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Original Article

Clinical Longevity and Functional Success of Direct vs. Indirect Restorations Post-Endodontic Therapy

Maurits C.F.M. de Kuijper[1,2*], Marco S. Cune[1,3,4], Mutlu Özcan[5], Marco M.M. Gresnigt[1,2]

[1]Department of Restorative Dentistry, The University of Groningen, University Medical Center Groningen, Center for Dentistry and Oral Hygiene, Groningen, Netherlands.
[2]Department of Special Dental Care, Martini Hospital, Groningen, Netherlands.
[3]Department of Oral-Maxillofacial Surgery, Prosthodontics and Special Dental Care, St Antonius Hospital Nieuwegein, Nieuwegein, Netherlands.
[4]Department of Oral-Maxillofacial Surgery, Prosthodontics and Special Dental Care, University Medical Center Utrecht, Utrecht, Netherlands.
[5]Division of Dental Biomaterials, the University of Zürich, Center for Dental and Oral Medicine, Clinic for Reconstructive Dentistry, Zürich, Switzerland.

***E-mail** ✉ m.c.f.m.de.kuijper@umcg.nl

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ABSTRACT

Fractures are a common concern for teeth that have had endodontic treatment and restoration. It is well-recognized that endodontic treatment reduces the flexibility of teeth, which reduces their resistance to breakage. This condition is caused by the drying of tooth structure during access cavity formation and endodontic treatment, as well as the loss of significant amounts of dentin and anatomical components such as cusps, marginal ridges, and the pulp chamber ceiling. The quantity of surviving tooth structure and the kind of restorative material used affect the longevity of teeth that have had endodontic therapy. The procedure for tooth restoration and the interactions that take place between the oral environment, the restorative material, and the tooth. The present review study aimed to investigate the success and current performance of direct vs. indirect restorations after endodontic treatment. It was shown that teeth with direct restorations had a greater tendency to follow up procedures, such as non-surgical retreatment, root-end operations, extraction, and further restorations, than teeth with indirect restorations. The statistical significance of these changes indicates that the kind of restoration influences the necessity of further treatments. In summary, the findings of the systematic review suggest that the restoration method selected for teeth with root canal therapy influences lifespan, success rates, and cost-effectiveness. Concerning particular restorations, metal-ceramic crowns outperformed composite resin restorations in terms of success rates; however, survival was not significantly different.

Keywords: Direct restorations, Indirect restorations, Systematic review, Endodontic treatment

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Introduction

Fractures are a common concern for teeth that have undergone endodontic treatment and repair [1]. It is well-recognized that endodontic treatment decreases teeth's flexibility, which lowers their resistance to breakage [2]. It is caused by the drying of tooth structure and the loss of a large quantity of dentin and important anatomical elements such as cusps, marginal ridges, and the pulp chamber ceiling during the formation of access cavities and endodontic treatment [3]. The amount of remaining tooth structure and the type of restorative material utilized determine how long teeth that have undergone endodontic treatment last [4]. The method used to

repair the tooth and how the tooth, the restorative substance, and the oral environment interact [5]. In the end, dental professionals frequently recommend installing prosthetic crowns over teeth that are receiving endodontic therapy [6]. Inlay and onlay repairs can also be used in some situations. A few instances of indirect restorative materials that are often employed for the development of inlays, onlays, and crowns contain lithium disilicate, which offers an elevated level of transparency and a broad color spectrum, and indirect composite resins, that are shown to strengthen the fracture resistance of teeth [6].

Onlays are a more conservative treatment than complete crowns [5], but both protect teeth from breaking, and some experts believe cuspal coverage is required to avoid breakage in teeth with extensive endodontically treated cavities [7].

Because of their superior aesthetic qualities, composite resins and ceramics are more frequently used for the restoration of teeth that have received endodontic treatment, even though there are other restorative materials available for this purpose [8]. What composite resins offer is the maximum preservation of tooth structure [9]. In contrast to composite restorations, ceramics in the oral cavity provide superior lifetime and compressive resistance [8]. There are differences of opinion in this area, however [6].

The present review study aimed to investigate the success and current performance of direct vs. indirect restorations after endodontic treatment.

Materials and Methods

This study used PubMed, Medline, and ScienceDirect to conduct a comprehensive literature search spanning 2000–2023. Search terms included “systematic review,” “direct restorations,” and “indirect restorations.” To illustrate how we chose which papers to search, we used the PRISMA flowchart **(Figure 1)**.

Inclusion criteria

- Case-control and randomized-control trials
- published in English between 2000 and 2023

Exclusion criteria

- tabExpert opinion, narrative reviews, systematic reviews
- research conducted outside the given time frame
- studies conducted in languages other than English
- studies conducted in vitro

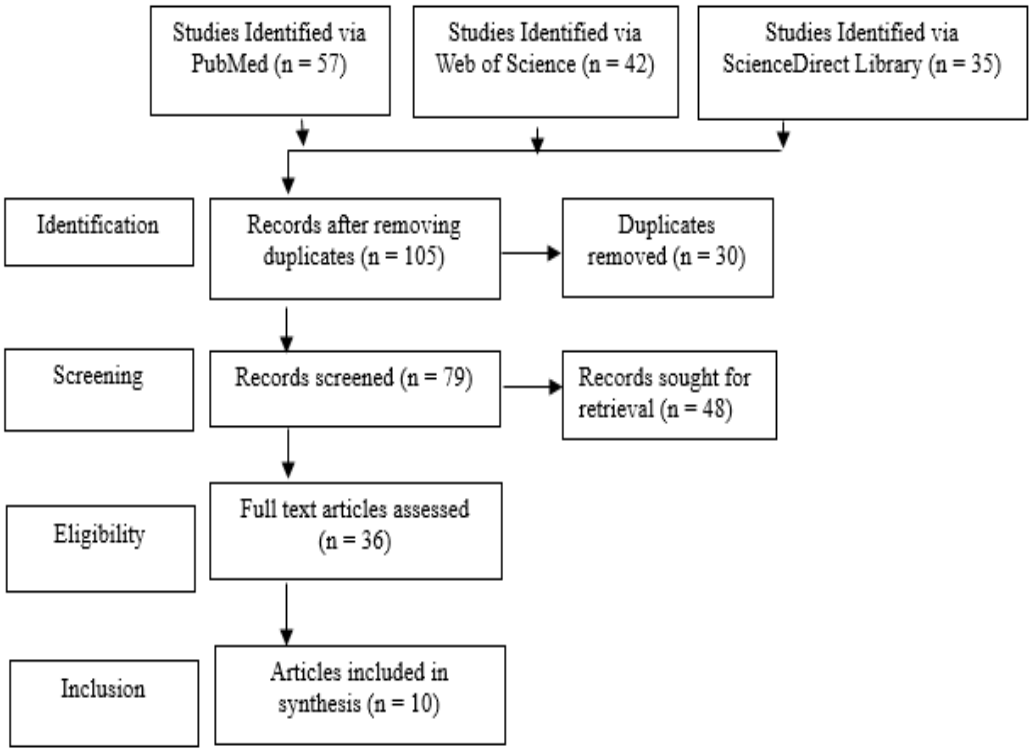

Figure 1. PRISMA Flow Diagram

Risk of bias assessment

Cochrane risk of bias assessment method was used to assess the quality of the studies included **(Table 1)**.

Table 1. Summary of Cochrane risk of bias assessment

Reference	Selection bias/appropriate control selection/baseline characteristics similarity	Selection bias in randomization	Selection bias in allocation concealment	Performance-related bias in blinding	Reporting bias/selective reporting of outcomes	Detection bias blinding outcome assessors	Accounting for confounding bias
Schwendicke and Stolpe [8]	-	+	+	+	+	+	+
Dawson *et al*. [10]	+	+	+	+	+	+	-
Lucarotti *et al*. [11]	+	+	+	+	+	+	+
Skupien *et al*. [12]	+	+	+	+	+	+	+
Von Stein-Lausnitz *et al*. [13]	+	+	+	+	-	+	+
Fráter *et al*. [14]	+	+	+	+	+	+	+
Maravić *et al*. [15]	-	+	+	+	+	+	+
Bromberg *et al*. [16]	+	+	+	+	+	+	+
Yazdi *et al*. [17]	+	+	+	+	+	+	+

Results and Discussion

To find the most economical option for restoring root canal-treated molars, Schwendicke and Stolpe [8] compared the costs of RBCs, FCs, and PCs, as indicated in **Table 2**. This ratio increased regardless of whether the cost of indirect restorations increased or the cost of direct repairs decreased. Without replacing any teeth, RBC was significantly more economical (the incremental cost-effectiveness ratio was 52.95 Euro/year). FC was more cost-effective and efficient when all teeth were replaced. In contrast to FCs and PCs, RBCs are less effective and more affordable. Both strategies' cost-effectiveness depended on whether patients or other payers were willing to pay.

Dawson *et al*. [10] found a statistically significant difference in the proportion of non-surgical retreatments, extractions, and further restorations within six months following root fillings compared to teeth repaired directly and indirectly.

Lucarotti *et al*. [11] evaluated the durability of restorations on teeth with and without filled roots. About 80,000 distinct adult patients were included in the study; 46% of these patients were men and 54% were women. During the eleven years of data, 30.073 of the 538.967 repair placements were root fills. Research comparing the longevity of restorations on treated and untreated teeth found that teeth with root canal therapy had shorter re-intervention intervals than teeth without the procedure.

A randomized clinical investigation was carried out by Skupien *et al*. [12] to evaluate the durability of metal-ceramic crowns and composite resin restorations. A composite resin repair or a metal-ceramic crown was given to 47 individuals (mean age 42.5, 11.5 years) with 57 endodontically treated teeth at random. One surface of each tooth was unharmed, but the endodontic procedure caused considerable coronal damage. A descriptive analysis was carried out utilizing FDI clinical criteria, and the survival of teeth and restorations was examined using log-rank tests and Kaplan-Meier statistics. Of the 57 restorations utilized on 47 patients, 30 were composite resin fillings and 27 were crowns. After one to five years of monitoring, there was a complete recall. Nonetheless, metal-ceramic crowns had a greater success rate ($P = 0.022$).

Von Stein-Lausnitz *et al*. [13] conducted an ex vivo investigation to compare the strength of recovered class III deficient maxillary central incisors with and without glass-fiber supports. On 72 removed human maxillary central incisors, we prepared the proximal class III cavities endodontically. Group carrying capacity differences were statistically significant, according to Kruskal-Wallis analysis ($P < 0.05$). Full-coverage restorations are not as good as less intrusive veneers. The condition was not improved by utilizing

the identical glass-fiber-fiber supports from the first installation.

To make sure that all repairs would withstand normal usage, Fráter *et al*. [14] placed them through a cyclic loading machine that ran up to 50,000 cycles or until they shattered. A matched post hoc comparison was conducted after the Kaplan-Meier analysis of survival. Twenty-five thousand tooth repairs failed. With a direct overlay and a fiber post instead of a cuspal covering, Group B3 employed flowable SFRC and had the greatest survival rate (P = 0.05) among all non-surgical therapy alternatives.

Finite element analysis (FEA) and an in vitro fracture resistance test were conducted by Maravi *et al*. [15]. The authors created models for three different kinds of composite restorations and evaluated fracture resistance using polymethyl methacrylate (PMMA) and periodontal ligament/alveolar bone (B). The models were subjected to an occlusal two-point axial stress of 850 N. Von Mises stresses and strains were calculated. There was little variation in the fracture resistance (N) throughout the categories.

This option was examined by Bromberg *et al*. [16], who compared the fracture resistance of molars replaced using indirect procedures with those treated using direct ones. The mesio-occluso-distal cavity was prepped, and standard endodontic procedures were carried out. A standardized testing device was used by the authors to assess the fracture resistance in newtons. To examine the data, the authors employed the Tukey test (P > 0.05) and one-way ANOVA. Healthy teeth have the lowest chance of breaking. Only ON outperformed TFP in terms of resistance recovery. Like IN, CR had the lowest rate of recovery.

Yazdi *et al*. [17] study set out to find out how resistant endodontically treated premolars with direct and indirect onlay restorations were to fractures and what sort of fractures may happen. In this in vitro investigation, 45 human maxillary premolars were used, 15 from each of the direct-only, indirect-only, and control (healthy teeth) groups. There were substantial differences in fracture resistance (P = 0.001) among the three groups. Fracture resistance differed statistically significantly (P < 0.001) between the two restoration groups and the group with healthy teeth. There was no statistically significant difference between the direct onlay restorations and the indirect onlay restorations in terms of fracture resistance (P = 0.6). The non-union rate increased statistically significantly in the indirect-only group, using the Chi-square test (P = 0.005).

Table 2. Summary of findings from each study.

Author's name	Objective	Samples	Test	Teeth	Restoration	Results
Schwendickeand Stolpe [8]	Comparing the cost-effectiveness of root canal-treated molar restorations using RBCs with FCs or PCs was the goal of the study. RBCs.	1		Molar	Molar restoration using RBCs with FCs or PCs.	When all of the teeth were replaced, FC was more effective and more cost-effective.
Dawson *et al*. [10]	This study compared the outcomes of teeth repair with direct and indirect restorations and evaluated the prevalence of extraction, root-end surgery, non-surgical retreatment, and restoration.	248,299	Chi-square tests		Extraction, root-end surgery, direct or indirect restorations, and then repair of teeth with root fillings	Within six months after a root filling, the number of non-surgical retreatments, extractions, and further restorations for teeth restored by direct restoration and indirect restoration differed statistically significantly.
Lucarotti *et al*. [11]	The purpose of the research was to determine if restorations on teeth with and without filled roots lasted.	538,967	18 years or older		Direct restoration, an indirect restoration, or a root filling	The time between re-interventions is shorter for teeth with root fillings than for those without.
Skupien *et al*. [12]	To evaluate the durability of metal-ceramic crowns and composite resin restorations on endodontically treated teeth that received a glass fiber post, this randomized clinical trial employed two distinct cementation techniques.	57	Kaplan-Meier statistics,		Metal-ceramic crowns and composite resin restorations	There was no difference in survival according to the log-rank test.

Von Stein-Lausnitz *et al.* [13]	The load capacity of Class III deficient maxillary central incisors that received either direct or indirect endodontic restoration—with or without glass-fiber posts—was evaluated in this ex vivo investigation.	72	Mann-Whitney U-test, Kruskal-Wallis test	Maxillary central incisors	Direct or indirect endodontic restoration, either with or without glass-fiber posts.	Indirect crown restorations are just as loadable as direct composite restorations for class III anomalies in maxillary central incisors receiving endodontic therapy.
Fráter *et al.* [14]	This in vitro study investigated the fracture behavior and fatigue survival of premolars that had undergone endodontic treatment (ET) and had been restored using various cuspal covering and post-core restorations.	108	Kaplan-Meyer survival analysis	Maxillary premolars	Post-core and cuspal covering restorations	When flowable SFRC was used as the luting-core material with fiber post and CAD/CAD overlays, group C3 outperformed the other groups in terms of fatigue survival ($P > 0.05$).
Maravić *et al.* [15]	Finite element analysis (FEA) and an in vitro fracture resistance test were used to examine the biomechanical characteristics of severely damaged premolars with composite restorations.	850		severely damaged Premolars	Direct restoration-DR; endo-crown-EC; post, core, and crown-C	There were no discernible variations in fracture resistance (N) across groups.
Bromberg *et al.* [16]	To investigate this possibility, the scientists compared the fracture resistance of molars fixed directly with that of molars restored indirectly.	50	Tukey test	Sound third molars	Sound teeth, onlays (ON), inlays (IN), direct CR, and transfixed fiberglass post (TFP) with direct CR.	The recovery rate in CR was the lowest and was comparable to IN's.
Yazdi *et al.* [17]	This research examined endodontically treated premolars with direct and indirect onlay restorations to determine the kind of fracture that may happen and the level of fracture resistance.	45	Chi-square test	Maxillary premolars	Direct and indirect	When comparing the two restoration groups to healthy teeth, there was a significant difference in fracture resistance ($P > 0.001$) between them.

According to current studies, restorations in teeth with root canal fillings all achieve a 34% ten-year survival rate to re-intervention. Sixty percent of crowned molar teeth with root fillings, fifty-seven percent of crowned premolar teeth with root fillings, and forty-two percent of crowned incisor teeth with root fillings continue to give suitable service while lacking the performance of crowns on teeth without root fillings [1, 5]. The survival rate observed in the present investigation is regarded as good because it was computed using only endodontically treated molars with an ETC score of II or III, and most of the molars had endodontic retreatment. A prospective cohort analysis found that a maximum of 79% of 196 endodontically treated teeth survived for at least 20 years [2, 3].

Because of their fundamental properties, PFC materials offer minimal protection against the spread of fatigue fractures [18]. The distance between the SFRC core and the stress initiation point on the surface is critical if the SFRC core is to serve primarily as a crack-stopper. Thus, the material's resistance to fatigue and the type of failure mode it displays may be influenced by the thickness of the PFC on the surface. The use of a PFC surface layer that is 2 mm thick in this study might be one reason why non-restorable fracture patterns in the SFRC-core groups continue to exist. This supports earlier studies that show the need for a thick SFRC and PFC layer [19, 20].

Unlike the other groups under investigation, the CB group's dentin showed the highest levels of von Mises stresses close to the base of the post-preparation cavity rather than the vestibular cervical part of the tooth. A tooth's resistance to fracture is decreased by endodontic access by pulp chamber roof removal, root canal widening, and prolonged use of high-concentration chemicals. Furthermore, compared to MOD substitutes, healthy teeth are more resistant to cracking [19–21].

Clinically, full crown restorations in premolars and molars fail at identical rates. Since the development of minimally invasive dentistry, maintaining dental tissue has become crucial. As a result, end crowns and direct restorations have been developed and marketed in recent years. The purpose of these restorations is to

preserve the retentive form of healthy tooth tissues. Nevertheless, premolars appear to experience endocrine failure more frequently than molars in clinical settings [22, 23].

A retrospective investigation revealed that the survival percentage of 1960 posteriorly treated teeth was 94.1% after an average service term of 27 months. It is challenging to compare the two aforementioned research with the current inquiry because 95% of CIs are not provided. For 174 molars endodontically treated by 12 general dentists, the approximate failure rate with a root-filled molar was 2.7. These changes are significant for the current study even if they are not always statistically significant [24]. Because of their special shape and position within the dental arch, premolars that have undergone endodontic treatment may be challenging to repair. Compared to anterior teeth, premolars are more susceptible to high stresses in both axial and shear directions. However, because of their steeper cusps and smaller crowns, they are also more sensitive than molars, especially if a large quantity of tissue has been destroyed. Furthermore, the pulp chamber of premolars is significantly smaller than that of molars, which allows the endocrine system to be retained [25, 26].

FEA and in vitro studies have demonstrated that end crowns in premolars function as well as entire crowns, but not in a clinical setting, according to a recent comprehensive review. There are a few possible causes for this. First, it is unlikely that the patient's mouth would experience the static fracture that is frequently used in in vitro investigations. When restorations fail after intraoral use, fatigue is nearly invariably the cause [27]. Thus, it was demonstrated that the attachment strengths of posts to root dentin were significantly impacted by thermal or thermomechanical aging, which was not taken into account in the current investigation. Additionally, the current work has demonstrated that the intraoral environment and tooth-loading parameters during mastication cannot be precisely replicated in vitro [28]. Rather, their ability to replicate the tooth-restoration complex's stress distribution is limited [29, 30].

The effectiveness of direct and indirect onlays for repairing endodontically treated premolars was assessed in the present investigation in terms of failure causes and fracture resistance. According to the findings, people with natural teeth had the highest fracture resistance, while those with direct onlay restorations had the lowest. The current study looked at the fracture resistance and failure causes of direct and indirect onlays utilized to restore endodontically treated premolars. Direct onlay restorations had the lowest fracture resistance, while natural teeth had the highest. However, the direct and indirect groups did not differ significantly in terms of fracture resistance [31, 32]. According to observational data, masticatory forces at the back teeth in a clinical environment can reach 725 N [33].

Static axial loads and the reactions of direct composite restorations, composite endocrines, posts, cores, and crowns are adequate for the restoration of endodontically treated molars with substantial tissue loss. Furthermore, when combining an in vitro experiment with FEA in the same investigation, it's critical to take into account how various supporting tissue models may alter the outcomes [34].

A root-filled molar's longevity was 1037 years on average, with 18 failures throughout that period. When doing endodontic therapy, endodontic specialists have been shown to increase tooth survival rates in comparison to ordinary dentists [35, 36].

Almost all (99.2%) of the direct restorations in this research were made using resin composite. Direct or indirect cuspal covering and tooth structure preservation may be more significant than the material selection. To ascertain the direct or indirect impact of bonded restorations with a cuspal covering on the survival of teeth that have had endodontic treatment, more investigation is required in clinical studies. Even though endodontically treated teeth can undergo adhesive rehabilitation, the majority of the molars in this research were indirectly restored with complete contour crowns. With a partial indirect repair, the tooth structure could be better conserved [26].

Conclusion

To sum up, the findings of the systematic review show that the choice of restoration method for teeth with root canal therapy affects lifespan, success rates, and cost-effectiveness. The selection of restoration procedures for teeth with root canal therapy affects lifespan, success rates, and cost-effectiveness, according to the systematic review's findings. It was discovered that RBCs were less costly than FCs or PCs, but they were less effective. Depending on whether teeth were replaced and if patients or payers were prepared to pay, the cost-effectiveness ratio changed. More follow-up care was needed for direct restorations than indirect restorations, according to the study. Furthermore, the re-intervention intervals for teeth with root fillings were shorter than those of teeth without them. While there was no discernible difference in survival, metal-ceramic crowns outperformed composite resin restorations in terms of success rates for certain restorations.

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