes (9–11, 23–25, 31). Examples of the matching variables used in various models, along with the corresponding number of cases in each comparison group, are presented in Table 6. Future studies with larger sample sizes should incorporate a

TABLE 5. Demographic characteristics of IC by relevant factors before (n=488) and after propensity score matching (n=120)

Factors	Before propensity score matching						After propensity score matching					
	Total (n=488)		Non-survival (n=23)		Survival (n=465)		Total (n=120)		Non-survival (n=10)		Survival (n=110)	
	n	%	n	%	n	%	n	%	n	%	n	%
Sex												
Male	195	38.6	12	6.2	183	93.8	51	42.5	4	7.8	47	92.2
Female	293	61.4	11	3.8	282	96.2	69	57.5	6	8.7	63	91.3
Tooth type												
Anterior	87	17.8	1	1.1	86	98.9	15	12.5	0	0.0	15	100.0
Premolar	173	35.5	7	4.0	166	96.0	35	29.2	2	5.7	33	94.3
Molar	228	46.7	15	6.6	213	93.4	70	58.3	8	11.4	62	88.6
Tooth location												
Maxillary	249	51.0	10	4.0	239	96.0	61	50.8	5	8.2	56	91.8
Mandibular	239	49.0	13	5.4	226	94.6	59	49.2	5	8.5	54	91.5
Type of root canal treatment												
Initial root canal treatment	453	92.8	21	4.6	432	95.4	119	99.2	10	8.4	109	91.6
Root canal retreatment	35	7.2	2	5.7	33	94.3	1	0.8	0	0.0	1	100.0
Crown type												
Full metal	84	17.2	9	10.7	75	89.3	33	27.5	2	6.1	31	93.9
PFM	344	70.5	13	3.8	331	96.2	84	70.0	8	9.5	76	90.5
All-ceramic	60	12.3	1	1.7	59	98.3	3	2.5	0	0.0	3	100.0
Opposing dentition												
Natural tooth	317	65.0	11	3.5	306	96.5	85	70.8	6	7.1	79	92.9
Fixed prosthesis	132	27.0	7	5.3	125	94.7	26	21.7	3	11.5	23	88.5
Removable prosthesis	39	8.0	5	12.8	34	87.2	9	7.5	1	11.1	8	88.9
Function as an abutment for prosthesis												
No	361	74.0	5	1.4	356	98.6	93	77.5	1	1.1	92	98.9
Bridge	29	6.0	7	24.1	22	75.9	10	8.3	5	50.0	5	50.0
Removable prosthesis	98	20.0	11	11.2	87	88.8	17	14.2	4	23.5	13	76.5
Presence of adjacent teeth												
0 side	21	4.3	7	33.3	14	66.7	4	3.3	2	50.0	2	50.0
1 side	145	29.7	11	7.6	134	92.4	27	22.5	6	22.2	21	77.8
2 sides	322	66.0	5	1.6	317	98.4	89	74.2	2	2.2	87	97.8
Occlusal parafunctional habits or occlusal interferences												
No	447	91.6	10	2.2	437	97.8	115	95.8	6	5.2	109	94.8
Yes	41	8.4	13	31.7	28	68.3	5	4.2	4	80.0	1	20.0
Restorative foundation												
Core	26	5.3	1	3.8	25	96.2	5	4.2	0	0.0	5	100.0
Post and core	462	94.7	22	4.8	440	95.2	115	95.8	10	8.7	105	91.3
Operator												
Undergraduate student	103	21.1	3	2.9	100	97.1	36	30.0	1	2.8	35	97.2
Postgraduate student	346	70.9	17	4.9	329	95.1	79	65.8	8	10.1	71	89.9
Qualified endodontist	39	8.0	3	7.7	36	92.3	5	4.2	1	20.0	4	80.0

IC: Intact crowns, PFM: porcelain-fused-to-metal

broader range of influencing factors to improve the reliability and generalizability of the results.

The retrospective data lacked detailed information on tooth condition prior to crown placement, including the amount of remaining tooth structure, status of the abutment, and size or depth of access cavities. For instance, significant structural loss, particularly in Class II cavities involving marginal ridge loss, increases the risk of fracture compared to a more preserved structure of teeth (32). Due to the retrospective nature of the data and limitations in clinical documentation, the assessment of pre-existing conditions in CRA may have been inaccurate or incomplete. As a result, access openings may have been performed through crowns on teeth with varying types and degrees of structural loss, influencing the survival outcomes. This lack of reliable baseline information may introduce bias and limit the validity of comparisons between groups. In addition to tooth condition, patients' medical histories, comprising further factors influencing the durability of the restoration, were also not available in most cases (33). These variations may introduce bias and potentially affect the observed survival outcomes.

Operator variability, including clinical judgment, decision-making, and treatment protocols (such as crown cementa-

TABLE 6. Examples of alternative propensity score matching models based on different matching variables and the number of matched CRA and IC

Model	Factors	Primary propensity score matching (without crown age)	Additional propensity score matching (with crown age)
1	Tooth type Crown type	120 cases matched	29 cases matched
2	Age Tooth type Crown type	120 cases matched	28 cases matched
3*	Age Sex Tooth type Crown type	120 cases matched	28 cases matched
4	Age Sex Tooth type Crown type Occlusal parafunctional habits or occlusal interferences	73 cases matched	12 cases matched
5	Age Sex Tooth type Crown type Tooth location Occlusal parafunctional habits or occlusal interferences	70 cases matched	11 cases matched
6	Age Sex Tooth type Crown type Tooth location Occlusal parafunctional habits or occlusal interferences Opposing dentition	43 cases matched	7 cases matched

*: Model used in this study. CRA: Crowns with repaired access cavities, IC: Intact crowns

tion techniques and adhesive systems), may have also influenced survival outcomes. The decision to retain or remove the crown was based on individual experience. Although such variability is difficult to control in retrospective studies, all procedures in our study followed standardised clinical protocols and were performed under dental operating microscopes in an academic setting. The operators, who were students, were supervised by instructors, which helped minimise inconsistencies. As corresponding treatment records were unavailable, some restorations may have been replaced or repaired in other settings during the follow-up period without our knowledge. This lack of information may have affected the accuracy of the survival analysis.

The limited sample size may have reduced the ability to detect failures in specific subcategories such as anterior teeth, all-ceramic crowns, amalgam restorations, or post-and-core restorations. Future studies with larger sample sizes should investigate these variables to enhance the identification of significant treatment factors influencing clinical outcomes.

Despite these limitations, our findings provide a valuable foundation for guiding clinical decision-making. By highlighting key factors that influence the longevity of restorations, they support more informed choices and treatment planning. From a cost-effectiveness perspective, considering both financial costs and clinical outcomes, we conducted a brief analysis using the incremental cost-effectiveness ratio (ICER) (34). Based on data from our institute, the ICER suggests that an additional expenditure of approximately USD 60 is associated with a 1% increase in survival probability for CRA. Therefore, CRA may offer greater economic efficiency in certain clinical scenarios. However, a comprehensive cost-effectiveness analysis is warranted to better assess the acceptability of the lower survival rate, given the reduced treatment costs, and support evidence-based decision-making in restorative treatment planning.

CONCLUSION

Post-endodontic CRA exhibited lower overall survival compared to IC. However, this finding is limited by the absence of crown age data and limitations inherent to the retrospective study design. Performing endodontic access through existing crowns may compromise the underlying abutment structure and crown integrity, potentially shortening restoration longevity. Occlusal parafunctional habits and interferences emerged as potential predisposing factors influencing restoration outcomes.

Disclosures

Ethics Committee Approval: The study was approved by the Ethics Committees of the Faculty of Dentistry and the Faculty of Pharmacy, Mahidol University, Institutional Review Board (no: MU-DT/PY-IRB 2024/DT017, date: 21/03/2024).

Informed Consent: Informed consent was obtained from all participants.

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