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Review Article

# Clinical behavior and survival of endodontically treated teeth with or without post placement: a systematic review and meta-analysis

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## Abstract

**Purpose:** Non-vital teeth usually exhibit substantial loss of coronal and radicular tooth structure, and use of posts after root canal treatment is controversial. This review examined whether placement of posts influences clinical behavior and survival probability of endodontically treated teeth (ETT).
**Methods:** An electronic search, without time restrictions, for publications written in English was undertaken in PubMed, Scopus, and Web of Science. Terms related to four main components (endodontically treated teeth, fixed prosthesis, post restoration, and survival rate) were used for the database search strategies.
**Results:** 57 studies met the inclusion criteria and were included in the qualitative analysis. Of the publications chosen for qualitative analysis, 17 clinical studies (11 prospective and 6 retrospective studies) were found to be suitable for quantitative analysis. These studies included 7,278 patients (7,330 ETT), with a mean age ± standard deviation (SD) of 45.46 ± 12.1 years. There was a statistically significant difference in survival rate between ETT with or without posts ($P < 0.001$).
**Conclusion:** As compared with teeth with no posts, post placement on ETT may improve clinical performance and survival probability of endodontically treated teeth.

Keywords: clinical trial, dental restoration, endodontically treated teeth, longevity, post, survival rate

## Introduction

Caries, restoration failure, and trauma are the important causes of pulpal inflammation requiring endodontic intervention [1]. The reduction in resistance in root canal–treated teeth is attributable to architectural changes related to primary causes of endodontic treatment, such as caries or fracture from trauma, or to clinical procedures required for endodontic treatment, such as removal of the pulp chamber roof and demineralized anatomical portion of the tooth crown [2]. Correct selection of restorative approaches is important for the success of root canal treatment (RCT) [3]. One study reported that satisfactory RCT in combination with sufficient post-endodontic coronal restoration yielded a success rate as high as 91.4% with regard to apical healing; however, in teeth with satisfactory RCT but insufficient post-endodontic restoration, the success rate was 44% [4].

In the past, a generalized approach to posts and crowns for root canal-treated tooth restoration was favored [5]. Today, the best protocol for post-endodontic restoration depends on individualized factors, such as residual tooth structure, periodontal health, occlusal forces, and patient oral hygiene [6]. Additionally, the principles of minimally invasive dentistry prioritize preservation of the entire sound structure of the tooth, to enhance its resistance, and direct composite restoration is regarded as a feasible restorative option because of the superior performance characteristics of resin composite materials and the quality of bonding adhesive systems on enamel and dentine [2,7]. Some clinical reports found that endodontically treated teeth last longer if they have an artificial covering crown [8,9]. However, a clinical trial found no significant difference in 3-year survival rates between teeth treated endodontically and those restored using adhesive direct composite reconstructions or full cast coverage [10].

Use of posts after RCT is controversial [11]. However, a basic principle in restoring endodontically treated teeth (ETT) is that before receiving a prosthetic restoration, a post-and-core foundation should be used for teeth with less than 50% of their coronal structure [11,12]. The main purpose of a post is to preserve a core buildup in a tooth with significant loss of coronal tooth structure [13]. Current post systems vary widely and include cast or prefabricated posts made from a variety of materials (precious, semi-, or nonprecious metal alloys, zirconia, carbon, and glass-fiber posts) [13]. Previously, dentists mainly used cast or prefabricated metal posts made from materials with a high modulus of elasticity (E), such as gold alloys, stainless steel, or titanium, since they were considered strong and clinically effective [14]. However, fiber posts are now more commonly used in clinical practice. Fiber posts were introduced about two decades ago and comprise materials with a lower E, such as glass, quartz, polyethylene, and carbon-reinforced composites [15]. In vitro research has revealed that incorporation of a fiber post into a direct composite restoration enhances the fracture resistance of ETT [16].

ETT with posts may develop complications [17]. Several studies reported that technical complications (i.e., loss of retention, post fracture, perforation, and root fracture) and biological complications (i.e., recurrent caries, recurrent periodontitis, and post-treatment periradicular disease) are not uncommon [17-19]. A systematic review analyzed data from four randomized controlled clinical trials of endodontic and prosthetic complications in teeth treated with fiber posts and restored with different prosthetic restorations within a minimum follow-up period of 16.37 months. The most frequently recorded failures were fiber post debonding, loss of retention of single crowns, and marginal gaps. Chippings and fractures were less frequent [20].

Factors that affect the survival rates of post systems include the type of post, adhesive cement, tooth site, root canal configuration, and final prosthetic restoration [20]. Some studies reported that metallic posts exhibit better adaptation and lower stress of roots as compared with glass-fiber posts [21]. A systematic review and meta-analysis of randomized clinical trials of the incidence rate of root fracture in post-retained restorations concluded that use of fiber and metal posts over a period longer than 5 years was associated with similar incidence rates of root fracture and survival rates (90% for metal posts and 83.9% for fiber posts) [22]. In a clinical study that followed a protocol for high-quality RCT and standardized restoration procedures, the 5-year survival rate for ETT was 92.5% for teeth restored with titanium posts, 97.1% for those restored with cast post and cores, and 94.3% for teeth without post-retained restorations [19].

Although some evidence suggests that placing a post and core to retain the restoration increases the risk of extraction [23], other studies have shown that this arrangement does not improve tooth survival [24]. In contrast, some studies have reported that the survival rate is better for ETT with posts than for those without posts [25]. Because the results have been inconsistent, further study is warranted.

This review evaluated whether placement of posts influences the clinical behavior and survival probability of endodontically compromised teeth.

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## Materials and Methods

This study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement guidelines [26] and was performed to investigate the survival rate of ETT in relation to post placement status. The study began with a systematic review of the literature.

### Search strategies

An electronic search of three databases (PubMed, Scopus, and Web of Science) for publications written in English was conducted from August 2023 until December 2023. Only studies published during the previous 20 years were considered. The search terms were related to four main components: endodontic treatment, post, restoration, and survival (Table 1). In addition, the reference lists of the identified studies were examined for possible additional studies. A manual search of prosthesis-related journals and relevant reviews on the topic was also performed.

### Inclusion criteria

Studies were included if they were retrospective or prospective clinical studies reporting evaluation of patients with ETT with or without post restorations, if they had a minimum duration of follow-up of 2 years, and if they were published during the previous 20 years. All included studies described the delivery of the final restoration. Any complications with the tooth or restoration on the ETT had to have been reported. In addition, to be included, a study had to report the survival rate of ETT, including restored teeth with and without posts.

### Study selection

An initial search of the electronic databases was used to identify studies that potentially met the inclusion criteria. During this search, the titles and abstracts of all studies were screened and read by the authors to identify those that appeared to meet the inclusion criteria. After this initial search, the full text of the identified studies was read to determine whether all inclusion criteria were met. Lack of consensus was resolved by discussion among the authors.

### Data extraction

The following data, when available, were then extracted from the included studies on a standard form: publication year, study design, number of patients, number of ETT, types of restoration materials, location of treated teeth, follow-up duration, survival rate, and types of complications.

### Quality assessment

For this review, the quality of the included studies was assessed with the Quality Assessment Tool for Case Series Studies of the National Institutes of Health, which uses nine criteria to evaluate study quality. These criteria were rated by the authors to evaluate the risk of bias in each study. Studies were then classified as "good," "fair," or "poor" based on the number of points. Studies classified as "good" (i.e., those with a minimum score of 7 points) have the least risk of bias, and the results are thus considered valid. Studies classified as "fair" are somewhat susceptible to bias in their results. Studies rated "poor" have a high risk of bias.

### Analyses

For quantitative analysis, a meta-analysis was conducted using the Review Manager (RevMan, Cochrane, London, UK) RevMan web software. Survival rate was the continuous outcome evaluated. Weighted mean differences were used to construct forest plots. ETT were classified as those with posts and without posts. The statistical unit was the number of ETT in each group. The outcome was also evaluated in subgroups based on the final restorations (direct or indirect) and the follow-up period (less than 5 years, 5 to 10 years, and more than 10 years). Whenever outcomes of interest were not clearly stated, the data were not analyzed. The $I^2$ statistic was used to express the percentage of total variation across studies due to heterogeneity. The inverse variance method was used for random effects when there was statistically significant ($P < 0.05$) heterogeneity, and a fixed-effects model was used when heterogeneity was not significant. The estimates of an intervention were expressed in mean difference as a percentage, with a 95% confidence interval.

**Table 1** Search terms used for the electronic search

| Component | Terms used |
|---|---|
| Endodontic treatment | (endodontic treatment OR root canal treatment OR non-vital teeth OR root canal OR endodontic OR root canal treatment OR endodontic OR endodontically treated OR pulpless tooth OR devitalized tooth OR nonvital tooth OR root filled teeth) |
| Post | (post OR prefabricated post OR fiber post OR fiber reinforced composite post OR cast metal post OR metal post metallic post OR still post OR titanium post OR metal core) |
| Restoration | (crown OR full veneer OR prosthetic restoration OR restoration OR prosthetic OR fixed prosthesis OR fixed dental prosthesis OR all-ceramics OR cuspal coverage OR composite resin OR conventional filling OR direct restoration) |
| Survival | (success OR fracture OR survival rate OR cumulative survival rate OR mean survival OR treatment outcome OR survival OR survival rate OR survival analysis OR dental restoration failure OR post failure OR composite failure OR crown failure OR prosthesis failure OR success OR success rate OR complications OR prognosis OR long term) |

## Results

The study selection process is summarized in Fig.1. The database search strategy, in combination with manual journal searches, yielded 1,291 papers. The authors independently screened the abstracts for articles related to the aim of the review, and 1,044 articles were excluded because they were not related to the topic or did not present clinical cases. Examination of the full text of the remaining 247 articles led to exclusion of 177 because they did not meet the inclusion criteria. Ultimately, 57 publications were included in the review for qualitative analysis [10,17-19,27-79].

Among the publications chosen for qualitative analysis, 17 clinical studies (11 prospective and six retrospective studies) were found to be suitable for quantitative analysis (Table 2). These studies included 7,278 patients (7,330 ETT), with a mean age ± standard deviation (SD) of 45.46 ± 12.1 years. Information on patient sex was available in 10 studies; there were 2,154 males (37.42%) and 3,602 females (62.58%).

All studies included in the quantitative analysis were of good quality (Table 3). The meta-analysis showed a significant difference in survival rate between ETT with or without posts ($P < 0.001$; Fig. 2). Quantitative analysis based on follow-up period revealed a significantly lower survival rate for ETT without posts as compared with teeth with post placement, after less than 5 years of follow-up ($P = 0.005$; Fig. 3). No significant difference was detected for a duration of follow-up of 5 to 10 years ($P = 0.11$) or longer than 10 years ($P = 0.05$). Analysis in relation to the type of final restoration revealed no significant difference in survival rate between ETT with or without post when it was restored with direct restorations only ($P = 0.65$) or with fixed prostheses only ($P = 0.06$; Fig. 4). However, previous studies using both direct and indirect restorations on the evaluated ETT reported a lower survival rate for ETT without posts ($P < 0.001$).

## Discussion

The present review compared long-term survival rates for ETT with and without posts. The null hypothesis—that ETT would exhibit similar success/survival regardless of the use of posts—was rejected. The meta-analysis revealed a significantly higher survival rate for teeth restored with posts. This finding is consistent with previous reports indicating that use of posts was associated with a lower ETT complication rate [25]. However, other reports found that post placement might increase the risk of root fracture, particularly in patients with oversized root canals [80,81].

The current electronic search included three databases with large collections of articles in the fields of medicine and dentistry. In addition, a manual search was performed to identify any relevant articles that were not found in the electronic search. The search process was limited to articles written in English since it would have been challenging to access journals in other languages. In addition, non-English articles would require translation if selected during the search process. The final search phase yielded the 63 articles included in this review, which is more than in other related reviews. Despite any limitations in the present study design, this study provides important data, because of the high number of ETT (7,330) and long dura-

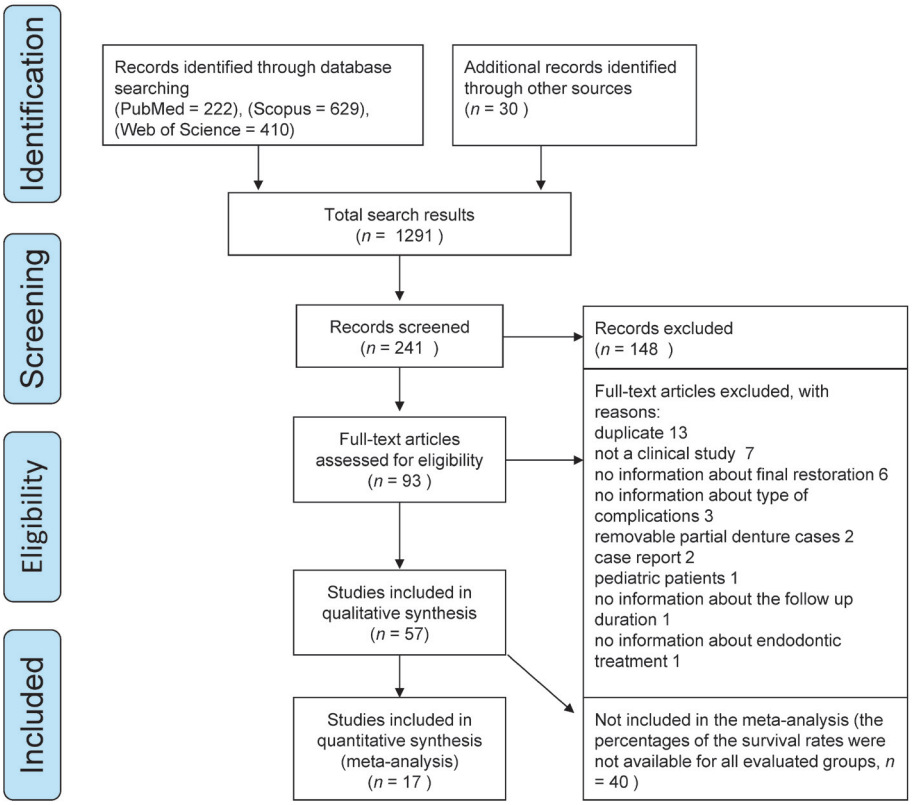


**Fig. 1** Study screening process

**Table 2** Studies included in the quantitative analysis

| Authors | Year | Number of patients (men/women) | Patients mean age or age range (years) | No. of endodontically treated teeth | Mean follow-up duration (years) |
|---|---|---|---|---|---|
| Mannocci et al. [31] | 2005 | 219 | 45 | 219 | 5 |
| Creugers et al. [32] | 2005 | 87 (43/44) | NM | 99 | 5 |
| De Backer et al. [36] | 2006 | 456 | NM | 1157 | 18 |
| Salvi et al. [19] | 2007 | 183 | NM | 308 | 5.2 ± 1.8 for prefabricated titanium posts, 6.2 ± 2.0 for cast post-and-cores, and 4.4 ± 1.7 for teeth without a post |
| Ferrari et al. [39] | 2007 | 210 (93/117) | 54 | 240 | 2 |
| Fokkinga et al. [40] | 2007 | 257 (98/159) | 36 | 307 | 17 |
| Cagidiaco et al. [43] | 2008 | 345 | (18-76) | 360 | 3 |
| Fokkinga et al. [44] | 2008 | 87 (43/44) | 36 | 96 | ≤17 |
| Bitter et al. [47] | 2009 | 90 (42/49) | 50 ± 15 | 120 | 2.7 |
| Zicari et al. [50] | 2011 | 144 (68/76) | 47 | 205 | 3 |
| Dammaschke et al. [56] | 2012 | 676 (351/325) | 56.2 | 676 | 9.7 |
| Ferrari et al. [55] | 2012 | 345 | NM | 360 | 6 |
| Scotti et al. [61] | 2015 | 247 (68/60) | 46.2 | 178 | 2.87 |
| Cloet et al. [67] | 2017 | 143 (68/75) | 47 ± 8.7 | 203 | 5.8 |
| Guldener et al. [68] | 2017 | 15 | NM | 144 | 8.8 |
| Ferrari et al. [72] | 2019 | 100 (55/45) | (18-79) | 120 | 3 |
| Sadaf [74] | 2020 | 3863 (men 32.53%; women 67.47%) | 37.27 | 4012 | 8 |

tion of follow-up. Another systematic review, with a similar aim, included only three articles and a total of 648 teeth [25]. To ensure inclusion of as many studies as possible that utilized commonly used treatment methods and materials, including those used today, only clinical studies published during the previous 20 years were included in the present analysis.

The present quantitative evaluation included 17 articles and approximately 7,330 ETT. Variation in clinical studies is a common concern and can lead to heterogeneity in the meta-analysis [82]. In the current review, the presence of statistical heterogeneity ($P < 0.05$) indicated variation among the included the studies. Therefore, a random-effects model was used to allow the investigated outcomes to differ in a normal distribution among the clinical studies. Some researchers suggest using a random-effects rather than a fixed-effects method, because the former is a more natural choice [83]. In addition, the present subgroup analyses were created to analyze included teeth in relation to type of final restoration and duration of follow-up.

Systematic reviews rely on published studies and should be conducted with a clear, well-described method for identifying relevant studies. The retrospective nature of systematic reviews makes them more dependent on the quality and quantity of the included studies. Studies differ in their inclusion criteria, which can complicate interpretation of the results. To avoid this, a quality assessment was used to evaluate the reliability of studies included in the meta-analysis. The quality of the present studies was good to high, which supports the reliability of the results. Assessment of the 17 studies included in the analysis indicated a low risk of bias, and the results obtained may thus be considered valid.

However, the included studies differed in the complications that were considered when evaluating survival rate. The absence of standardized cri-

**Table 3** Quality assessment tool for case series studies, by the National Institutes of Health

| Study | Year | Quality assessment tool for case series studies, by the National Institutes of Health | | | | | | | | | Total quality score |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 | |
| Mannocci et al. [31] | 2005 | √ | √ | √ | √ | √ | √ | √ | √ | √ | 9/9 |
| Creugers et al. [32] | 2005 | √ | √ | NR | √ | √ | √ | √ | √ | √ | 8/9 |
| De Backer et al. [36] | 2006 | √ | √ | X | √ | √ | √ | √ | √ | √ | 8/9 |
| Fokkinga et al. [40] | 2007 | √ | √ | X | X | √ | √ | √ | √ | √ | 7/9 |
| Salvi et al. [19] | 2007 | √ | √ | √ | X | √ | √ | √ | √ | √ | 8/9 |
| Ferrari et al. [39] | 2007 | √ | √ | √ | √ | √ | √ | X | √ | √ | 8/9 |
| Cagidiaco et al. [43] | 2008 | √ | √ | √ | √ | √ | √ | √ | √ | √ | 9/9 |
| Fokkinga et al. [44] | 2008 | √ | √ | X | √ | √ | √ | √ | √ | √ | 8/9 |
| Bitter et al. [47] | 2009 | √ | √ | √ | √ | √ | √ | X | √ | √ | 8/9 |
| Zicari et al. [50] | 2011 | √ | √ | √ | X | √ | √ | √ | √ | √ | 8/9 |
| Dammaschke et al. [56] | 2012 | √ | √ | X | X | √ | √ | √ | √ | √ | 7/9 |
| Ferrari et al. [55] | 2012 | √ | √ | √ | √ | √ | √ | √ | √ | √ | 9/9 |
| Scotti et al. [61] | 2015 | √ | √ | X | X | √ | √ | √ | √ | √ | 7/9 |
| Cloet et al. [67] | 2017 | √ | √ | √ | X | √ | √ | √ | √ | √ | 8/9 |
| Guldener et al.[68] | 2017 | √ | √ | √ | X | √ | √ | √ | √ | √ | 8/9 |
| Ferrari et al. [72] | 2019 | √ | √ | √ | √ | √ | √ | √ | √ | √ | 9/9 |
| Sadaf [74] | 2020 | √ | √ | X | X | √ | √ | √ | √ | √ | 7/9 |

Q1: Was study question or objective clearly stated?
Q2: Was study population clearly and fully described, including case definition?
Q3: Were cases consecutive?
Q4: Were subjects comparable?
Q5: Was intervention clearly described?
Q6: Were outcome measures clearly defined, valid, reliable, and implemented consistently across all study participants?
Q7: Was length of follow-up adequate?
Q8: Were statistical methods well-described?
Q9: Were results well-described?

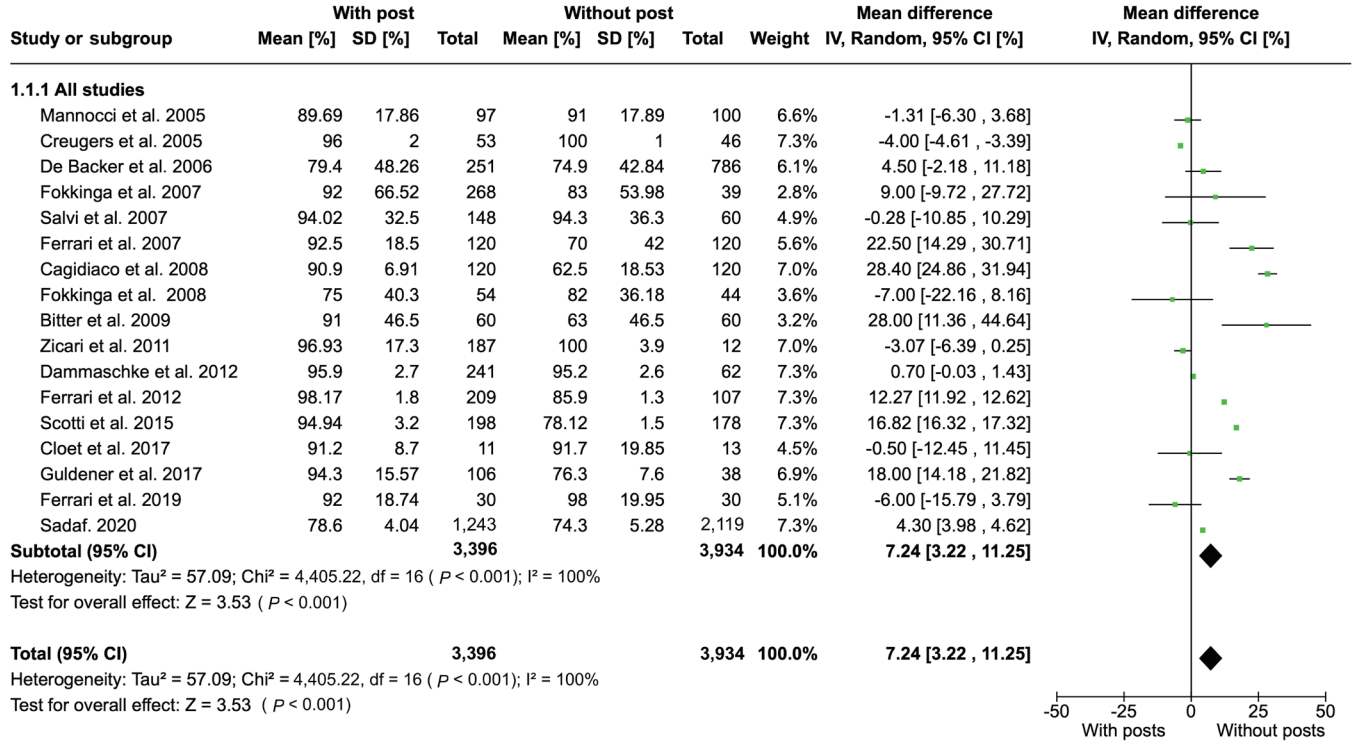


**Fig. 2** Forest plot for the survival rate of ETT with or without posts

teria during the evaluation of survival rates can result in heterogeneity and lead to difficulties in properly calculating survival. In this review, survival rate was investigated instead of failure rate, since several studies included two categories of failure, namely, absolute and relative failure, based on complication severity [55]. Some complications require restoration replacement or tooth extraction (absolute failure), while other complications are minor and require only adjustment of the restorations (relative failure) [67,72]. However, biological complications such as caries and endodontic treatments were categorized as failure in other studies. Survival rate was evaluated by using criteria reported in the included studies and was defined as a restored ETT that was still functional at the follow-up exam. For this reason, survival rate was evaluated in this review in relation to frequently reported biological complications (such as secondary caries and need for endodontic treatment) and technical complications (such as restoration/post fracture and debonding). Zicari et al. [50] recommended that criteria for evaluating failure should be clearly described in protocols for clinical studies of final restorations on ETT.

Follow-up duration varied greatly in previous studies, particularly clinical studies. In the current review, a minimum duration of follow-up of 2 years was a main inclusion criterion. Interestingly, the differences between the two evaluated ETT groups (i.e., those with and without posts) were greatest in studies with a follow-up duration less than 5 years, which reported that results were more favorable for teeth with posts (Fig. 3). In addition, in these studies the reported survival rate was higher than 90%

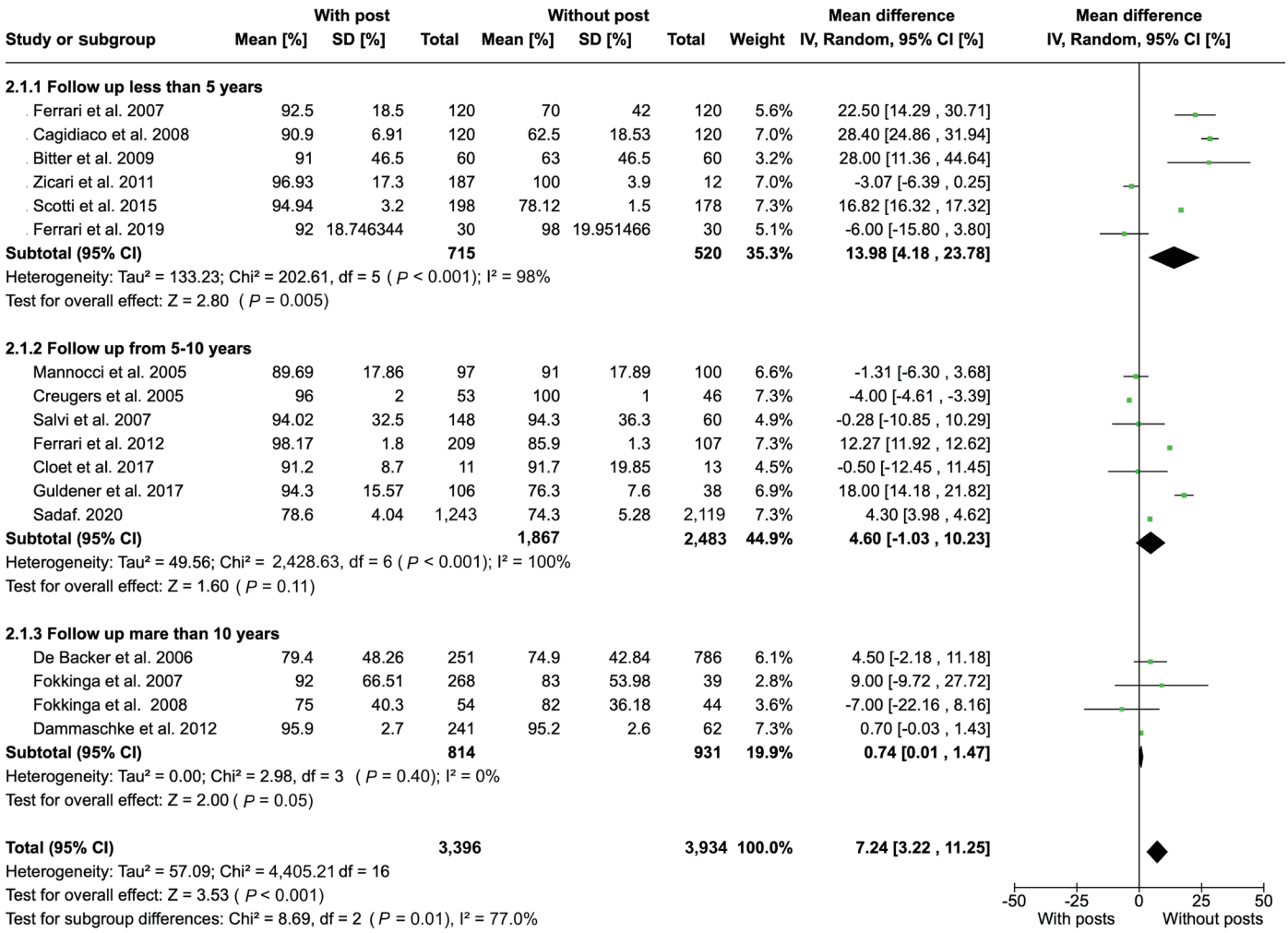


**Fig. 3** Forest plot for the survival rate of ETT with or without posts based on the follow up duration

for ETT with posts, significantly higher than for ETT without posts ($P$ = 0.005). These results are consistent with findings from other prospective and retrospective clinical studies of ETT survival rates [33,39,84]. In contrast, the survival rates for the ETT group without posts varied from 62.5% to 100% (Fig. 3). The seven studies with a follow-up duration between 5 and 10 years reported similar survival rates for ETT with or without posts ($P$ = 0.11). A prospective clinical study [32] of the survival rate of ETT treated with different types of core restorations reported a 100% survival rate for ETT restored with a direct composite without posts after 5 years of follow-up, which was slightly higher than the survival rate for restorations with a post (96%) [32]. The present meta-analysis showed comparable results for ETT with and without post placement after more than 10 years of follow-up ($P$ = 0.05). Another clinical study [44] reported that the survival rate for ETT after 17 years of follow-up did not differ between those with prefabricated metal posts and those without posts.

In this study, the survival rate in the included studies was 74.4% or higher for all examined ETT after long-term follow-up (Fig. 2). However, in a systematic review involving 317 patients [25] post placement was associated with a significantly lower ETT failure rate. These findings are consistent with the findings reported in a long-term clinical study of 100 patients, published in 2017 [68]. In that study, tooth loss was significantly lower for ETT restored with fiber posts than for ETT restored without a post. The survival rate was 94.3% for teeth with fiber posts and 76.3% for teeth without a post ($P$ < 0.001) [68]. Thus, the present results should be interpreted with caution because of variation in study design and follow-up period.

The type of coronal restoration is a principal factor in ensuring good long-term outcomes for ETT. Many prosthodontists prefer restoring ETT with an indirect restoration that provides cuspal coverage, such as crowns, because survival is better than that for conventional direct fillings [85]. This review evaluated survival for direct and indirect restorations on ETT in relation to post placement and found that post placement had a limited effect on ETT survival, regardless of the type of coronal restoration. A long-term clinical study [68] concluded that regular maintenance care improved long-term survival rates for ETT, regardless of the type of coronal restoration. However, as compared with ETT without posts, success rates were higher for ETT restored with fiber posts and either a direct restoration or a crown [68]. A 3-year clinical comparative study reported similar survival rates for ETT restored with a fiber post with final coronal restorations that were either direct composite or crown restorations and that metal-ceramic crowns did not provide better ETT longevity than direct composite restorations [10]. A randomized clinical trial [62] found that, for ETT with a glass-fiber post, survival was similar for indirect restorations and direct composite restorations after a follow-up of 5 years. A systematic review of clinical studies [86] evaluating the long-term performance of direct and indirect restoration for root-treated teeth concluded that ETT with crown restorations had an acceptable long-term survival probability at 10 years, while direct restorations yielded only short-term satisfactory survival. In contrast, a retrospective study found that root canal-treated premolar and molar teeth with full crowns exhibited higher fracture resistance than did teeth restored with direct fillings, such as glass-ionomer cement or amalgam [56]. In the present quantitative analysis, the overall survival rate for the included studies, regardless of the type of final restoration, ranged from 62.5% to 100%, which is within the range reported in the literature [87-89]. Moreover, placement of an immediate final restoration on an ETT might improve long-term outcomes [90].

ETT survival is affected by factors other than the presence of post restorations. Some laboratory and clinical investigations reported that the

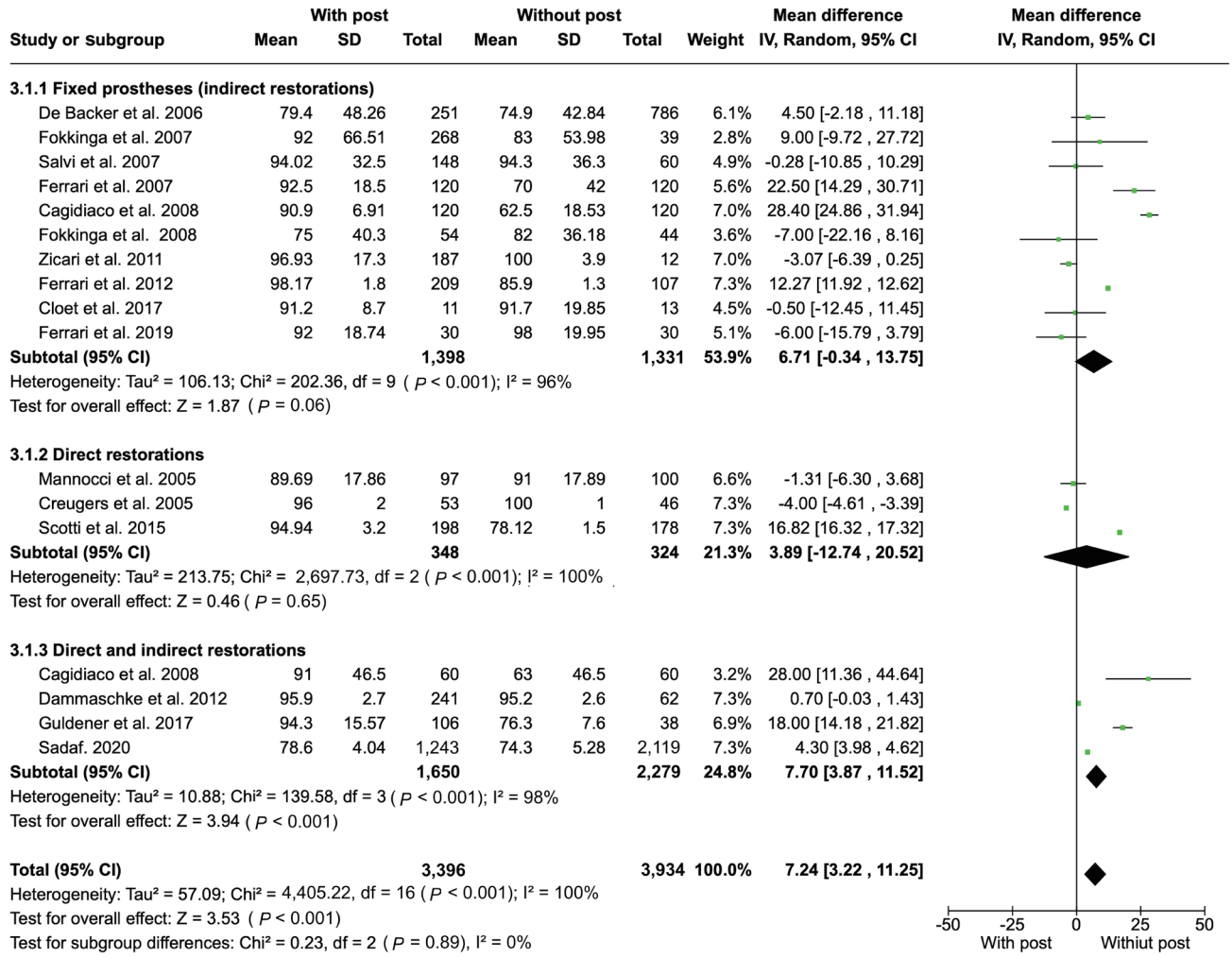


**Fig. 4** Forest plot for the survival rate of ETT with or without posts based on the final restorations

amount of residual coronal tooth structure has a significant impact on the failure rate of restorations on ETT [33,91,92]. This accords with the present findings. A randomized controlled trial of endodontically treated premolars found that the risk of failure was higher for restored teeth lacking a ferrule than for teeth with at least one retained coronal wall [55]. Another randomized clinical trial [47] reported that fiber post placement reduced failure risk for teeth with no coronal wall above 2 mm of the gingival level. The authors suggested that post placement on teeth with limited substance loss should be critically evaluated to prevent overuse [47]. Furthermore, a previous review highlighted the importance of preserving tooth structure to reduce fracture resistance in post-core reconstructed teeth [93] and indicated that the evidence shows that post placement may not help if the intention is to reinforce the tooth. Some clinical studies have suggested that ETT location is associated with long-term survival [94,95]. Naumann et al. [95] reported significantly higher failure rates endodontically for anterior teeth with fiber post restorations than for posterior teeth. In a prospective observational clinical study, tooth type significantly affected post longevity, and post-retained crowns placed in the upper anterior region had a failure rate three times that of restorations placed in the posterior region [94]. An in vitro study [96] of fracture resistance of composite restorations on nonvital teeth with and without posts found that fracture resistance depended considerably on the angle of applied force: oblique forces were more damaging than axial forces [96]. In addition to these factors, a randomized controlled clinical study [66] indicated that parafunctional habits such as bruxism were associated with higher risks of mechanical and technical complications in ETT with prosthodontic rehabilitation.

Complications associated with restored ETT can affect restoration longevity and may be caused by biological or technical factors. The most common complications reported in the present included studies were biological complications such as secondary caries and failed endodontic treatment, and technical problems such as debonding and restoration fracture. In addition to complication mode, the most severe complication of ETT with a post might be root fracture [97]. In this review, several studies reported the incidence of root fracture, which was an indication for tooth extraction [47,50,61]. For that reason, the risk of root fracture in these cases was less than would be expected from an in vitro investigation [98]. Not all the included studies provided detailed descriptions of detected complications. In one retrospective study [56], the main criterion used to calculate survival rate was whether a tooth showed no sign of fracture during a follow-up visit. Salvi et al. [19] calculated the incidence of abutment tooth loss and reported two categories of complications—technical (i.e., loss of retention and post fracture) and biological (i.e., recurrent caries and post-treatment periradicular disease). After a mean observation period of more than 4 years, they found that 89% of abutment teeth had no complications and 4.8% had technical and/or biological complications; the remaining 6.2% were associated with abutment tooth loss [19]. Furthermore, biological complications such as caries, periodontal problems, and endodontic problems were given as the reasons for 66% of crown or tooth removals in an 18-year retrospective study [36]. Technical complications such as loss of retention and post fracture were not uncommon for ETT with posts [99]. In a 3-year clinical study [10] of the survival of ETT restored with full cast coverage or with direct composite restoration the most common complication types observed were post loss of retention and marginal gaps on radiographs [10].

Although dentists have long debated the use of posts before final restoration of ETT, posts are still recommended for some cases, especially when a small amount of residual dental tissue is available to improve restoration retention [100]. The present findings showed a higher survival probabil-

ity for restorations with posts than for restorations without posts, which indicates that post placement should precede a crown or direct filling for an ETT. The present review will help in the decision-making process for restoring teeth after RCT. Although this meta-analysis did not investigate complication rate in relation to the type of post material, the clinical performance of teeth will likely be influenced by the post material used for restoring ETT.

In conclusion, the present findings suggest that, as compared with teeth with no posts, post placement on ETT improves clinical performance and survival probability. To ensure optimal outcomes, dentists should consider both these aspects of treatment when providing individualized treatment for their patients.

## Abbreviations

E: elasticity; ETT: endodontically treated teeth; PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analysis; SD: standard deviation; RCT: root canal treatment

## Conflicts of Interest

The authors declare no conflicts of interest that are directly relevant to the content of this article.

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Not applicable

## Author Contributions

AA: conceptualization, methodology, writing, review, editing, and supervision; SA: conceptualization, data acquisition, and methodology; NA: conceptualization, data acquisition, and methodology; HA: conceptualization, writing, review, and editing. All authors read and approved the final version of the manuscript.

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## Data Availability Statements

Data related to this article are available from the corresponding author upon request.

## References

1. Morgano SM, Brackett SE (1999) Foundation restorations in fixed prosthodontics: current knowledge and future needs. J Prosthet Dent 82, 643-657. doi: 10.1016/s0022-3913(99)70005-3
2. Reeh ES, Messer HH, Douglas WH (1989) Reduction in tooth stiffness as a result of endodontic and restorative procedures. J Endod 15, 512-516. doi: 10.1016/s0099-2399(89)80191-8
3. Morimoto S, Rebello de Sampaio FB, Braga MM, Sesma N, Özcan M (2016) Survival rate of resin and ceramic inlays, onlays, and overlays: a systematic review and meta-analysis. J Dent Res 95, 985-994. doi: 10.1177/0022034516652848
4. Ray HA, Trope M (1995) Periapical status of endodontically treated teeth in relation to the technical quality of the root filling and the coronal restoration. Int Endod J 28, 12-18. doi: 10.1111/j.1365-2591.1995.tb00150.x
5. Colman HL (1979) Restoration of endodontically treated teeth. Dent Clin North Am 23, 647-662.
6. Scotti N, Scansetti M, Rota R, Pera F, Pasqualini D, Berutti E (2011) The effect of the post length and cusp coverage on the cycling and static load of endodontically treated maxillary premolars. Clin Oral Investig 15, 923-929. doi: 10.1007/s00784-010-0466-y
7. Nagasiri R, Chitmongkolsuk S (2005) Long-term survival of endodontically treated molars without crown coverage: a retrospective cohort study. J Prosthet Dent 93, 164-170. doi: 10.1016/j.prosdent.2004.11.001
8. Aquilino SA, Caplan DJ (2002) Relationship between crown placement and the survival of endodontically treated teeth. J Prosthet Dent 87, 256-263. doi: 10.1067/mpr.2002.122014
9. Dammaschke T, Steven D, Kaup M, Ott KH (2003) Long-term survival of root-canal-treated teeth: a retrospective study over 10 years. J Endod 29, 638-643. doi: 10.1097/00004770-200310000-00006
10. Mannocci F, Bertelli E, Sherriff M, Watson TF, Ford TR (2002) Three-year clinical comparison of survival of endodontically treated teeth restored with either full cast coverage or with direct composite restoration. J Prosthet Dent 88, 297-301. doi: 10.1067/mpr.2002.128492
11. Vârlan C, Dimitriu B, Vârlan V, Bodnar D, Suciu I (2009) Current opinions concerning the restoration of endodontically treated teeth: basic principles. J Med Life 2, 165-172.
12. Al-Sanabani FA, Al-Makramani BM, Alaajam WH, Al-Ak'hali MS, Alhajj MN, Nassani MZ et al. (2023) Effect of partial ferrule on fracture resistance of endodontically treated teeth: a meta-analysis of in-vitro studies. J Prosthodont Res 67, 348-359. doi: 10.2186/jpr.JPR_D_22_00170
13. Ploumaki A, Bilkhair A, Tuna T, Stampf S, Strub JR (2013) Success rates of prosthetic restorations on endodontically treated teeth; a systematic review after 6 years. J Oral Rehabil 40, 618-630. doi: 10.1111/joor.12058
14. Agrawal VS, Shah A, Kapoor S (2022) Effect of fiber orientation and placement on fracture resistance of large class II mesio-occluso-distal cavities in maxillary premolars: an in vitro study. J Conserv Dent 25, 122-127. doi: 10.4103/jcd.jcd_384_21
15. Salameh Z, Sorrentino R, Papacchini F, Ounsi HF, Tashkandi E, Goracci C et al. (2006) Fracture resistance and failure patterns of endodontically treated mandibular molars restored using resin composite with or without translucent glass fiber posts. J Endod 32, 752-755. doi: 10.1016/j.joen.2006.02.002
16. Mangold JT, Kern M (2011) Influence of glass-fiber posts on the fracture resistance and failure pattern of endodontically treated premolars with varying substance loss: an in vitro study. J Prosthet Dent 105, 387-393. doi: 10.1016/s0022-3913(11)60080-2
17. Kramer EJ, Meyer-Lueckel H, Wolf TG, Schwendicke F, Naumann M, Wierichs RJ (2019) Success and survival of post-restorations: six-year results of a prospective observational practice-based clinical study. Int Endod J 52, 569-578. doi: 10.1111/iej.13040
18. Segerström S, Astbäck J, Ekstrand KD (2006) A retrospective long term study of teeth restored with prefabricated carbon fiber reinforced epoxy resin posts. Swed Dent J 30, 1-8.
19. Salvi GE, Siegrist Guldener BE, Amstad T, Joss A, Lang NP (2007) Clinical evaluation of root filled teeth restored with or without post-and-core systems in a specialist practice setting. Int Endod J 40, 209-215. doi: 10.1111/j.1365-2591.2007.01218.x
20. Sorrentino R, Di Mauro MI, Ferrari M, Leone R, Zarone F (2016) Complications of endodontically treated teeth restored with fiber posts and single crowns or fixed dental prostheses-a systematic review. Clin Oral Investig 20, 1449-1457. doi: 10.1007/s00784-016-1919-8
21. Santos AF, Meira JB, Tanaka CB, Xavier TA, Ballester RY, Lima RG et al. (2010) Can fiber posts increase root stresses and reduce fracture? J Dent Res 89, 587-591. doi: 10.1177/0022034510363382
22. Figueiredo FE, Martins-Filho PR, Faria ESAL (2015) Do metal post-retained restorations result in more root fractures than fiber post-retained restorations? A systematic review and meta-analysis. J Endod 41, 309-316. doi: 10.1016/j.joen.2014.10.006
23. Ng YL, Mann V, Gulabivala K (2011) A prospective study of the factors affecting outcomes of nonsurgical root canal treatment: part 1: periapical health. Int Endod J 44, 583-609. doi: 10.1111/j.1365-2591.2011.01872.x
24. Ng YL, Mann V, Gulabivala K (2010) Tooth survival following non-surgical root canal treatment: a systematic review of the literature. Int Endod J 43, 171-189. doi: 10.1111/j.1365-2591.2009.01671.x
25. Zhu Z, Dong XY, He S, Pan X, Tang L (2015) Effect of post placement on the restoration of endodontically treated teeth: a systematic review. Int J Prosthodont 28, 475-483. doi: 10.11607/ijp.4120
26. Moher D, Liberati A, Tetzlaff J, Altman DG; PRISMA Group (2009) Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Ann Intern Med 151, 264-269. doi: 10.7326/0003-4819-151-4-200908180-00135
27. Glazer B (2000) Restoration of endodontically treated teeth with carbon fibre posts--a prospective study. J Can Dent Assoc 66, 613-618.
28. Ellner S, Bergendal T, Bergman B (2003) Four post-and-core combinations as abutments for fixed single crowns: a prospective up to 10-year study. Int J Prosthodont 16, 249-254.
29. Monticelli F, Grandini S, Goracci C, Ferrari M (2003) Clinical behavior of translucent-fiber posts: a 2-year prospective study. Int J Prosthodont 16, 593-596.
30. King PA, Setchell DJ, Rees JS (2003) Clinical evaluation of a carbon fibre reinforced carbon endodontic post. J Oral Rehabil 30, 785-789. doi: 10.1046/j.1365-2842.2003.01178.x
31. Mannocci F, Qualtrough AJ, Worthington HV, Watson TF, Pitt Ford TR (2005) Randomized clinical comparison of endodontically treated teeth restored with amalgam or with fiber posts and resin composite: five-year results. Oper Dent 30, 9-15.
32. Creugers NH, Kreulen CM, Fokkinga WA, Mentink AG (2005) A 5-year prospective clinical study on core restorations without covering crowns. Int J Prosthodont 18, 40-41.
33. Naumann M, Blankenstein F, Dietrich T (2005) Survival of glass fibre reinforced composite post restorations after 2 years-an observational clinical study. J Dent 33, 305-312. doi: 10.1016/j.jdent.2004.09.005
34. Grandini S, Goracci C, Tay FR, Grandini R, Ferrari M (2005) Clinical evaluation of the use of fiber posts and direct resin restorations for endodontically treated teeth. Int J Prosthodont 18, 399-404.
35. Wegner PK, Freitag S, Kern M (2006) Survival rate of endodontically treated teeth with posts after prosthetic restoration. J Endod 32, 928-931. doi: 10.1016/j.joen.2006.06.001
36. De Backer H, Van Maele G, De Moor N, Van den Berghe L, De Boever J (2006) An 18-year retrospective survival study of full crowns with or without posts. Int J Prosthodont 19, 136-142.
37. Cagidiaco MC, Radovic I, Simonetti M, Tay F, Ferrari M (2007) Clinical performance of fiber post restorations in endodontically treated teeth: 2-year results. Int J Prosthodont 20, 293-298.
38. Naumann M, Sterzenbac G, Alexandra F, Dietrich T (2007) Randomized controlled clinical pilot trial of titanium vs. glass fiber prefabricated posts: preliminary results after up to 3 years. Int J Prosthodont 20, 499-503.
39. Ferrari M, Cagidiaco MC, Goracci C, Vichi A, Mason PN, Radovic I et al. (2007) Long-term retrospective study of the clinical performance of fiber posts. Am J Dent 20, 287-291.
40. Fokkinga WA, Kreulen CM, Bronkhorst EM, Creugers NH (2007) Up to 17-year controlled clinical study on post-and-cores and covering crowns. J Dent 35, 778-786. doi: 10.1016/j.jdent.2007.07.006
41. Piovesan EM, Demarco FF, Cenci MS, Pereira-Cenci T (2007) Survival rates of endodontically treated teeth restored with fiber-reinforced custom posts and cores: a 97-month study. Int J Prosthodont 20, 633-639.
42. Turker SB, Alkumru HN, Evren B (2007) Prospective clinical trial of polyethylene fiber ribbon-reinforced, resin composite post-core buildup restorations. Int J Prosthodont 20, 55-56.
43. Cagidiaco MC, García-Godoy F, Vichi A, Grandini S, Goracci C, Ferrari M (2008) Placement of fiber prefabricated or custom made posts affects the 3-year survival of end-

odontically treated premolars. Am J Dent 21, 179-184.
44. Fokkinga WA, Kreulen CM, Bronkhorst EM, Creugers NH (2008) Composite resin core-crown reconstructions: an up to 17-year follow-up of a controlled clinical trial. Int J Prosthodont 21, 109-115.
45. Näpänkangas R, Raustia A (2008) Twenty-year follow-up of metal-ceramic single crowns: a retrospective study. Int J Prosthodont 21, 307-311.
46. Signore A, Benedicenti S, Kaitsas V, Barone M, Angiero F, Ravera G (2009) Long-term survival of endodontically treated, maxillary anterior teeth restored with either tapered or parallel-sided glass-fiber posts and full-ceramic crown coverage. J Dent 37, 115-121. doi: 10.1016/j.jdent.2008.10.007
47. Bitter K, Noetzel J, Stamm O, Vaudt J, Meyer-Lueckel H, Neumann K et al. (2009) Randomized clinical trial comparing the effects of post placement on failure rate of postendodontic restorations: preliminary results of a mean period of 32 months. J Endod 35, 1477-1482. doi: 10.1016/j.joen.2009.07.026
48. Gómez-Polo M, Llidó B, Rivero A, del Río J, Celemín A (2010) A 10-year retrospective study of the survival rate of teeth restored with metal prefabricated posts versus cast metal posts and cores. J Dent 38, 916-920. doi: 10.1016/j.jdent.2010.08.006
49. Mancebo JC, Jiménez-Castellanos E, Cañadas D (2010) Effect of tooth type and ferrule on the survival of pulpless teeth restored with fiber posts: a 3-year clinical study. Am J Dent 23, 351-356.
50. Zicari F, Van Meerbeek B, Debels E, Lesaffre E, Naert I (2011) An up to 3-year controlled clinical trial comparing the outcome of glass fiber posts and composite cores with gold alloy-based posts and cores for the restoration of endodontically treated teeth. Int J Prosthodont 24, 363-372.
51. Signore A, Kaitsas V, Ravera G, Angiero F, Benedicenti S (2011) Clinical evaluation of an oval-shaped prefabricated glass fiber post in endodontically treated premolars presenting an oval root canal cross-section: a retrospective cohort study. Int J Prosthodont 24, 255-263.
52. Schmitter M, Hamadi K, Rammelsberg P (2011) Survival of two post systems--five-year results of a randomized clinical trial. Quintessence Int 42, 843-850.
53. Naumann M, Koelpin M, Beuer F, Meyer-Lueckel H (2012) 10-year survival evaluation for glass-fiber-supported postendodontic restoration: a prospective observational clinical study. J Endod 38, 432-435. doi: 10.1016/j.joen.2012.01.003
54. Sterzenbach G, Franke A, Naumann M (2012) Rigid versus flexible dentine-like endodontic posts--clinical testing of a biomechanical concept: seven-year results of a randomized controlled clinical pilot trial on endodontically treated abutment teeth with severe hard tissue loss. J Endod 38, 1557-1563. doi: 10.1016/j.joen.2012.08.015
55. Ferrari M, Vichi A, Fadda GM, Cagidiaco MC, Tay FR, Breschi L et al. (2012) A randomized controlled trial of endodontically treated and restored premolars. J Dent Res 91, 72s-78s. doi: 10.1177/0022034512447949
56. Dammaschke T, Nykiel K, Sagheri D, Schäfer E (2013) Influence of coronal restorations on the fracture resistance of root canal-treated premolar and molar teeth: a retrospective study. Aust Endod J 39, 48-56. doi: 10.1111/aej.12002
57. Skupien JA, Opdam N, Winnen R, Bronkhorst E, Kreulen C, Pereira-Cenci T et al. (2013) A practice-based study on the survival of restored endodontically treated teeth. J Endod 39, 1335-1340. doi: 10.1016/j.joen.2013.06.028
58. Sarkis-Onofre R, Jacinto RC, Boscato N, Cenci MS, Pereira-Cenci T (2014) Cast metal vs. glass fibre posts: a randomized controlled trial with up to 3 years of follow up. J Dent 42, 582-587. doi: 10.1016/j.jdent.2014.02.003
59. Bateli M, Kern M, Wolkewitz M, Strub JR, Att W (2014) A retrospective evaluation of teeth restored with zirconia ceramic posts: 10-year results. Clin Oral Investig 18, 1181-1187. doi: 10.1007/s00784-013-1065-5
60. Juloski J, Fadda GM, Monticelli F, Fajó-Pascual M, Goracci C, Ferrari M (2014) Four-year survival of endodontically treated premolars restored with fiber posts. J Dent Res 93, 52s-58s. doi: 10.1177/0022034514527970
61. Scotti N, Eruli C, Comba A, Paolino DS, Alovisi M, Pasqualini D et al. (2015) Longevity of class 2 direct restorations in root-filled teeth: a retrospective clinical study. J Dent 43, 499-505. doi: 10.1016/j.jdent.2015.02.006
62. Skupien JA, Cenci MS, Opdam NJ, Kreulen CM, Huysmans MC, Pereira-Cenci T (2016) Crown vs. composite for post-retained restorations: a randomized clinical trial. J Dent 48, 34-39. doi: 10.1016/j.jdent.2016.03.007
63. Ferrari M, Sorrentino R, Juloski J, Grandini S, Carrabba M, Discepoli N et al. (2017) Post-retained single crowns versus fixed dental prostheses: a 7-year prospective clinical study. J Dent Res 96, 1490-1497. doi: 10.1177/0022034517724146
64. Naumann M, Sterzenbach G, Dietrich T, Bitter K, Frankenberger R, von Stein-Lausnitz M (2017) Dentin-like versus rigid endodontic post: 11-year randomized controlled pilot trial on no-wall to 2-wall defects. J Endod 43, 1770-1775. doi: 10.1016/j.joen.2017.06.030
65. Caserío Valea M, Alonso de la Peña V (2017) Titanium posts and bonded amalgam core longevity: a 22-year clinical survival retrospective study. J Am Dent Assoc 148, 75-80. doi: 10.1016/j.adaj.2016.09.012
66. Monaco C, Llukacej A, Baldissara P, Arena A, Scotti R (2017) Zirconia-based versus metal-based single crowns veneered with overpressing ceramic for restoration of posterior endodontically treated teeth: 5-year results of a randomized controlled clinical study. J Dent 65, 56-63. doi: 10.1016/j.jdent.2017.07.004
67. Cloet E, Debels E, Naert I (2017) Controlled clinical trial on the outcome of glass fiber composite cores versus wrought posts and cast cores for the restoration of endodontically treated teeth: a 5-year follow-up study. Int J Prosthodont 30, 71-79. doi: 10.11607/ijp.4861
68. Guldener KA, Lanzrein CL, Siegrist Guldener BE, Lang NP, Ramseier CA, Salvi GE (2017) Long-term clinical outcomes of endodontically treated teeth restored with or without fiber post-retained single-unit restorations. J Endod 43, 188-193. doi: 10.1016/j.joen.2016.10.008
69. Bergoli CD, Brondani LP, Wandscher VF, Pereira G, Cenci MS, Pereira-Cenci T et al. (2018) A multicenter randomized double-blind controlled clinical trial of fiber post cementation strategies. Oper Dent 43, 128-135. doi: 10.2341/16-278-c
70. Jirathanyanatt T, Suksaphar W, Banomyong D, Ngoenwiwatkul Y (2019) Endodontically treated posterior teeth restored with or without crown restorations: a 5-year retrospective study of survival rates from fracture. J Investig Clin Dent 10, e12426. doi: 10.1111/jicd.12426
71. Cerny D, Eckert S, Mounajjed R (2019) Retrospective 9-year clinical outcome report on adhesive post-endodontic treatment of anterior teeth using prefabricated fiber posts. Int J Prosthodont 32, 14-16. doi: 10.11607/ijp.5913
72. Ferrari M, Ferrari Cagidiaco E, Goracci C, Sorrentino R, Zarone F, Grandini S et al. (2019) Posterior partial crowns out of lithium disilicate (LS2) with or without posts: a randomized controlled prospective clinical trial with a 3-year follow up. J Dent 83, 12-17. doi: 10.1016/j.jdent.2019.01.004
73. Wierichs RJ, Kramer EJ, Wolf TG, Naumann M, Meyer-Lueckel H (2019) Longevity of composite build-ups without posts-10-year results of a practice-based study. Clin Oral Investig 23, 1435-1442. doi: 10.1007/s00784-018-2565-0
74. Sadaf D (2020) Survival rates of endodontically treated teeth after placement of definitive coronal restoration: 8-year retrospective study. Ther Clin Risk Manag 16, 125-131. doi: 10.2147/tcrm.S223233
75. Sarkis-Onofre R, Amaral Pinheiro H, Poletto-Neto V, Bergoli CD, Cenci MS, Pereira-Cenci T (2020) Randomized controlled trial comparing glass fiber posts and cast metal posts. J Dent 96, 103334. doi: 10.1016/j.jdent.2020.103334
76. Bruhnke M, Wierichs RJ, von Stein-Lausnitz M, Meyer-Lückel H, Beuer F, Naumann M et al. (2022) Long-term survival of adhesively luted post-endodontic restorations. J Endod 48, 606-613. doi: 10.1016/j.joen.2022.02.006
77. Morimoto S, Fraga RM, Tedesco TK, Özcan M, Sampaio F, Raggio DP (2022) Two-year survival of ceramic endocrowns and partial coverage ceramic restorations with fiber post: a 2-year double-blind randomized clinical trial. Eur J Prosthodont Restor Dent 30, 252-261. doi: 10.1922/EJPRD_2374Morimoto10
78. da Luz-Silva G, Vetromilla BM, Pereira-Cenci T (2022) Influence of post type on periapical status: a prospective study in a Brazilian population. Clin Oral Investig 26, 781-787. doi: 10.1007/s00784-021-04057-6
79. Bergoli CD, Machry RV, Schwantz JK, Brondani LP, Pereira-Cenci T, Pereira GKR et al. (2023) Survival rate and treatment success of glass fiber posts cemented with two adhesive cementation strategies after up to 106 months: a randomized clinical trial. Clin Oral Investig 27, 2197-2206. doi: 10.1007/s00784-023-04939-x
80. Heydecke G, Butz F, Strub JR (2001) Fracture strength and survival rate of endodontically treated maxillary incisors with approximal cavities after restoration with different post and core systems: an in-vitro study. J Dent 29, 427-433. doi: 10.1016/s0300-5712(01)00038-0
81. Schwartz RS, Robbins JW (2004) Post placement and restoration of endodontically treated teeth: a literature review. J Endod 30, 289-301. doi: 10.1097/00004770-200405000-00001
82. Thompson SG (1994) Why sources of heterogeneity in meta-analysis should be investigated. BMJ 309, 1351-1355. doi: 10.1136/bmj.309.6965.1351
83. Ades AE, Lu G, Higgins JP (2005) The interpretation of random-effects meta-analysis in decision models. Med Decis Making 25, 646-654. doi: 10.1177/0272989x05282643
84. Malferrari S, Monaco C, Scotti R (2003) Clinical evaluation of teeth restored with quartz fiber-reinforced epoxy resin posts. Int J Prosthodont 16, 39-44.
85. Sequeira-Byron P, Fedorowicz Z, Carter B, Nasser M, Alrowaili EF (2015) Single crowns versus conventional fillings for the restoration of root-filled teeth. Cochrane Database Syst Rev 2015, Cd009109. doi: 10.1002/14651858.CD009109.pub3
86. Stavropoulou A, Koidis PT (2007) A systematic review of single crowns on endodontically treated teeth. J Dent 35, 761-767.
87. Heydecke G, Peters MC (2002) The restoration of endodontically treated, single-rooted teeth with cast or direct posts and cores: a systematic review. J Prosthet Dent 87, 380-386. doi: 10.1067/mpr.2002.123848
88. Balkenhol M, Wöstmann B, Rein C, Ferger P (2007) Survival time of cast post and cores: a 10-year retrospective study. J Dent 35, 50-58.
89. Parisi C, Valandro LF, Ciocca L, Gatto MR, Baldissara P (2015) Clinical outcomes and success rates of quartz fiber post restorations: a retrospective study. J Prosthet Dent 114, 367-372. doi: 10.1016/j.prosdent.2015.03.011
90. Song M, Park M, Lee CY, Kim E (2014) Periapical status related to the quality of coronal restorations and root fillings in a Korean population. J Endod 40, 182-186. doi: 10.1016/j.joen.2013.10.017
91. Akkayan B (2004) An in vitro study evaluating the effect of ferrule length on fracture resistance of endodontically treated teeth restored with fiber-reinforced and zirconia dowel systems. J Prosthet Dent 92, 155-162. doi: 10.1016/j.prosdent.2004.04.027
92. Tan PL, Aquilino SA, Gratton DG, Stanford CM, Tan SC, Johnson WT et al. (2005) In vitro fracture resistance of endodontically treated central incisors with varying ferrule heights and configurations. J Prosthet Dent 93, 331-336. doi: 10.1016/j.prosdent.2005.01.013
93. Fernandes AS, Dessai GS (2001) Factors affecting the fracture resistance of post-core reconstructed teeth: a review. Int J Prosthodont 14, 355-363.
94. Naumann M, Blankenstein F, Kiessling S, Dietrich T (2005) Risk factors for failure of glass fiber-reinforced composite post restorations: a prospective observational clinical study. Eur J Oral Sci 113, 519-524. doi: 10.1111/j.1600-0722.2005.00257.x
95. Naumann M, Reich S, Nothdurft FP, Beuer F, Schirrmeister JF, Dietrich T (2008) Survival of glass fiber post restorations over 5 years. Am J Dent 21, 267-272.
96. Krejci I, Duc O, Dietschi D, de Campos E (2003) Marginal adaptation, retention and fracture resistance of adhesive composite restorations on devital teeth with and without posts. Oper Dent 28, 127-135.
97. Hatzikyriakos AH, Reisis GI, Tsingos N (1992) A 3-year postoperative clinical evaluation of posts and cores beneath existing crowns. J Prosthet Dent 67, 454-458. doi: 10.1016/0022-3913(92)90072-i
98. Fokkinga WA, Kreulen CM, Vallittu PK, Creugers NH (2004) A structured analysis of in vitro failure loads and failure modes of fiber, metal, and ceramic post-and-core systems. Int J Prosthodont 17, 476-482.
99. Raygot CG, Chai J, Jameson DL (2001) Fracture resistance and primary failure mode of endodontically treated teeth restored with a carbon fiber-reinforced resin post system in vitro. Int J Prosthodont 14, 141-145.
100. Peroz I, Blankenstein F, Lange KP, Naumann M (2005) Restoring endodontically treated teeth with posts and cores--a review. Quintessence Int 36, 737-746.