Journal of Dentistry 156 (2025) 105699

Contents lists available at ScienceDirect

Journal of Dentistry

journal homepage: www.elsevier.com/locate/jdent

Direct restorations versus full crowns in endodontically treated molar teeth: A three-year randomized clinical trial

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ARTICLE INFO

Keywords:
Endodntically treated teeth
Composite resin restorations
Metal-ceramic crowns
Survival rate
Success rate
Randomized controlled trial

ABSTRACT

Objectives: To compare the survival and success rates of direct composite resin restorations versus metal-ceramic crowns in endodontically treated molar teeth with minimal structure loss.
Methods: This clinical trial included 60 participants, each with an endodontically treated molar with at least three remaining axial walls (>2mm). Half of the participants received direct restorations, and half metal-ceramic crowns. USPHS criteria were used at baseline and annually for three years. Kaplan-Meier and log-rank tests analyzed survival/success rates. Cox regression evaluated predictors, and Mann-Whitney U and Wilcoxon tests compared USPHS outcomes.
Results: Fifty-three participants completed the 3-year follow-up (7 dropped out). The three-year survival rate for crowns was 93.3 % (95 % CI: 78.7 %-98.2 %), while the direct restoration group had 76.7 % (95 % CI: 59.1 %-88.2 %). The difference was insignificant ($P = 0.061$). Success rates were also comparable (crowns=90.0 % vs. restorations=76.7 %; $P = 0.138$). Bruxism significantly predicted failure (HR=12.8, 95 % CI: 1.2–133.3, $P = 0.032$). Direct restorations had worse outcomes than crowns regarding caries ($P = 0.018$), surface texture ($P = 0.019$), and marginal integrity ($P = 0.006$). Crowns had worse outcomes in terms of periodontal indices ($P = 0.032$) and presence of periapical infection ($P = 0.023$). Over time, direct restorations significantly deteriorated in terms of caries ($P = 0.041$), margin discoloration ($P = 0.007$), margin integrity ($P = 0.026$), and fracture ($P = 0.034$), while crowns showed no significant changes.
Conclusion: For endodontically treated molars with minimal structure loss, both direct composite resin restorations and full crowns demonstrated similar survival and success after 3 years of function. However, crowns were more predictable, especially for bruxers. Direct restorations may suit cases with lower occlusal loads, endodontic monitoring, or budget constraints.
Clinical significance: This study showed similar 3-year survival/success rates of direct composite restorations compared to metal-ceramic crowns in restoring endodontically treated molar teeth with minimal structural loss. These results indicate that direct restorations may be suitable alternatives for molars with minimal structural loss, particularly in cases with reduced occlusal loads, a need for endodontic monitoring, or financial limitations.

1. Introduction

The loss of tooth structure in endodontically treated teeth (ETT) due to caries, restorative interventions, and endodontic procedures significantly weakens their resistance to mechanical stresses, making them more susceptible to fracture [1–4]. Restoring these teeth is essential to protect the remaining tooth structure and prevent further structural failure [5]. Traditionally, many studies have recommended full-coverage crowns or some other form of cuspal coverage for restoring posterior ETT, showing higher survival rates for crowned teeth [6–12]. Studies have also found crowned ETT to require fewer reinterventions than ETT restored with direct restorations, and early crown placement

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https://doi.org/10.1016/j.jdent.2025.105699
Received 5 February 2025; Received in revised form 8 March 2025; Accepted 16 March 2025
Available online 17 March 2025

was reported to reduce coronal leakage and coronal fractures [13,14].

However, many of the supporting studies for crown use were primarily retrospective in nature and did not take into account the amount of tooth structure remaining before restoring ETT with crowns [15]. Remaining tooth structure was shown to be positively correlated with the fracture resistance of ETT [16–18]. A tooth that has lost both marginal ridges is at a higher risk of fracture compared to a tooth with only an occlusal cavity [4]. Restoring both with a full-coverage crown may lead to unnecessary removal of sound tooth structure. A key principle in replacing missing dental structures is to restore function and aesthetics with minimal biological cost [19]. Therefore, more conservative treatments, such as direct restorations, have been suggested for restoring ETT with minimal structure loss [20].

Direct restorations offer several advantages compared to crowns, including preservation of tooth structure, lower cost, reduced treatment time, and the potential for endodontic re-intervention and chairside repairs [21]. However, there is a lack of extensive clinical research focusing specifically on ETT with minimal structure loss [22–24]. Mannocci et al. [22] found that endodontically treated premolars with minimal occlusal-proximal cavities had similar failure rates when restored with fiber posts and composite restorations compared to those restored with crowns. Similarly, Nagasiri and Chitmongkolsuk [23] reported favorable five-year survival rates for endodontically treated molars with occlusal cavities restored using direct restorations.

A recent systematic review found insufficient evidence to compare full-coverage crowns with direct restorations of ETT and suggested that clinicians should base their decisions on restoring ETT based on their own clinical experience [25]. Additionally, Ng and Gulabivala [26], in a comprehensive systematic review, highlighted that the belief that all ETT require crowns may be overstated, as evidence is limited regarding the interaction of tooth type, location, tissue loss, restoration type, and occlusal loading.

Given these gaps in evidence, this randomized clinical trial aimed to evaluate the survival and success rates of direct composite resin restorations compared to metal-ceramic crowns for restoring endodontically treated molar teeth with minimal structural loss, specifically those with at least three intact axial walls. The null hypothesis was that direct composite resin restorations and metal-ceramic crowns would have no significant difference in their three-year survival or success rates when used to restore endodontically treated molar teeth with minimal structural loss.

2. Methods

2.1. Trial design

The present study was conducted in full accordance with the World Medical Declaration of Helsinki and conformed to the COSORT statement for randomized clinical trials. The study protocol was reviewed and approved by the Deanship of Academic Research at the University Hospital (IRB number: 75/2019/2319) and registered at ClinicalTrials.gov (ID number: NCT04249726).

2.2. Participants

The study population included patients at the University of Jordan Hospital undergoing root canal treatment for molar teeth. Enrollment began on October 10, 2019, and continued for one year until the required sample size was met. After caries removal and root canal treatment by endodontic consultants in the Endodontic Department, patients were assessed by two examiners for eligibility based on predetermined inclusion and exclusion criteria. Consecutive sampling was applied, enrolling all patients who met the inclusion criteria.

Patients were included if they had an endodontically treated molar with structure loss limited to an occlusal cavity with four remaining axial walls or an occlusal-proximal cavity with three remaining axial walls (axial wall thickness >2 mm). Exclusion criteria covered both patient- and tooth-related factors. Patients were excluded if they were under 16, had severe medical or mental conditions, neuromuscular dysfunction, auditory issues, xerostomia, poor oral hygiene, or failed to sign consent. At the tooth level, exclusions included teeth lacking an opposing dentition or proximal contacts, serving as abutments, having deep subgingival margins (>0.6 mm), visible cracks, probing depths >3 mm, or mobility.

Patients identified as candidates for inclusion in this clinical trial were invited to participate and provided with an invitation letter, information sheet, and a consent form. Patients who signed the consent form were enrolled into the study. Upon enrollment, participants underwent a baseline examination, including clinical assessments and periapical radiographs to ensure the technical adequacy of the root canal treatment (proper working length, dense obturation with no apparent voids, no over- or under-extension), integrity of the coronal seal, and absence of clinical symptoms.

The participants were then randomized using a computer-generated sequence in Microsoft Excel version 16.93 into two groups. In the first group, the teeth were restored with direct composite resin restoration. In the second group, the teeth were restored with a direct composite resin restoration, followed by a full coverage metal-ceramic crown. Participants were followed up and assessed annually for a period of three years.

2.3. Sample size

The sample size for this study was calculated based on a predefined allowable difference of 12 %, an expected survival rate of 96 %, a significance level of 0.05, and a power of 90 %. After accounting for a 20 % dropout rate, the final sample size required was 29 participants per group.

2.4. Interventions

All restorative treatments were conducted in a prosthodontic consultant clinic within the Prosthodontic Department at the University of Jordan Hospital. Participants in the restoration group required one visit, while those in the crown group required two visits.

For the direct restoration group, the tooth was isolated with a rubber dam, and the temporary restoration was removed. The enamel was selectively etched with 37.5 % phosphoric acid (Gel Etchant, Kerr, CA, USA), rinsed, and thoroughly dried. A layer of universal adhesive (Scotchbond Universal, 3 M ESPE, Bracknell, UK) was actively applied for 20 ss, air-thinned, and light-cured for 20 ss using a curing unit (Bluephase, Ivoclar Vivadent, Schaan, Liechtenstein). A thin layer of flowable composite (Filtek Supreme Flowable Restorative, 3 M ESPE, Bracknell, UK) was then applied to the dentin and cured for 40 ss.

For occlusal-proximal cavities, a sectional matrix system (Number 1001 Palodent V3, Dentsply Sirona, York, PA, USA) and a wedge (Palodent V3 Wedges, Dentsply Sirona, York, PA, USA) were used to enhance interproximal adaptation of the matrix. The proximal wall was built using a microhybrid resin composite (Filtek Z350, 3 M ESPE, Bracknell, UK) and light-cured for 40 ss.

In both occlusal and occlusal-proximal cavities, bulk-fill posterior restorative material (Filtek Bulk Fill, 3 M ESPE, Bracknell, UK) was applied in increments of <4 mm thickness to create the core of the restoration, with each increment cured for 40 ss. The occlusal morphology of the restoration was created using microhybrid composite resin (Filtek Z350, 3 M ESPE, Bracknell, UK) applied in increments of <2 mm, with each increment cured for 40 ss.

A layer of glycerine gel (Liquid Strip, Ivoclar Vivadent, Schaan, Liechtenstein) was applied and light-cured for 10 ss to minimize the oxygen inhibition layer. The occlusal surface was then checked to ensure it maintained the patient's original occlusion, avoiding any new interferences. The restoration was finished with ultra-fine diamond finishing burs and polished using polishing discs (Sof-Lex Diamond

Polishing System, 3 M ESPE, Bracknell, UK).

For participants in the crown group, a direct composite resin restoration was initially done in the same manner as described for the direct restoration group. After finishing the restoration, three silicone putty indices (Zhermack Elite HD+, Zhermack, Badia Polesine, Italy) were created: one for the provisional crown and two, sectioned mesio-distally and bucco-lingually, to serve as reduction guides for the crown preparation. The preparation for a full-coverage metal-ceramic crown was then performed using a round-end tip, medium-grit diamond bur (856; Komet, USA) to create an equigingival deep chamfer finish line of 1 mm with rounded internal line angles, 1.5–2 mm of occlusal reduction, and 1.2–1.5 mm of axial reduction. The silicone indices were used to verify the reduction. Conventional impressions were made using a one-stage putty and light body addition-reaction silicone (Elite HD+, Zhermack, Badia Polesine, Italy). An impression of the opposing arch was taken with irreversible hydrocolloid (Zhermack Hydrogum, Zhermack, Badia Polesine, Italy), and occlusal registration was performed using bite registration material (Occlufast Rock, Zhermack, Badia Polesine, Italy). The provisional crown, made from acrylic resin (Acrytemp, Zhermack, Badia Polesine Italy), was bonded with an eugenol-free temporary cement (RelyX Temporary Cement, 3 M ESPE, Bracknell, UK).

All crowns were fabricated by the same dental technician. Impressions were cast using Type 4 gypsum (Fujirock, GC, Japan), and subsequently scanned. The metal core of the crown was designed with CAD software (Exocad GmbH, Darmstadt, Germany); a full-contour design was created and then reduced digitally by 1 mm to allow sufficient thickness for the ceramic. The metal core was produced by selective laser melting (SLM 280 HL, SLM Solutions Group AG, Lübeck, Germany) using cobalt-chromium alloy powder (ADORBOND CC, Ador Edelmetalle GmbH, Hilden, Germany). The metal core was veneered with

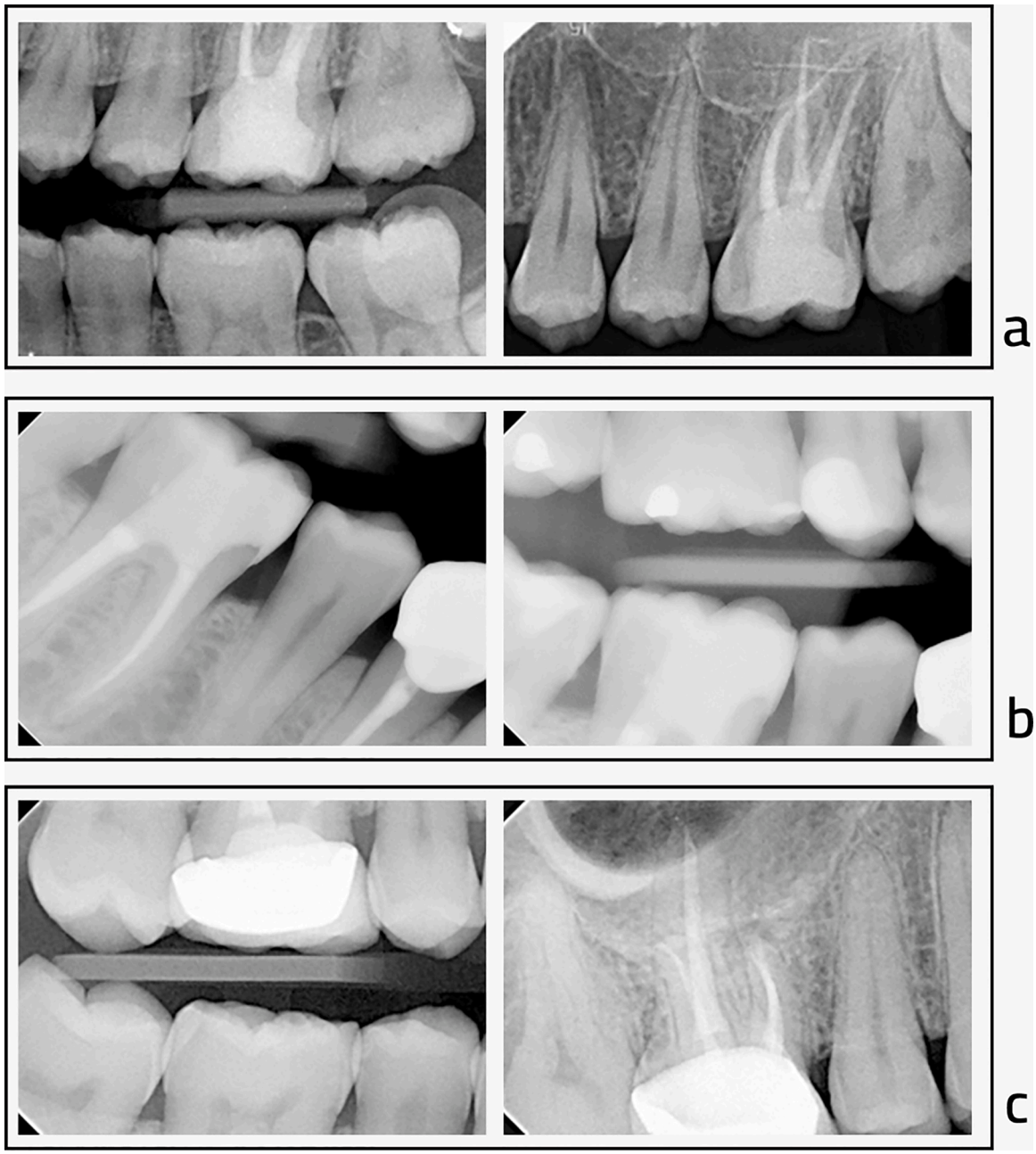


Fig. 1. Bitewing and periapical radiographs taken at the 36-month follow-up appointment. Image A showes an endodontically treated molar restored with an occlusal composite resin restoration, image B showes an endodontically treated molar restored with an occlusal-proximal composite resin restoration, and image C showes an endodontically treated molar restored with a metal-ceramic crown.

fluorapatite-leucite glass ceramic (Noritake Super Porcelain EX-3, Kuraray Noritake Dental Inc., Tokyo, Japan).

After one week, the crowns were tried in to verify marginal and interproximal fit, shade, and occlusion. If adjustments were needed, they were polished chair-side using diamond-impregnated silicone instruments (CeraGlaze, Kerr, CA, USA) and diamond pastes (DiaSheen, Kerr, CA, USA). All crowns were cemented using a resin-modified glass ionomer cement (RelyX Luting Plus, 3 M ESPE, Bracknell, UK).

2.5. Outcomes

Participants underwent a baseline assessment immediately following treatment, which included both clinical and radiographic evaluations. Follow-up assessments were conducted annually for three years post-treatment. These assessments were performed by two independent evaluators using a modified United States Public Health Service (USPHS) criteria [27]. Restoration quality was scored based on margins condition, anatomical form, surface texture, shade match, and signs of fracture or caries, according to the following system: Alpha indicated clinically ideal conditions with no issues requiring intervention; Bravo referred to minor deviations that did not compromise function or aesthetics and required no significant intervention; Charlie denoted notable deviations that impacted clinical performance or aesthetics, necessitating repair or localized intervention; and Delta represented severe deficiencies requiring restoration replacement or other major intervention.

Radiographic evaluations involved bitewing and periapical radiographs taken with a paralleling device (XCP Extension Cone Paralleling System, Dentsply Sirona, PA, USA) to detect marginal defects, recurrent caries, and signs of infection in the treated tooth (Fig. 1). Additionally, a thorough periodontal examination was conducted, which included the assessment of bleeding on probing and the measurement of pocket depths. All these parameters were scored in accordance with the modified USPHS criteria, ensuring consistency and uniformity across clinical, periodontal, and radiographic evaluations.

Failure was defined as any event requiring the removal and replacement of the restoration. Examples included marginal gaps, secondary caries near the margins, restoration fracture, tooth fracture, crown decementation, periapical lesions requiring endodontic retreatment. These corresponded to a USPHS score of Delta or, in certain situations, Charlie. Teeth that were deemed non-restorable during the observation period were also classified as failures.

At the final follow-up, success was defined as any restoration maintaining Alpha or Bravo scores in all evaluated USPHS criteria, while complications referred to any restoration with one or more Charlie or Delta ratings, provided it had not met the failure threshold (requiring removal or replacement).

Both evaluators were required to agree on the scores assigned for each criterion, with any differences resolved through discussion until consensus was reached. To ensure consistency, inter-examiner reliability was assessed using Cohen's kappa statistic, with a kappa value of 0.737 indicating substantial agreement. Intra-examiner reliability was also measured by having each examiner re-evaluate a subset of cases after two weeks, which yielded a kappa value of 0.783 for Examiner A, and 0.857 for Examiner B.

2.6. Blinding

Blinding of the operators or participants was not possible due to the nature of the intervention.

2.7. Statistical methods

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) software version 22.0 [28]. Survival and success rates were calculated using Kaplan-Meier analysis, and differences between groups were assessed using the log-rank test. The Cox proportional hazards model was used to compute hazard ratios for various predictors. Normality of the data was inspected using histograms and Q-Q plots. Additionally, z-scores for skewness were evaluated, and values greater than ± 1.96 indicated that the VAS data were not normally distributed. Consequently, the Mann-Whitney U test was used to assess differences in the USPHS criteria between groups, while the Wilcoxon signed-rank test evaluated changes within groups over time. Statistical significance was set at $p < 0.05$.

3. Results

3.1. Participant flow and baseline data

A total of 60 participants were enrolled. The baseline characteristics of the participants for the entire cohort in both groups are presented in Table 1. Chi-square tests, Mann-Whitney U tests, and Fisher's exact tests were used to compare categorical and continuous variables between the restoration and crown groups, as appropriate.

The flow diagram of participants inclusion in the study is presented in Fig. 2. During the follow-up period, seven participants (11.7 %) dropped out due to failure to attend review appointments, leaving 53 participants for the final analyses. The sample-size calculation accounted for a 20 % dropout, the actual rate was lower, ensuring the study retained adequate power. Participants who did not attend the final review appointments were censored at the time of their last recorded follow-up. Their data were included in the survival analysis up to the point of dropout, as they contributed meaningful data during the period they were under observation.

Table 1
Comparison of baseline characteristics between the restoration and crown groups for the entire cohort ($N = 60$), including gender, age, jaw location, tooth type, presence of adjacent contacts, lateral forces, parafunctional habits, and cavity type.

	Restoration group: n (%)	Crown group: n (%)	Test statistics	P-value
Gender				
Male	6 (20.0)	11 (36.7)	2.052	0.152[a]
Female	24 (80.0)	19 (63.3)		
Age (Median, IQR)	18.5 (16.0 - 25.025)	32.0 (25.5 – 38.0)	171.500	<0.001[b,*]
Jaw				
Maxilla	14 (46.7)	17 (56.7)	0.601	0.438[a]
Mandible	16 (53.3)	13 (43.3)		
Tooth type				
1st molar	20 (66.7)	24 (80.0)	1.364	0.243[a]
2nd molar	10 (33.3)	6 (20.0)		
Presence of adjacent				
One contact	7 (23.3)	6 (20 %)	0.098	1.000[c]
Two contacts	23 (76.7)	24 (80 %)		
Lateral forces				
Absent	28 (93.3)	29 (96.7)	0.351	1.000[c]
Present	2 (6.7)	1 (3.3)		
Parafunctional habit				
Absent	27 (90.0)	29 (96.7)	1.071	0.612[a]
Present	3 (10.0)	1 (3.3)		
Cavity type				
Occlusal	24 (80.0)	17 (56.7)	3.774	0.052[a]
Occlusal proximal	6 (20.0)	13 (43.3)		

[a] Chi-square test.
[b] Mann-Whitney U Test.
[c] Fisher's Exact Test.
[*] Statistically significant.

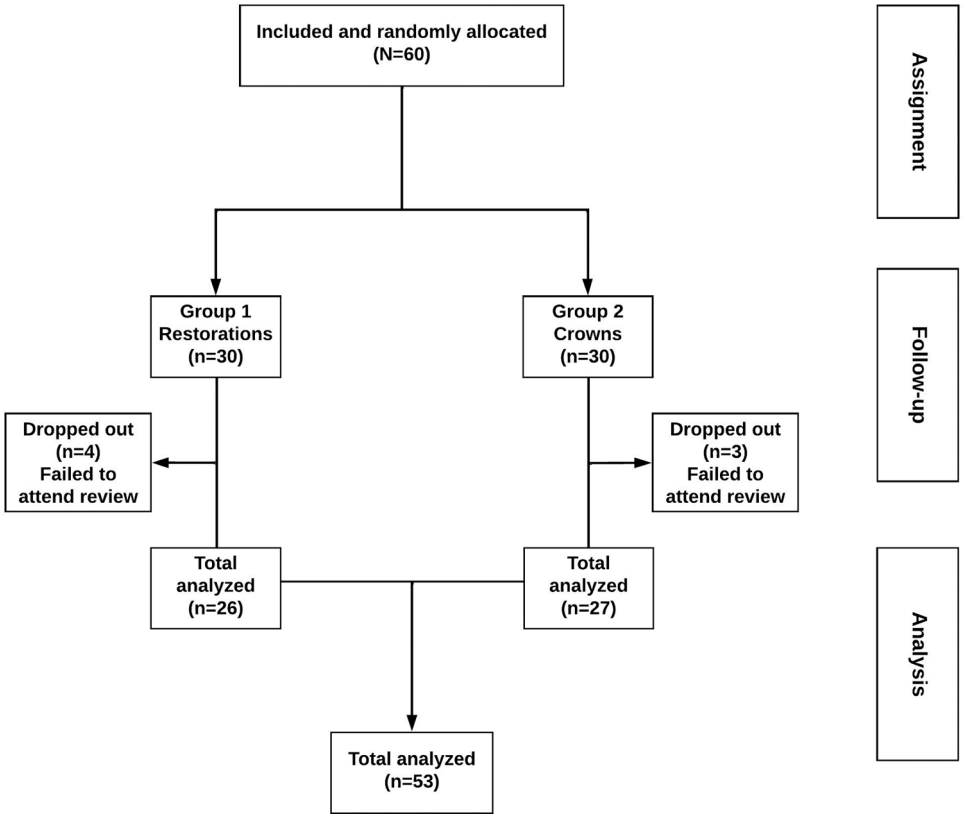


Fig. 2. Study flowchart.

3.2. Outcomes and estimation

Fig. 3 presents the Kaplan-Meier survival curves of the restorations for the two groups. The three-year survival rate for the crown group was 93.3 % (95 % Confidence Interval [CI]: 78.7 % – 98.2 %). In comparison, the direct restoration group exhibited a three-year survival rate of 76.7 % (95 % CI: 59.1 % – 88.2 %). A log-rank test indicated no statistically significant difference in survival distributions between the direct restoration and crown groups ($P = 0.061$, Chi-square = 3.503).

Seven direct restorations failed in total. Three teeth developed secondary caries at the margins, necessitating restoration replacement. Two teeth fractured at the restoration level near the marginal ridge, while two fractured at the tooth level between the cusp and marginal ridge. All fractured restorations/teeth were replaced with crowns at the participants' request to minimize further fracture risk. Notably, two participants with fractures were identified as bruxers during examination.

In the crown group, two failures were reported. Both cases required intervention due to symptomatic and radiographic signs of apical pathology necessitating endodontic treatment. In one case, apical surgery was deemed unfeasible due to limited surgical accessibility, requiring crown removal for endodontic intervention. In the other case, the tooth was deemed hopless and was extracted.

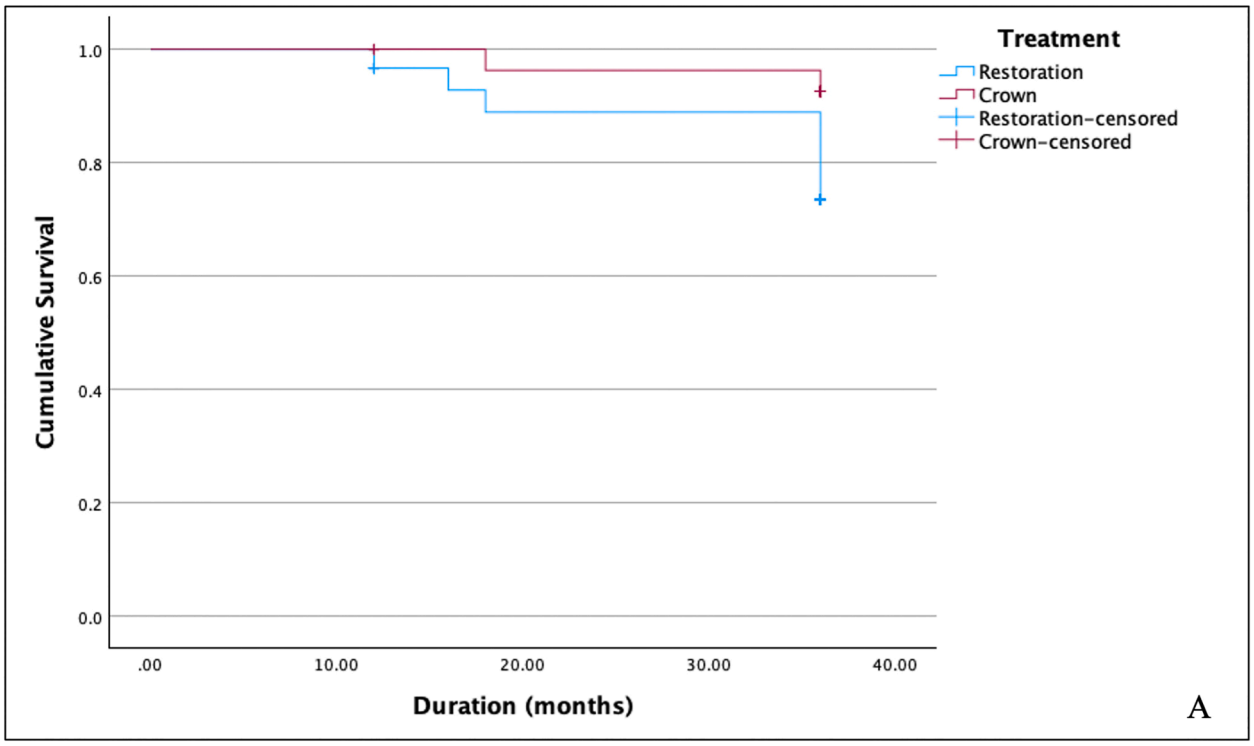
At the final review, all surviving direct restorations achieved an Alpha/Bravo rating, resulting in a success rate of 76.7 % (95 % CI: 62.0 – 92.0), which was similar to the survival rate. For the crown group, only one crown exhibited a ceramic chipping complication (Charlie rating), yielding a success rate of 90.0 % (95 % CI: 79.0 – 100.0). The difference between the two groups was not statistically significant (Log-rank test, P = 0.138, Chi-square = 2.199) (Fig. 3).

Table 2 presents the results of the Cox proportional hazards model analysis for different variables influencing survival rates. The overall model fit was not statistically significant (Chi-square = 14.918, $p = 0.093$). Among the variables, parafunctional habits (bruxism) was the only significant predictor of event occurrence ($p = 0.032$). The hazard ratio for Parafunction was 12.8 (95 % CI: 1.2 – 133.3), indicating that the presence of parafunction was associated with a 12.8-fold increase in the risk of event occurrence compared to its absence. No other variables reached statistical significance, although treatment type (restoration vs crown) approached significance ($p = 0.068$) with a hazard ratio of 0.131 (95 % CI: 0.015 – 1.162).

Table 3 presents the USPHS outcomes at baseline and the last review appointment for participants who either completed the 3-year period or experienced a failure earlier ($n = 53$). These participants were included in the analyses. The remaining 7 participants dropped out without further review data and were therefore excluded. A comparison of baseline characteristics between those included in the analysis and those who dropped out showed no significant differences ($P > 0.05$).

The Mann-Whitney U Test results indicated significant differences between the restoration and crown treatments in several USPHS criteria at the end of the study period. Restorations performed worse compared to crowns in terms of caries ($Z = -2.369$, $P = 0.018$), surface texture ($Z = -2.338$, $P = 0.019$), and marginal integrity ($Z = -2.752$, $P = 0.006$). Marginal discoloration showed boarderline significance ($Z = -1.935$, $P = 0.053$). In contrast, crowns scored worse than restorations in periodontal assessment, with more teeth in the crown group having experienced increased bleeding on probing and slight increase in pocket depth ($Z = -2.145$, $P = 0.032$), as well as in periapical infection ($Z = -2.281$, $P = 0.023$).

The Wilcoxon Signed-Rank Test demonstrated that several USPHS criteria scores significantly worsened over the study period for restorations. Specifically, significant changes were observed in caries ($Z = -2.041$, $P = 0.041$), margin discoloration ($Z = -2.714$, $P = 0.007$), marginal integrity ($Z = -2.220$, $P = 0.026$), and fractures ($Z = -2.121$, $P = 0.034$). In contrast, no significant changes were observed in the crown group over the course of the study.



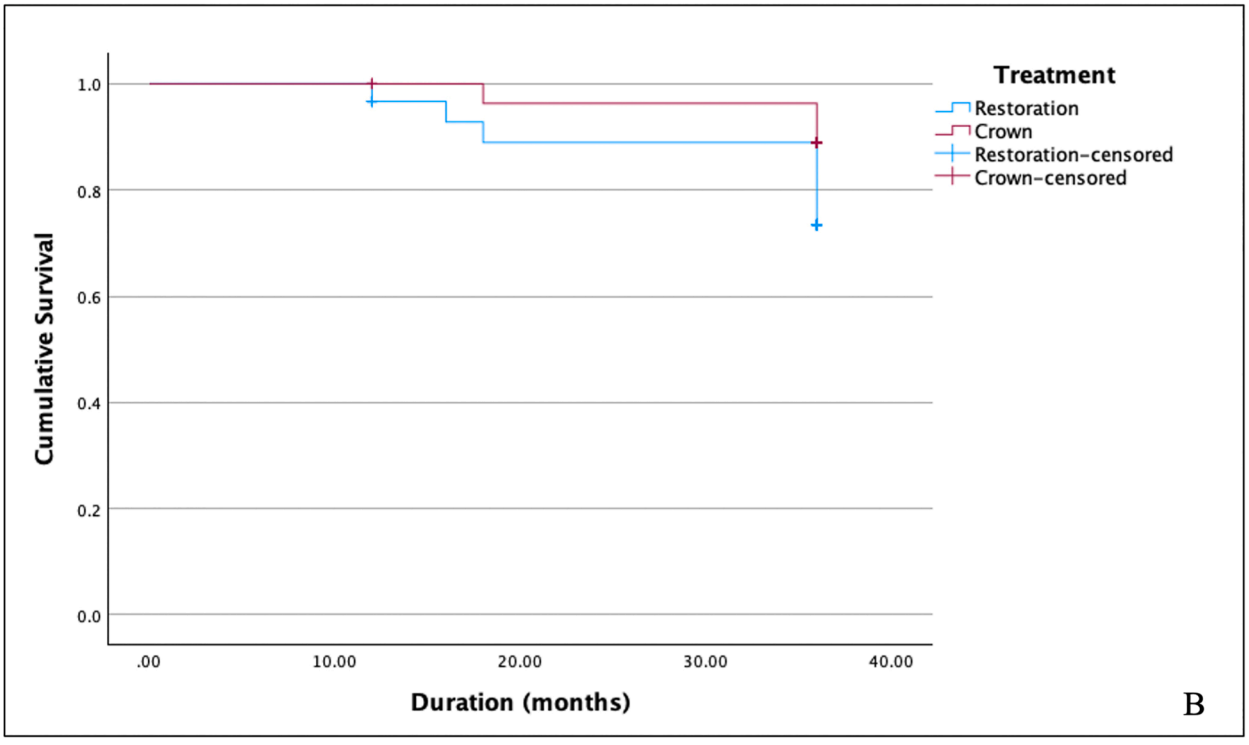


Fig. 3. Kaplan-Meier survival rates (A) and success rates (B) for endodontically treated molar teeth restored with direct composite resin restorations and metal-ceramic crowns over a three-year follow-up period.

4. Discussion

To the knowledge of the authors, this is the first randomized clinical trial specifically focused on endodontically treated molar teeth with minimal tooth structure loss, comparing direct composite resin restorations to metal-ceramic crowns. The findings showed no significant difference in the overall three-year survival or success rates between the two treatment modalities; therefore, the null hyposthesis was accepted. However, composite resin restorations demonstrated less favorable clinical performance over time compared to crowns.

The comparable survival rates observed for direct restorations and crowns in the current study differ from previous research, which often reported significantly better outcomes for crowns [6–10,26]. For instance, Aquilino and Caplan [8] found that ETT not restored with

Table 2
Results of the Cox proportional hazards model analysis for factors influencing the survival of endodontically treated molar teeth restored with direct composite resin restorations or metal-ceramic crowns.

Factor	HR	95 % CI	p-value
Treatment type (crown vs restoration)	0.1	0.0 to 1.2	0.068
Gender (male vs female)	1.3	0.2 to 8.5	0.803
Age	1.0	0.9 to 1.1	0.635
Jaw (maxilla vs mandible)	2.0	0.4 to 10.3	0.391
Tooth (first molar vs second molar)	0.5	0.0 to 3.6	0.237
Adjacent tooth (one proximal contact vs two contacts)	0.7	0.1 to 8.6	0.758
Lateral forces (present vs absent)	9.4	0.4 to 234.1	0.173
Parafunctional habits; bruxism (present vs absent)	12.8	1.2 to 133.3	0.032*
Cavity type (occlusal vs occlusal proximal)	. 0.5	0.073 to 3.4	0.486

HR: Hazard ratio.
CI: Confidence interval.
* Statistical significance.

crowns were lost at a rate six times higher than those restored with crowns. However, most existing research on ETT survival were retrospective cohort studies, which often did not take into account variations in tooth conditions, particularly the amount of remaining tooth structure before restoration [29]. The differing results in the present study may be attributed to the strict inclusion criteria, which included only teeth with minimal structural loss. This possibly minimized the typical advantages of crowns over direct restorations in providing structural support [30].

The findings from the current study are similar to those of Mannocci et al. [22], who studied endodontically treated premolar teeth with minimal structural loss and found no significant differences in survival rates between teeth restored with restorations and those restored with crowns [24]. Although the present study focused on molar teeth, which are subject to higher occlusal loads and are generally more prone to fractures and secondary caries compared to premolars, the results suggest that composite restorations could also be a viable option for molars when the tooth structure loss is minimal [9].

Failures in the direct restoration group were mainly due to caries and fractures, all requiring restoration replacement. Skupien et al. [13] reported similar complications but repaired the restorations instead of replacing them. In our study, replacement allowed reassessment of the remaining tooth structure to choose the best treatment option. In the crown group, failures were due to endodontic problems. One tooth required retreatment, and another was extracted. While some studies excluded such failures from their analyses, we included them, as crowns complicated endodontic retreatment by requiring complete removal to access the canals [22]. In contrast, direct restorations would have allowed easier access for root canal treatment without full restoration removal. It is worth noting that, without these endodontic complications, which are unrelated to the restoration type, the crown survival rate could approach 100 %.

Among the factors tested for their impact on survival rates, parafunctional habits like bruxism were found to be the only significant predictor of failure. ETT inherently require more load than vital teeth to elicit a proprioceptive response, which reduces their natural defense against masticatory forces [31]. Cuspal coverage offers more favorable load distribution than direct restorations and therefore could be less susceptible to fracture in patients with bruxism [32]. The use of protective measures such as occlusal splints is essential for improving restoration survival in these patients [33].

Neither gender nor age significantly affected tooth survival, consistent with existing literature [11,34]. The location of the teeth in the maxillary or mandibular arches, as well as whether they were first or second molars, did not influence survival rates, which is in contrast with other studies that reported worse survival for teeth located more posteriorly [8,34]. Additionally, although previous research suggested that a higher number of proximal contacts may increase survival, our findings showed no significant impact, likely because all included teeth had at least one proximal contact [35,36]. There were also no differences in survival between teeth with three axial walls versus those with four, despite the potential weakening from the loss of one marginal ridge [4].

In terms of performance, despite the comparable success rates for both treatment options, direct composite resin restorations demonstrated higher incidences of caries, marginal discoloration, loss of marginal integrity, and fractures, suggesting they are more prone to deterioration and breakdown over time. Conversely, crowns demonstrated greater stability but were associated with poorer periodontal health, likely due to suboptimal contouring or increased difficulty in maintaining hygiene around the margins. These findings align with

Table 3
USPHS and periodontal probing ratings at baseline and review appointment for participants who completed the study ($n = 53$). Group 1: Direct Restorations, Group 2: Crowns.

	Group	Baseline Alpha	Baseline Bravo	Baseline Charlie	Baseline Delta	Review Alpha	Review Bravo	Review Charlie	Review Delta
Caries	1	25 (96.2)	1 (3.8)	0 (0.0)	0 (0.0)	21 (80.8)	2 (7.7)	0 (0.0)	3 (11.5)
	2	27 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	27 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)
Margin Discoloration	1	20 (76.9)	6 (23.1)	0 (0.0)	0 (0.0)	14 (53.8)	10 (38.5)	1 (3.8)	0 (0.0)
	2	24 (88.9)	3 (11.1)	0 (0.0)	0 (0.0)	21 (77.8)	6 (22.2)	0 (0.0)	0 (0.0)
Surface Texture	1	26 (96.3)	1 (3.7)	0 (0.0)	0 (0.0)	19 (73.1)	7 (26.9)	0 (0.0)	0 (0.0)
	2	29 (96.7)	1 (3.3)	0 (0.0)	0 (0.0)	26 (96.3)	1 (3.7)	0 (0.0)	0 (0.0)
Margin Integrity	1	22 (84.6)	4 (15.4)	0 (0.0)	0 (0.0)	16 (61.5)	6 (23.1)	2 (7.7)	2 (7.7)
	2	26 (96.3)	1 (3.7)	0 (0.0)	0 (0.0)	25 (92.6)	2 (7.4)	0 (0.0)	0 (0.0)
Colour	1	14 (53.8)	12 (46.2)	0 (0.0)	0 (0.0)	14 (53.8)	12 (46.2)	0 (0.0)	0 (0.0)
	2	11(40.7)	15 (55.6)	1 (3.7)	0 (0.0)	11 (40.7)	15 (55.6)	1 (3.7)	0 (0.0)
Fractures	1	25 (96.2)	1 (3.8)	0 (0.0)	0 (0.0)	21 (80.8)	0.00 %	0.00 %	5 (19.2)
	2	27 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	26 (96.3)	1 (3.7)	0 (0.0)	0 (0.0)
Periapical Infection	1	25 (96.2)	1 (3.8)	0 (0.0)	0 (0.0)	27 (100)	0 (0.0)	0 (0.0)	0 (0.0)
	2	26 (96.3) ***No BOP, pocketing < 3.5***	1 (3.7) ***BOP, pocketing < 3.5***	0 (0.0) ***Pocketing < 5.5mm***	0 (0.0) ***Pocketing > 5.5mm***	22 (81.5) ***No BOP, pocketing < 3.5***	3 (11.1) ***BOP, pocketing < 3.5***	0 (0.0) ***Pocketing < 5.5mm***	2 (7.4) ***Pocketing > 5.5mm***
Periodontal examination	1	4 (15.4)	22 (84.6)	0 (0.0)	0 (0.0)	5 (19.2)	20 (76.9)	1 (3.8)	0 (0.0)
	2	1 (3.7)	26 (96.3)	0 (0.0)	0 (0.0)	0 (0.0)	25 (92.6)	2 (7.4)	0 (0.0)

previous studies showing that crowns perform better overall than direct restorations [13].

However, a significant biological cost is associated with crown preparation, and they are more expensive than direct restorations [19]. Therefore, offering patients a choice between a crown and a direct restoration, when clinically appropriate, can help tailor treatment to their needs. The decision should consider individual patient and tooth-specific factors, including the extent of structural loss, occlusal forces, the prognosis of endodontic treatment, and financial considerations [26]. Other options, like partial coverage restorations, might provide a balance by protecting the tooth while removing less of its structure [37–39]. More research comparing restorations, full crowns, and partial coverage restorations would be of significant value.

This study had several strengths that enhance the reliability of its findings. Including only one restoration per participant helped to prevent clustering effects. Additionally, unlike other studies with broader inclusion criteria, this study focused specifically on molars with minimal structural loss, allowing for a more accurate assessment of restorative outcomes while minimizing potential confounding factors [13]. This approach aligned with the recommendations of several systematic reviews, which emphasized the need for clinical trials to control variables such as coronal tooth structure, tooth type, and baseline characteristics to accurately assess the influence of restoration type on the survival and success of endodontically treated posterior teeth [26,29,40].

The study also had limitations such as the inability to blind participants and examiners due to the nature of the interventions [25]. Additionally, the study did not employ a stratified randomization technique, which is recommended for small sample sizes to ensure a balanced distribution of baseline variables, such as endodontic prognosis and bruxism [41]. The lack of follow-up data from the participants who dropped out means their potential outcomes are unknown and may have introduced attrition bias, as these individuals were not included in the analyses. However, the dropout rate was relatively low and accounted for in the sample size calculation, and was similar between the two groups. The three-year follow-up may not fully reflect long-term survival patterns and complications. Extending the follow-up period and increasing the sample size through multicenter studies would enhance the generalizability of the findings and provide a more comprehensive evaluation of long-term outcomes.

5. Conclusion

For endodontically treated molar teeth with minimal structural loss, both composite restorations and metal-ceramic crowns showed comparable survival and success rates after three years. However, crowns were more durable and stable over time. Bruxism was associated with an increased risk of failure. Composite restorations remain a viable option for teeth with minimal structural loss, favorable occlusal loads, budget constraints, and when a longer observation period is needed for potential future endodontic intervention.

Funding

This work was supported by the Deanship of Academic Research at the University of Jordan, Amman, Jordan

CRediT authorship contribution statement

Motasum Abu-Awwad: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Ruba Halasa:** Writing – original draft, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Laila Haikal:** Writing – original draft, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Ahmad El-Ma'aita:** Writing – review & editing, Validation, Resources, Data curation, Conceptualization. **Mohammad Hammad:** Writing – review & editing, Validation, Resources, Data curation, Conceptualization. **Haralampos Petridis:** Writing – review & editing, Visualization, Validation, Supervision, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors would like to thank Dr Sirin Shaban and Dr Nour Daas for their valuable input and help in the manuscript.

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