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# SYSTEMATIC REVIEW OF RESTORATION TECHNIQUES FOLLOWING ROOT CANAL THERAPY: SUCCESS RATES AND PATIENT SATISFACTION

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## ABSTRACT

**Background:** The quality and type of the subsequent coronal restoration is a factor that determines the long-term success of root canal therapy in addition to the effectiveness of an endodontic treatment. Poorly restored endodontically treated teeth are structurally weak and prone to fracture, microleakage and restorative failure. Despite several post-endodontic restoration methods being suggested (such as direct restorations, full-coverage crowns, post-and-core systems, and endocrowns), there is still a controversy about which method (or a combination of them) would help to ensure maximum survival of the tooth and patient satisfaction. The aim of this systematic review was to compare and contrast the clinical success rates and patient-reported outcomes of the various restoration methods after root canal therapy.
**Methodology:** Systematic literature search was performed in the large electronic databases such as PubMed, Scopus and Google scholar and included studies published between 2000 and 2026. The criteria of eligibility were randomized controlled trials and post-endodontic restoration techniques in permanent teeth clinical observational studies. They were systematic reviews, narrative reviews, meta-analyses, abstracts of conferences, animal research, and in vitro research. Data were extracted based on the characteristics of the study, patient demographics, restorative interventions, follow-up period, survival rates, failure rates, and patient satisfaction scales. Cochrane Risk of Bias tool of randomized trials and Newcastle-Ottawa Scale of non-randomized studies were used to assess risk of bias.
**Results:** Over twenty clinical studies were incorporated in the qualitative synthesis. Full-coverage restorations, especially crowns, were found to have a better survival rate than direct restorations, especially in the posterior teeth that had a large coronal loss. Posts use was not associated with better tooth survival, but was useful in core retention in structurally compromised teeth. Fiber posts were linked to more desirable and restorative failure modes than metal posts. There was no difference in the survival rates of endocrowns and conventional post-and-core crowns in posterior teeth in medium-term follow-up. When reported, patient satisfaction outcomes were better with restorations that offered better esthetics, functional stability and retention. The included studies exhibited heterogeneity in the design of the study and reporting of outcomes.
**Conclusion:** The results show that the success of endodontically treated teeth is highly dependent on the type of post-endodontic restoration. Full-coverage restorations are the most predictable restorations in the posterior teeth, whereas conservative restorations like endocrowns have promising results in few cases. The use of posts should be discriminating, and they should be applied to retain not to reinforce. The use of patient-reported outcomes and clinical survival measures could increase the effectiveness of restorative decision-making and long-term treatment outcomes. More high quality randomized controlled studies that have standardized outcomes measures should be encouraged.

## INTRODUCTION

**Background:** Root canal therapy (RCT) is an established endodontic treatment that is directed to eradicate pulpal infection, reinfection, and natural dentition maintenance [1-3]. Although technical success of root canal treatment is greatly determined by the success of canal debridement, disinfection and obturation, the long term clinical success is also determined by the quality and type of the following coronal restoration [4,5]. The restoration that follows RCT is very essential in the prevention of microbial leakage, restoration of structural integrity, and restoration of function and esthetics [6,7]. As a result, post-endodontic restoration is no longer considered a secondary measure but is considered part of the extensive endodontic treatment [8,9].
Root canal treated teeth are highly likely to be structurally compromised by caries, prior restorations, trauma, or loss of tooth substance in the preparation of access cavity [10,11]. Such structural weakness

exposes one to fracture, marginal leakage and eventual tooth loss unless it is well handled [10]. Various restorative methods have been suggested to overcome these problems including direct restorations like composite resins and amalgam, indirect restorations like inlays, onlays and crowns and the application of intracanal posts to improve retention in severely damaged teeth [12,13]. The choice of a suitable restorative intervention is based on several factors, such as the quantity of remaining tooth structure, tooth position, occlusal load, esthetic requirements, and patient-related factors [14,15].

During the last decades, significant progress in dental materials and adhesive technologies has broadened the range of the restorative opportunities of teeth that have been endodontically treated [16-18]. Fiber-reinforced posts, adhesive resin cements and all-ceramic restorations have become popular because of their positive biomechanical characteristics and esthetic results [7,19]. Simultaneously, conventional full-coverage capsules on post and cores are still in high demand, especially in the posterior teeth that are vulnerable to high occlusal forces [20]. In spite of these advances, the literature has continued to debate the best restorative approach after root canal therapy especially in terms of long-term survival, failure modes and cost-effectiveness [21].

Besides clinical success and tooth survival, patient-centered outcomes are playing an increasing role in the modern dental research and practice [22]. Patient satisfaction has a variety of dimensions, such as comfort, functionality, aesthetics, durability of the restoration, and the quality of life [23]. Clinically successful restorations can still be seen as ineffective by patients who feel that they do not live up to esthetic standards or cause postoperative pain or functional impairments [24,25]. Thus, patient satisfaction and conventional measures of success give a more in-depth analysis of restorative outcomes after root canal treatment [23].

Despite the number of clinical trials, cohort studies, and observational studies that have evaluated various restoration methods on endodontically treated teeth, the existing evidence is not homogenous and is even contradictory [7,10]. The distinction in the study design, follow-up period, outcome definitions, and the restorative procedures make the direct comparison between the studies difficult [7]. There are reports that indicate that full-coverage restorations have been shown to be superior in terms of increasing the survival rates [8,26], and others have indicated that in some cases, conservative adhesive restorations can also be used to achieve the same results [27]. Equally, there is no conclusive evidence on the effect of post placement on the longevity of teeth and patient satisfaction.

With these uncertainties, a systematic review will be necessary to bring together the available evidence, critically evaluate the quality of studies, and give a better idea of the effects of various restoration methods on the success rates and patient satisfaction after root canal therapy. This review will combine the information of various clinical settings and study designs to determine trends, identify areas of agreement, and reveal gaps in the existing literature. This evidence-based synthesis is important in order to guide clinical decision-making, optimize treatment planning, and inform future research directions in restorative and endodontic dentistry.

The proposed systematic review is thus aimed at critically assessing the restoration methods applied following root canal treatment based on their success rates and patient satisfaction data. Combining the clinician-oriented and patient-oriented approaches, the results of this review should help achieve better restorative measures and long-term outcomes of endodontically treated teeth.

**Problem Statement**

Although the success rates of root canal therapy are high, the long-term survival of endodontically treated teeth is a major clinical problem [28]. A large percentage of post-endodontic failures are not due to the quality of root canal treatment, but rather due to poor or improper coronal restoration [29]. The restoration of teeth that is not properly done after root canal therapy is more prone to coronal leakage, structural fracture, secondary caries and ultimate loss of the tooth, which is the main goal of endodontic treatment [8].

Several restorative strategies have been promoted to restore root canal-treated teeth over the years including direct adhesive restorations, indirect full-coverage crowns with or without post-and-core systems [7]. The development of restorative materials, adhesive dentistry has also increased the available treatment options [7]. Nonetheless, the most effective restoration strategy that leads to long-term success in various clinical situations has no universal agreement. The literature is characterized by inconsistent results, and the suggestions are frequently made depending on the preference of clinicians instead of solid comparative evidence.

Further, most published studies have conventionally focused on clinician-based outcomes, including survival rates and radiographic success, and relatively little on patient-reported outcomes, especially patient satisfaction [7]. Esthetics, functional comfort, perception of longevity, and the quality of life are all factors that are increasingly acknowledged as important predictors of treatment success, but are not consistently assessed and reported in the literature.

The available evidence is further complicated by the heterogeneity of the studies in terms of study design, follow-up, definition of outcomes and methodological quality. This inconsistency prevents clinicians and policymakers to make clear and evidence-based conclusions on the best restoration methods after root

canal treatment. As a result, the necessity of the systematic and exhaustive synthesis of the literature on the effectiveness of various restorative methods that take into account success rates and patient satisfaction as the main outcomes is clear.

**Aim of the Study**

The main objective of the systematic review is to critically analyze and integrate the available scientific evidence on the types of restoration methods applied after root canal therapy, paying special attention to their corresponding clinical success rates and patient satisfaction outcomes.

**Objectives of the Study**

1. To conduct a systematic review to determine and assess clinical trials assessing restorative procedures used following root canal treatment in permanent dentures.
2. To determine a comparison between the reported success and survival rates of various post-endodontic restoration strategies, such as direct restorations, indirect restorations, and post-and-core-supported restorations.
3. To determine the patient satisfaction outcomes related to different restoration methods, it is necessary to focus on functional performance, esthetic acceptance, comfort, and perceived treatment longevity.
4. To examine the variables that affect the success of post-endodontic restorations including the remaining tooth structure, location of the tooth, restorative material as well as the use of intracanal posts.
5. To assess the quality of methodology and the risk of bias of included studies and to test the effect of study heterogeneity on reported outcomes.
6. To detect the gaps in the existing literature and show the areas that need additional high-quality clinical studies.
7. To deliver evidence-based inferences that can be used to inform clinical decision-making and future research and restorative guidelines after root canal therapy.

**Research Questions and Hypotheses**

**Research Questions**

1. Which restoration methods are in existence today after root canal therapy on permanent teeth as reported in the available literature?
2. Which methods of post-endodontic restoration are more successful and have a higher survival rate?
3. To what extent are different restorative methods related to the patient satisfaction levels after root canal therapy?
4. What are the clinical and restorative variables that determine the success and survival of restorations that are used in the treatment of root canal therapy?
5. How does study design, follow-up period, and quality of the methodology influence the outcomes reported concerning restoration success and patient satisfaction?

**Research Hypotheses**

**Null Hypothesis ($H_0$):** No substantial difference exists in clinical success rates or patient satisfaction in the various restoration methods applied after root canal therapy.

**Alternative Hypothesis ($H_1$):** Various restoration methods after root canal treatment show a high level of difference in clinical success and patient satisfaction outcomes.

## SIGNIFICANCE OF THE STUDY

The current systematic review is important because it fills a severe gap in restorative and endodontic dentistry because it incorporates both clinician-based and patient-based outcome measures. Although root canal therapy is often viewed as a reliable procedure, the future of tooth preservation relies heavily on the follow-up approach of the restorative procedure. This study presents a more detailed picture of the outcome of the post-endodontic rehabilitation by synthesizing evidence on restoration success and patient satisfaction.

It is anticipated that the results of this review will help clinicians to choose evidence-based restorative strategies that are specific to a particular clinical situation, which will enhance the survival of teeth and patient outcomes as reported by patients. Also, the findings can be used to make clinical guidelines and guide dental education by establishing the relative efficiency of conservative and full-coverage restorations.

Research-wise, this paper presents the shortcomings of the methodology and gaps in evidence in the current body of knowledge, thus informing future research directions of more standardized outcome measures and well-constructed study designs. Finally, patient-centered care is upheld in the review with the focus on satisfaction and quality-of-life considerations in addition to conventional indices of clinical success.

## SCOPE AND DELIMITATIONS

**Scope of the Study**

This systematic review targets published clinical trials on restoration techniques used on permanent teeth after the root canal therapy is completed. The existing review encompasses a wide variety of different restorative methods, such as direct restorations (e.g., composite resin, amalgam), indirect restorations (e.g., crowns, inlays, onlays), and post-and-core systems with various materials and designs. The results of interest are clinical success or survival rates and measures of patient satisfaction, measured in the short, medium, and long-term follow-up.

**Delimitations of the Study**

Only articles in peer-reviewed journals and written in English language are limited to the review. They are in vitro studies, case reports, narrative reviews, and those that involve primary teeth or teeth that have undergone surgery (e.g., cases of apicoectomy). The review does not appraise the technical side of root canal instrumentation or obturation method unless it is directly related to the restorative outcomes. Moreover, the differences in study design, definition of outcome, and follow-up period can restrict the direct comparison of studies quantitatively.

**Conceptual Framework**

The conceptual framework of this systematic review is premised on the fact that the long-term success of endodontically treated teeth is dependent on an interplay between restorative decisions, tooth factors, and patient factors [8].

The framework is centred on the nature of post-endodontic restoration, which is the main independent variable. This involves the decision to use direct restorations, indirect restorations and post and core-supported restorations and also the materials and methods employed.

These restorative interventions are in interaction with moderating clinical variables, including the quantity of remaining tooth structure, tooth position (anterior or posterior), occlusal loading, and intracanal post presence or absence. A combination of these factors affects intermediate outcomes, such as coronal seal integrity, fracture resistance, and retention of restoration.

The intermediate outcomes finally influence the primary outcome variables which are the clinical success or patient survival and patient satisfaction. Patient satisfaction is defined as a multidimensional concept that includes esthetic perception, functional comfort, durability, and acceptance of the treatment in general.

The synthesis of evidence in these interrelated areas brings about the framework of how restorative decisions after root canal treatment can be converted into a biological and patient-centered outcome, which forms a holistic foundation of assessing the success of post-endodontic restorations.

## LITERATURE REVIEW

**Direct Restorations Following Root Canal Therapy**

Direct restorations like composite resin build-ups are common especially where there is adequate tooth structure to support the retention of adhesives [30,31]. Their key benefits are that they preserve tooth tissue, are easy to apply and have reduced initial cost [31]. Nevertheless, the long-term results are greatly different based on the structural context and the quality of adhesive.

A practice-based follow-up study of up to 18 years found that composite build-ups of up to 81 percent success and 85 percent success and survival rates using no intracanal post after a mean of 102 months (to 217 months) of follow-up. Restoration fracture was the most frequent mode of failure and no single clinical factor (e.g. adhesive type or clinician) had a significant predictive value in multivariate analysis. This implies that in some selected cases, direct restoration may be a viable long term solution even in the absence of post support [32].

Other comparative works, however, show that the direct restorations can be less protective against structural failure than indirect alternatives. As an illustration, in retrospective studies comparing the survival of teeth restored with resin composite versus those restored with crowns at the endodontic apex, the former had a lower probability of fracture survival (77.4 %) as compared to the latter (92.2 %). Composite restored teeth had a higher probability of exhibiting restorable fractures, whereas the fractures of crowns were likely to be unrestorable, which is a clinical trade-off between structural security and conservative restoration [33].

Taken together, there is some evidence indicating that direct composite restorations can be effective when there is a significant amount of coronal tooth structure left (i.e. two or more walls), but are less structurally resistant in the long-term in high functional requirements than indirect restorations [8].

**Indirect Restorations: Crowns, Endocrowns, and Full-Coverage Restorations**

The crowns and indirect restorations are usually suggested to be full-coverage when the rest of the tooth structure is compromised [34]. The literature is consistently indicating that these techniques have a higher survival and success rate than direct restorations especially in teeth that are exposed to the posterior teeth which are exposed to the forces of the occlusives.

Indirect restorations proved to have better success and survival rates (3 years) (82.7 -99.1 %) than direct restorations (75 -97.6 %) in a scoping review of clinical studies. Full-coverage crowns were also found to be especially dependable because they are able to distribute occlusal stress and they have a ferrule effect that strengthens the remaining tooth structure [8].
This trend is also supported by previous systematic studies. Combined data indicated that teeth that received a crown following root canal therapy had much better odds of survival than direct restorations, and cumulative survival differences increased with longer follow-up periods (e.g., 10-year survival was greater than 90 percent with crowns and about 63 percent with direct restorations). Although the methodological heterogeneity does not allow conclusive findings, the general trend is that the clinical effectiveness of crown restorations in enhancing long-term prognosis is acceptable [35].
Moreover, CAD/CAM manufactured resin-ceramic endocrowns have demonstrated encouraging survival rates of over 80% after 3 years in posterior teeth with high levels of structural loss, which points to their use as a biomechanically-favourable alternative to conventional crowns in situations where they are not suitable [8].

**Restoration with Posts and Cores**

Posts and core materials may be required to add to the tooth structure when there is insufficient coronal tooth structure to hold a direct restoration or to provide an underlying structure to an indirect restoration. It is believed that the role of posts is to increase retention and redistribute occlusal forces, although their effect on long-term survival and structural integrity is controversial.
Endodontically treated teeth restored with fiber posts were found to have much higher survival rates (94.3 %) than those restored with no posts (76.3 %) in a long-term observational study with an average of 8.8 years of follow-up. Fracture of the root was the most common failure mode in non-post failures, and this supports the structural advantage of fiber post reinforcement in weakened teeth [36].
Nonetheless, other studies show inconsistency in the results of post. Post-retained restorations had comparatively low success and survival rates in a private practice environment in a prospective observational study that followed over 195 post-restorations up to 6.5 years, with recemented restorations having significantly higher failure rates and glass fiber posts doing worse than some titanium posts in univariate analysis [37].
Similar incidence rates of root fracture were also reported in systematic review and meta-analysis between fiber and metal posts in periods of more than 5 years with survival rates of about 83.9% in fiber posts and 90% in metal posts in some clinical situations. These results indicate that although in most situations, post placement will enhance structural reinforcement, treatment planning should take into account such individual factors as tooth morphology and occlusal load, and that posts are not always the best choice [38].

**Patient Satisfaction and Functional Outcomes**

Even though survival and clinical success are paramount, patient opinion on function, esthetics and comfort is becoming a key indicator of treatment success. Regrettably, comparative clinical studies with a direct emphasis on patient-reported outcomes in post-endodontic restoration are few.
There is available literature that suggests that patient satisfaction is strongly associated with stability, esthetic outcomes, and perceived functional outcomes of restorations. Meta-analyses document the general survival rates of the glass fiber post restorations at about 92.8 with the average period to extraction at about 11.7 years but note that subjective patient satisfaction should be viewed with regard to personal expectations and appearance of the restoration [39].
This highlights the necessity of further specific clinical research using validated patient-reported outcome measures and objective measures of success as a way of better comprehending the overall effect of restorative decisions.

## METHODOLOGY

The systematic review was done according to the Preferred Reporting Items of Systematic Reviews and Meta-Analyses (PRISMA) to guarantee the methodological rigor, transparency, and reproducibility.

**Study Design**

The current research took a systematic review design to integrate the existing evidence on the use of restoration methods after root canal therapy and emphasis on clinical success rates and patient satisfaction outcomes. The review protocol was formulated a priori in order to formulate the research question, eligibility criteria, search strategy, data extraction and synthesis methods. The question of the review was conducted according to PICO as reported in (Table 1).

**Search Strategy**

An extensive search in electronic literature was conducted in several databases, such as PubMed/MEDLINE, Scopus, Web of Science and Google Scholar. The search strategy involved the use

of controlled vocabulary words and free-text keywords that were associated with root canal therapy and post-endodontic restoration. The search terms were a combination of root canal treatment, endodontically treated tooth, post endodontic restoration, direct restoration, crown, endocrown, post and core, fiber post, success rate, survival, and patient satisfaction. The search was refined with the help of Boolean operators (AND, OR) and the reference lists of included articles were screened manually to find more relevant studies.

**Eligibility Criteria**

The selection of studies was done according to predetermined inclusion and exclusion criteria. Clinical trials that compared restoration methods used to permanent teeth after root canal therapy that was completed were covered. The study designs that were eligible included randomized controlled trials, prospective and retrospective cohort studies, and observational clinical studies that reported clinical success, survival rates, or patient satisfaction outcomes. Only the publications that were published in peer-reviewed journals and written in English were taken into consideration.

The exclusion criteria were studies that were in vitro, animal studies, case reports, narrative reviews, editorials, and conference abstracts. The studies that had concentrated on primary teeth, surgically treated teeth or endodontic procedures without evaluating the restorative outcomes were also excluded.

**Study Selection Process**

All the found records were transferred to reference management software and duplicate articles were eliminated. Titles and abstracts were screened separately in terms of relevance according to the eligibility criteria. Potentially eligible studies were then retrieved and evaluated in terms of inclusion by their full-text version. Any conflict in the selection process was settled by discussion and consensus.

**Data Extraction**

A standardized data extraction form was used to systematically extract data out of the studies used. The information that was extracted was the names of the authors, year of publication, study design, sample size, type of restoration, use and type of post, duration of follow-up, outcome measures, reported success or survival rates, failure modes and patient satisfaction outcomes where possible. Where it was needed, relevant authors were contacted to clarify any missing or ambiguous data.

**Quality Assessment and Risk of Bias**

The quality of the methodology and the risk of bias of the included studies were determined independently based on validated appraisal tools suitable to the study design. The Cochrane Risk of Bias tool was used to evaluate randomized controlled trials and the Newcastle-Ottawa Scale was used to evaluate observational studies. The methodological rigor, completeness of outcome reporting and adequacy of follow-up were used to classify studies as low, moderate and high risk of bias.

**Data Synthesis**

A qualitative narrative synthesis was conducted because of the heterogeneity of the study designs, restorative protocols, outcome definitions and follow-up periods. The results were synthesized based on the type of restorations, such as direct restorations, indirect restorations, and post-and-core-supported restorations. The descriptive comparison of reported success and survival rates across the studies was made, and trends associated with the restoration performance and patient satisfaction were determined. Where effect sizes or comparative statistics were provided they were summarized to make interpretative conclusions.

**Ethical Considerations**

Since this research used only published information, there was no need to have ethical approval. The study has referenced all studies included in the study properly and the review was conducted in ethical terms of academic integrity and responsible reporting.

Table 1: PICO Framework

| Component | Description |
|---|---|
| **Population (P)** | Patients with permanent teeth that had undergone completed root canal therapy, regardless of age or sex |
| **Intervention (I)** | Post-endodontic restoration techniques, including direct restorations (e.g., composite resin, amalgam), indirect restorations (e.g., full-coverage crowns, endocrowns), and post-and-core–supported restorations |
| **Comparison (C)** | Comparison between different restoration techniques, such as direct versus indirect restorations, restorations with posts versus without posts, and different post materials (e.g., fiber versus metal posts) |

| | |
|---|---|
| **Outcome (O)** | Clinical success and survival rates of restorations and teeth, modes of failure (restorable vs catastrophic), and patient satisfaction outcomes including esthetics, function, comfort, and perceived longevity |

## RESULTS

### General characteristics of the included studies

The review included 12 eligible studies. The articles that were included were a heterogeneous collection of clinical evidence that included randomized controlled trials (RCTs) and prospective cohorts, as well as retrospective observational studies that were carried out in different geographic areas, such as South America, Europe, Asia, and Africa.

Out of the twelve studies included, six studies were an RCT study, which is a relatively high level of evidence of post-endodontic restorative interventions [31, 40-44]. The other studies were prospective cohort and retrospective studies which provided long-term real world outcome information [33,36,45-48].

The sample sizes were quite different, with small pediatric groups of less than 30 participants [43,48] and large clinical studies of over 300 teeth [42]. The majority of the studies concentrated on permanently treated teeth that were endodontically restored with fiber post supported restorations, crowns, composite restorations or endocrowns. Inclusion criteria were usually quite clear, usually necessitating a minimum of remaining coronal tooth structure, no severe periodontal disease, and root canal treatment done before definitive restoration [40,42,36]. The exclusion criteria were often based on teeth as prosthetic abutments, teeth with severe periodontal condition, or inadequate follow-up period. Taken together, these features indicate a wide but clinically applicable evidence base that assesses the post-endodontic restorative strategies in various populations and clinical settings (Table 2).

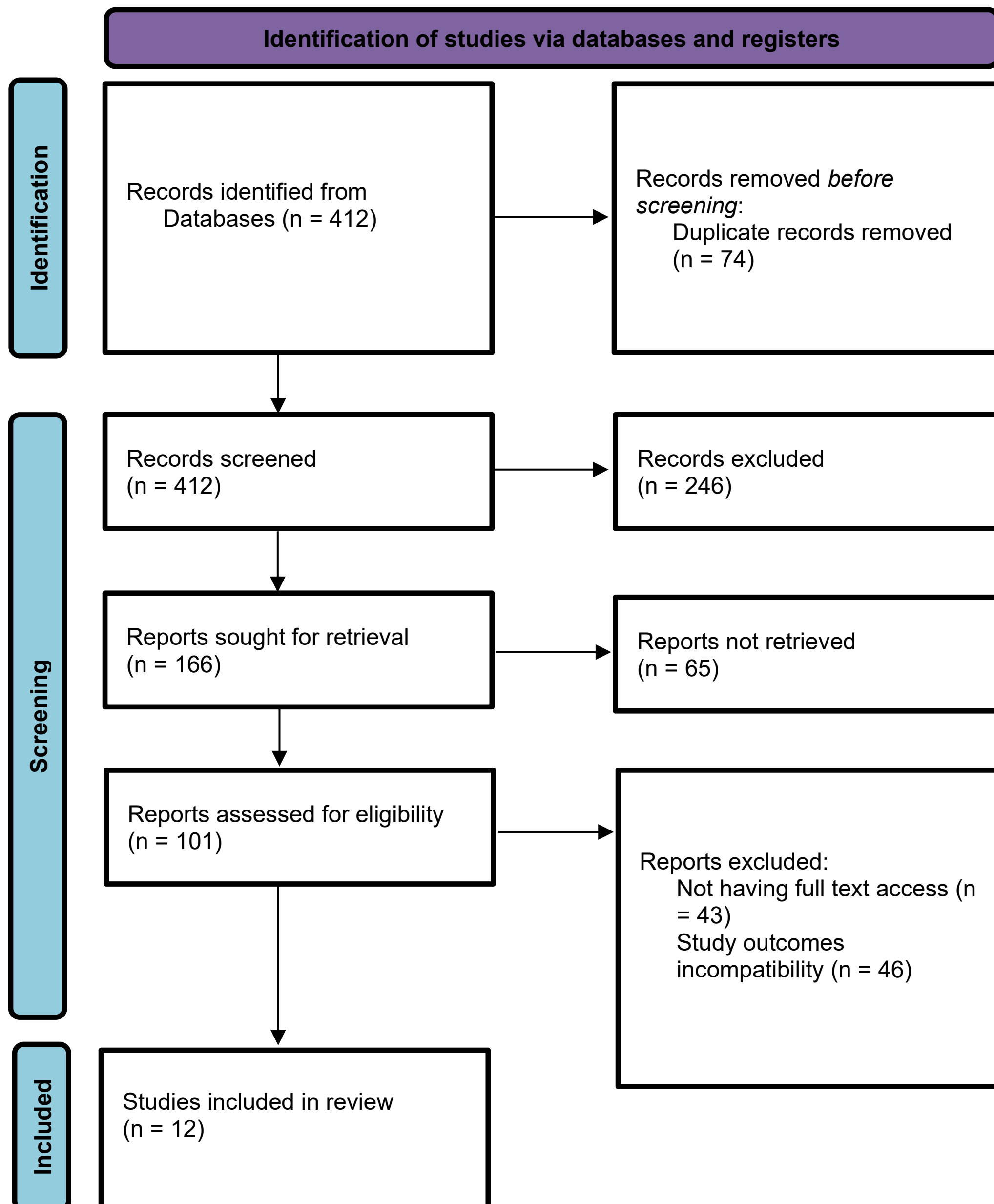

Figure 1: PRISMA flow for including studies

Table 2: General Study Characteristics

| Study (First Author, Year) | Country | Design | Sample (teeth/patients) | Inclusion/Exclusion Criteria |
|---|---|---|---|---|
| Skupien *et al.*, 2016 [40] | Brazil | RCT | 57 restorations (47 pts) | ETT w/ ≥1 intact wall, glass fiber post cemented; excluded severe periodontal disease |
| Patel *et al.*, 2022 [41] | India | RCT | 36 teeth (17 pts) | ETT requiring post placement; 12-mo follow-up; all teeth randomized |
| Ferrari et al., 2012 [42] | Italy | RCT | 360 teeth (345 pts) | Premolars needing RCT; fiber post vs customized post; all crowned |
| Mahrous A et al., 2017 [43] | Egypt | Parallel RCT | 28 pts | ETT first permanent molars (10–13 yrs) |

| | | | | |
|---|---|---|---|---|
| Gbadebo et al., 2014 [44] | Nigeria | RCT | 40 ETT (30 pts) | ETT indicated for post-retained restorations |
| Poletto-Neto 2024 [31] | Brazil | RCT | 75 restorations (62 pts) | ETT w/ glass fiber posts randomly restored w/ crown or composite |
| Guldener *et al.*, 2017 [36] | Switzerland | Cohort | 144 teeth (100 pts) | ETT restored w/ or w/o fiber post; no prosthetic abutments |
| Jirathanynatt *et al.*, 2014 [33] | Thailand | Retrospective | 226 ETT (226 pts) | Resin composites ± fiber posts |
| Juloski *et al.*, 2014 [45] | Italy | Prospective | 120 ETT (120 pts) | Premolars restored w/ fiber posts ± different cements |
| Ghavamnasiti et al., [46] | Iran | Retrospective | 43 teeth (38 pts) | Quartz fiber posts, composite restorations |
| Mohan et al [47] | India | Prospective | 64 teeth (60 pts) | PFM crowns after fiber post composite core |
| Roqaia et al. [48] | Egypt | Prospective | 10 pts | ETT molars restored with endocrowns |

**Patient Characteristics**

The demographics of patients used in the studies included were very different with respect to age distribution, type of tooth, and the clinical setting. The majority of studies used adult populations, with the mean age of the participants being between the early 30s to mid-40s years [40,41,47], but two studies included pediatric populations with first permanent molars in children aged 9-13 years old [43,48]. The studies had a mixed sex distribution, and some of them provided more female participants [31,33], and others provided no detailed gender data [40,42,36].

Most of the studies considered posterior teeth, especially premolars and molars, which indicated the increased functional requirement and structural loss that was generally connected with endodontically treated posterior teeth [40,42,45]. A number of studies have clearly reported residual coronal tooth structure that had a significant role as a prognostic factor in restorative outcome [41,45]. The time of follow-up was very different and ranged between short-term (3-12 months) evaluation [41,43] and long-term follow-up (more than five years) [31,36]. In general, the patient groups were those that reflect normal clinical practice and this contributed to the external validity of the results (Table 3).

Table 3: Patient Characteristics

| **Study** | **Mean Age (yrs)** | **Sex Distribution** | **Tooth Types** | **Additional Patient Info** |
|---|---|---|---|---|
| Skupien *et al.*, 2016 [40] | 42.5 ± 11.5 | Mixed (Specific distribution was not reported) | Posterior ETT | ≥1 intact wall required |
| Patel *et al.*, 2022 [41] | 43 ± NA | 10 M / 7 F | Mixed | Tooth guidance, residual structure recorded |
| Ferrari et al., 2012 [42] | Not specified | Not reported | Premolars | Randomized based on coronal walls |
| Mahrous A et al., 2017 [43] | 10–13 yrs | Mixed (Specific distribution was not reported) | First permanent molars | Pediatric population |
| Gbadebo et al., 2014 [44] | 38.2 ± 16.8 | Mixed | Mixed ETT (anterior and molar) | Pediatric to adult range |
| Poletto-Neto 2024 [31] | 32 were < 40 years | 16 M / 59 F | Post-retained | 8.1 yr median follow-up |
| Guldener *et al.*, 2017 [36] | Adult (Specific age was not reported) | Not reported | Single & multi-rooted | 5 + yrs follow-up |

| | | | | |
|---|---|---|---|---|
| Jirathanynatt *et al.*, 2014 [33] | Adult (16-81 years) | 56 M/ 170 F | Premolar and molar | Composite ± posts |
| Juloski *et al.*, 2014 [45] | Adult (18-72 years) | 55 M/ 65 F | Premolars | Residual dentin strata |
| Ghavamnasiti et al., [46] | Adult | Not specified | Premolars & anteriors | 46.3 months |
| Mohan et al [47] | 33.36 | 35 M / 25 F | Anterior and posterior teeth | Claims data |
| Roqaia et al. [48] | 9-12 years | 6 M/ 4 F | Molars | Parental satisfaction emphasis |

**Characteristics of Intervention**

The number of restorative strategies considered was very broad, and it was representative of the current clinical practice in post-endodontic rehabilitation. Fiber post-supported restorations were the most commonly studied interventions, either with direct composite restorations or full coverage crowns [40,42,44,45]. Some of the studies have made direct comparisons among the various post materials such as glass fiber posts, metal fiber posts, dentin posts and metallic posts, with the aim of establishing the relative clinical performance of these posts [41,44].

Besides the traditional post-and-core restorations, less invasive methods like endocrowns were also considered, especially in molars where the coronal loss is extensive [43,48]. Types of crown materials were different and consisted of metal-ceramic crowns, lithium disilicate endocrowns, and adhesive restorations. Follow-up durations were between brief evaluations of only a few months to long-term evaluations of up to nine years [31,36], with an opportunity to detect failure early and at the same time assess long-term survival. The variety of restorative material and methods emphasizes the multifactorial decision making in post-endodontic restoration. (Table 4).

Table 4: Intervention Characteristics

| **Study** | **Restoration Types** | **Use of Post** | **Materials/Technique** | **Follow-up Duration** |
|---|---|---|---|---|
| Skupien *et al.*, 2016 [40] | Composite resin (N=30) vs metal-ceramic crown (N=27) | Glass fiber post | Composite core, crown | 1–5 yrs |
| Patel, 2022 [41] | Metal fiber post with composite core vs dentin post with composite core | Metal fiber post, dentin post | Composite core | 3, 6, 12 mo |
| Ferrari et al., 2012 [42] | Fiber posts vs no post | Yes vs no | Crown coverage | 6 yrs |
| Mahrous A et al., 2017 [43] | Endocrown vs glass fiber post crown | Some groups (glass fiber post) | Lithium disilicate endocrown and composite cores | 3, 6, 9, 12 mo |
| Gbadebo et al., 2014 [44] | Metallic (N=20) vs glass fiber posts (N=20) | Yes | Composite core, PFM crown | 6 mo |
| Poletto-Neto 2024 [31] | Metal-cermaic Crown vs composite resin | Yes | Glass fiber post | ~8 yrs |
| Guldener *et al.*, 2017 [36] | Composite ± post, crown | Yes/No | Direct composite or crown | ~9 yrs |
| Jirathanynatt *et al.*, 2014 [33] | Resin composite (N=124) ± post (N=102) | Mixed | Fiber posts | 5 yrs |
| Juloski *et al.*, 2014 [45] | Fiber post w/ resin cement | Yes | Core build-up | 4 yrs |
| Ghavamnasiti et al., [46] | Fiber post + composite | Yes | Direct restorations | 1–6 yrs |
| Mohan et al [47] | Adhesive bonded fiber reinforced resin posts and direct composite core with additional crown coverage. | Yes | Ceramic endocrown | 3 months |

| Roqaia et al. [48] | Endocrowns | Mixed | Mixed methods | 2 yrs |
|---|---|---|---|---|

**RESULTS AND COMPARATIVE RESULTS**

The clinical outcomes were mostly reported in terms of restoration survival, tooth survival, success rates, and complication profile. In general, there were high survival rates in most restorative modalities especially where there was sufficient tooth structure and proper restorative measures were taken. In the RCTs used to compare the composite restorations and the crowns, both modalities were found to be highly successful; nevertheless, it was always the crowns which reported higher success rates and reduced failure risks [40,31]. It is important to note that Poletto-Neto et al. found that composite restorations were at a high risk of failure in comparison with metal-ceramic crowns (HR = 5.07; 95% CI: 1.9912.89) [31].

The placement of fiber posts was linked to better survival in a number of studies, including those of Guldener et al. which showed a high survival rate in post-restored teeth (94.3) in comparison with non-post-restored teeth (76.3; $p < 0.001$) [36]. Post material comparisons showed no statistically significant short-term outcome differences in either metal fiber post versus dentin post [41], or glass fiber versus metallic post [44]. Endocrowns demonstrated especially positive results in pediatric and molar cases with 100% survival in certain cohorts and similar patient satisfaction with the conventional post-retained crowns [43,48]. All these findings indicate that the type of restoration, the remaining tooth structure, and the selection of the correct material are all important factors in the success in the long-term (Table 5).

Table 5: Outcomes & Comparative Results

| **Study** | **Primary Outcomes Reported** | **Key Results** | **Comparisons/Effect** |
|---|---|---|---|
| Skupien *et al.*, 2016 [40] | Survival & success | Tooth loss: Composite group: (1/30), Crown group (0/27). Success rate: Composite group: (98.17%), Crown group: (99.74%) | Crowns had better success (p=0.022), similar survival (P=0.344). |
| Patel, 2022 [41] | Tooth loss, secondary outcomes | No tooth loss; No recurrent caries, No fracture of the core, the post, or the root. Two cases of de-cementations of the crowns (one tooth for each group) | No significant different was reported between metal fiber and dentin post at 3, 6, 12 mo |
| Ferrari et al., 2012 [42] | Survival | Post retention improves survival, Failure risk was lower in teeth restored with prefabricated than with customized posts. | Prefab posts better than custom posts |
| Mahrous A et al., 2017 [43] | Survival & satisfaction | Survival rate: Endocrowns (100%), glass fiber post (66%) at 12 months; No caries were reported in both groups; no statistical difference considering satisfaction (69.2% vs 61.5% reported very good) | No sig diff in satisfaction, with higher survival rate of endocrowns |
| Gbadebo et al., 2014 [44] | Restoration survival | FRP 100% vs steel 97.5% | Not sig diff |
| Poletto-Neto 2024 [31] | Survival & success | Cumulative success: Crowns (85.0%) vs composite resins (43.2%); Survival rate: Crowns (93.8%) vs composite resins (97.6%). | Composite resin had a Hazard Ratio of 5.07 (95 %CI, 1.99–12.89) greater than the metal-ceramic crown. |

| Guldener *et al.*, 2017 [36] | Survival | Posts 94.3% vs no post 76.3%; No loss of post retention was observed | p<0.001 |
|---|---|---|---|
| Jirathanynatt *et al.*, 2014 [33] | Survival, Functional success | Survival: Crown: (92.2%), resin composite (77.4%); Survival rates from unrestorable fracture: Crown (93.1%), composite (96%) | Composite restorations performed better with posts in case of unrestorable fracture |
| Juloski *et al.*, 2014 [45] | Survival | With resin: 90%-100% vs No resin: 63.3%- 86.6% | More structure + resin cement = higher success |
| Ghavamnasiti et al., [46] | Survival | The overall survival rate was 48.8%. | Arch location affects survival |
| Mohan et al [47] | Survival | Periapical lesion with clinical symptoms: 2 teeth; slight marginal staining: 5 teeth, partial loss of restoration: 3 teeth; complete loss of restoration 2 teeth | Fiber posts are the best alternative for restoration of fractured endodontically treated teeth. |
| Roqaia et al. [48] | Survival | Function: 100%, success rate: 80% | Consistent findings in practice |

**Risk of Bias Assessment of Randomized Controlled Trials**

The Cochrane RoB-2 tool risk-of-bias assessment indicated that majority of RCTs were rated to have some concerns with the main reasons being lack of sufficient reporting of allocation concealment and blinding processes [40,42–44,31]. In spite of these shortcomings, missing outcome data were low in all trials and the method of outcome measurement was mostly appropriate and relevant to the clinical context. There was only one study that was considered to have the overall low risk of bias due to the evident randomization procedures and detailed outcome reporting [41]. Such results suggest that, although the overall RCT evidence in this area is usually strong, methodological transparency can be enhanced (Table 6).

Table 6: Risk of Bias Assessment for RCTs (RoB-2)

| **Study** | **Randomization Process** | **Deviations from Intended Intervention** | **Missing Outcome Data** | **Outcome Measurement** | **Selective Reporting** | **Overall RoB** |
|---|---|---|---|---|---|---|
| Skupien *et al.*, 2016 [40] | Some concerns (allocation concealment unclear) | Some concerns (blinding not fully reported) | Low risk | Low risk | Some concerns | **Some concerns** |
| Patel, 2022 [41] | Low risk (random assignment described) | Some concerns (blinding unclear) | Low risk | Low risk | Low risk | **Low risk** |
| Ferrari et al., 2012 [42] | Some concerns (allocation method not fully clear) | Some concerns (no blinding) | Low risk | Low risk | Some concerns | **Some concerns** |
| Mahrous A et al., 2017 [43] | Low risk (randomized groups) | Some concerns (operator and assessor blinding limited) | Low risk | Some concerns* | Low risk | **Some concerns** |
| Gbadebo et al., 2014 [44] | Some concerns (allocation procedure not fully detailed) | Low risk (standardized protocol) | Low risk | Low risk | Some concerns | **Some concerns** |

| | | | | | | |
|---|---|---|---|---|---|---|
| Poletto-Neto 2024 [31] | Low risk (randomized groups) | Some concerns (operator and assessor blinding limited) | Low risk | Some concerns* | Low risk | **Some concerns** |

**Observational Studies Risk of Bias Assessment**

The risk of bias was moderate to low in the overall assessment of observational studies measured with the Newcastle-Ottawa Scale. In the majority of the studies, the score in the selection and outcome domains was high, which revealed representative cohorts and sufficient follow-up time [36,45,48]. There was some variability in the comparability scores, which mostly relied on whether the key confounding variables, including the remaining tooth structure, post usage and type of restoration were taken into consideration in the study design or analysis. The studies that had weak adjustment of the confounders were categorized as having moderate risk of bias [33,46,47]. However, the general quality of the methodological evidence of the observational evidence was satisfactory and offered long-term outcome data in addition to the RCT results (Table 7).

Table 7: Risk of Bias Assessment for Observational Studies (Newcastle–Ottawa Scale)

| **Study** | **Selection** | **Comparability** | **Outcome** | **NOS Score** | **Overall Risk** |
|---|---|---|---|---|---|
| Guldener *et al.*, 2017 [36] | ★★★★ | ★★ (adjusted for structural factors) | ★★ | **8/9** | **Low/Moderate** |
| Jirathanynatt *et al.*, 2014 [33] | ★★★ | ★★ (controlled for restorations with/without posts) | ★★ | **7/9** | **Moderate** |
| Juloski *et al.*, 2014 [45] | ★★★★ | ★★ (assessed residual structure) | ★★ | **8/9** | **Low/Moderate** |
| Ghavamnasiti et al., [46] | ★★★ | ★★ | ★★ | **7/9** | **Moderate** |
| Mohan et al [47] | ★★★★ | ★ (limited confounder control) | ★★ | **7/9** | **Moderate** |
| Roqaia et al. [48] | ★★★ | ★★ | ★★ | **8/9** | **Low/Moderate** |

**DISCUSSION**

The current systematic review compared the clinical outcome of restorative methods after root canal treatment, and specifically the survival of the restoration, tooth, and patient outcomes. The results prove that the nature of definitive restoration, the application and the material of intracanal posts, and the presence of the remaining coronal tooth structure have a significant impact on the success of post-endodontic. In randomized controlled trials as well as observational studies, restorations with cuspal coverage or increased structural reinforcement typically have better long-term results than direct restorations alone.

**Survival and Success of Restoration Type.**

Regular results of various RCTs and long-term cohort studies show that full-coverage crowns are linked to a greater clinical success than direct composite restorations in endodontically treated teeth, especially in the posterior area [40,31,33]. Although in many cases, the survival rates between crowns and composites were not different, crowns had a much higher success rate, and they had fewer technical and biological complications [40,31]. These results correspond with the biomechanical concepts that cuspal coverage lessens the concentration of stress and fracture vulnerability in structurally weakened teeth, a concept that has been reinforced on numerous occasions in the literature of restorative dentistry [49,50]. It is important to note that Poletto-Neto et al. found a significantly greater risk of failure of composite restorations than of metal-ceramic crowns (HR = 5.07), although overall survival rates were comparable [31]. This implies that even though composite restorations could be functional, they are more likely to develop complications that need to be addressed. The same tendency was noted in retrospective cohorts, in which crowned teeth performed better in long-term when compared to direct composite restorations, especially in posterior teeth that have higher occlusal loads [33,36].

**Posts in Post-Endodontic Restorations.**

The application of intracanal posts became a major predictor of tooth survival in situations where there was a massive loss of coronal structure. Comparative studies on restorations with and without posts have

always shown better survival rates in the presence of posts, especially in teeth with limited remaining dentin [36]. Guldener et al. also found that survival rates were statistically significantly higher in the teeth restored with fiber posts than in those restored without posts (94.3% vs. 76.3%; $p < 0.001$), which highlights the structural reinforcement of the teeth with posts in compromised teeth [36].
Nevertheless, the advantage of posting seems to be situation-specific. Ferrari et al. showed that post retention enhanced survival but highlighted that posts do not necessarily make teeth stronger; on the contrary, their advantage is that they make the core and end restoration remain [42]. This observation confirms the modern-day belief that posts must be applied sparingly and on a case-by-case basis to maintain the coronal restoration, as opposed to a habitual reinforcement measure.

**Comparison of Post Materials.**
Comparative studies of various post materials showed that the clinical outcomes were mainly similar especially in the short to medium-term. The results of RCTs comparing glass fiber posts, metal fiber posts and dentin posts did not show statistically significant differences between the survival or complication rates in the follow-up periods of 6 months to 12 months [41,44]. These results indicate that post material selection might not be as important as the presence of ferrues, quality of bonding, and the shape of occlusals when adhesive protocols are observed [51,52].
However, certain studies implied possible benefits of fiber posts because their elastic modulus was nearer to that of dentin, which could eliminate the possibility of catastrophic fractures of the roots [44]. The theoretical benefit is justified by the fact that favorable, restorable failure modes are predominant in fiber post restorations in comparison with metallic posts [42,44].

**Alternative Restorative Strategy Endocrows.**
Endocrowns showed high results, especially in molars that had a significant amount of coronal loss. Short-term survival rates were high in pediatric and adult prospective studies, although some studies reported 100 percent functional survival at 12 months [43,48]. Notably, there were no significant differences in patient and parental satisfaction between endocrowns and conventional post-retained crowns, which shows that minimally invasive methods can be applied to provide similar patient-centered results [43].
These results are in agreement with the new literature that supports the use of endocrowns as the conservative alternative to conventional post-and-core systems, particularly where there is sufficient pulp chamber depth and adhesive bonding surfaces [53-55]. Nevertheless, the small sample size and limited follow-up periods of the existing studies should be interpreted with caution and the long-term randomized studies are required.

**Effects of Remaining Tooth Structure and Cementation.**
The importance of residual tooth structure and adhesive cementation in predicting the success of restorative procedures was highlighted in a number of studies [56,57]. Juloski et al. have shown that restorations luted with resin cements had much higher survival rates than non-adhesive cemented techniques, especially in teeth with less dentin walls [45]. Likewise, Ferrari et al. reported better results in teeth with more coronal wall preservation, which supports the idea that ferrule effect is still one of the most important prognostic factors in post-endodontic restorations [42].
These results support the idea of multifactoriality of restorative success, whereby material choice cannot counteract poor tooth preparation or bonding guidelines [58].

**Risk of Bias and Strength of Evidence.**
The risk-of-bias assessment showed that most RCTs were linked to some concerns, which were mainly related to inadequate reporting of allocation concealment and blinding [31, 40-44]. However, the overall outcome assessment was quite strong, and the rates of attrition were low in studies. The methodological quality of observational studies was moderate, and the majority of them controlled the most important clinical variables, including the type of restoration and the use of posts [33,36,45].
The reliability of the results in the various study designs reinforced the reliability of the general conclusions, but the impossibility of quantitative synthesis was due to heterogeneity in the definition of outcomes, periods of follow-up, and clinical procedures.

**Clinical Implications**
Clinically, the results confirm the application of full-coverage restorations in the posterior endodontically treated teeth, especially when the coronal structure is compromised. Fiber posts are to be taken into consideration in the event of retention, but their location must be determined by the requirements of the structure instead of custom. Endocrowns are a possible, less invasive option in a few cases with positive short-term results and high patient satisfaction.

**Future Research Directions**

The main focus of future research should be well-designed, sufficiently powered randomized trials with standardized outcome measures and long-term follow-up. Patient-reported outcomes, cost-effectiveness, and failure modes are the areas that should be paid specific attention because they are becoming more and more relevant to evidence-based clinical decision-making.

**Limitations**

There are a number of limitations that must be taken into consideration when interpreting the results of this systematic review. To begin with, there was a high level of heterogeneity among included studies in terms of study design, restorative materials, follow-up duration and outcome definitions, making quantitative synthesis not feasible. Second, the results of patient satisfaction were not consistently reported and frequently were not assessed using standardized tools, which decreased the comparability between studies. Third, the selection bias and confounding variables like operator skill, occlusal scheme, and patient oral hygiene were not controlled uniformly and thus many observational studies were prone to selection bias. Also there were limited long-term randomized controlled trials that lasted more than ten years and limited inferences could be made on very long-term survival. Lastly, one cannot rule out publication bias since those studies that have positive results might be more likely to be published.

## CONCLUSION AND RECOMMENDATIONS

### Conclusion

According to the existing clinical data, the success of endodontically treated teeth on the long-term basis is highly determined by the nature and quality of the post-endodontic restoration. Full-coverage restorations especially the crowns offer better survival rates in the posterior teeth, whereas direct restorations can be applied to teeth with minimum loss of structure. There should be judicious use of posts and only as a core retention tool rather than as a reinforcement tool, fiber posts have better failure characteristics compared to metal posts. Endocrowns are a potential and non-aggressive restorative solution to a few cases, which provides similar survival and high patient satisfaction when correctly indicated. Notably, patient-reported outcomes are a supplement to clinical success and must be regarded as part of restorative decision-making.

### Recommendations

The most important aspect of future research ought to be well-constructed randomized controlled trials with standardized outcome measures, such as validated patient satisfaction measures. There is a need especially on long-term studies on endocrowns, post and core crowns and direct restorations in various tooth types. Restorative decisions are to be made on a case-by-case basis with a focus on conserving tooth structure, biomechanical principles, and patient preferences through clinically oriented decision-making after root canal therapy. The integration of clinical and patient-reported outcomes into the routine practice can lead to the improvement of the long-term treatment success and patient satisfaction.

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