GRADUATION PROJECT

Degree in Dentistry

POST-ENDODONTIC ADHESIVE INDIRECT RESTORATIONS IN POSTERIOR TEETH

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ABSTRACT

Introduction: Endodontically treated posterior teeth (ETT) present significant structural and biomechanical challenges due to the loss of dental tissue and increased risk of fracture. Traditionally, these teeth have been restored with full crowns, however, the devlopment of adhesive dentistry has led to more conservative approaches using indircet restorations; **Objectives:** The aim of this study is to evaluate the clinical performance, mechanical behavior and logevity of adhesive indirect restorations in posterior ETT and compare these with conventional restorative approaches; **Methodology:** A litterature review was conducted using databases such as PubMed, MEDLINE and Dentistry & Oral Sciences Source. Studies were selected according to predefined inclusion criteria focusing on posterior endodontically teeth restored with adhesive indirect restorations. Both clinical and in vitro studies were included; **Results:** The analyzed studies show that adhesive indirect restorations, including inlays, onlays, overlays and endocrowns provide favorable outcomes in terms of fracture resistance, sress distribution and tooth structure preservation. Sevral studies report comparable or improved performance when compared to conventional full crowns. However, variations exist depending on the restorative material, preparation design and bonfing protocol; **Conclusion:** Adhesive indirect restorations represent a reliable and minimally invasive option for the restoration of posterior ETT. While they may not completely replace conventional techniques, they offer significant advantages in appropriate clinical situations. Further long-term studies are required to standarize clinical protocols.

KEYWORDS

Dentistry; endodontically treated teeth; adhesive restorations; onlays; posterior teeth.

RESUMEN

Introducción: Los dientes posteriores tratados endodónticamente presentan importantes desafíos estructurales y biomecánicos debido a la pérdida de tejido dental y al mayor riesgo de fractura. Tradicionalmente, estos dientes se han restaurado con coronas completas, sin embargo, el desarorollo de la odontología adhesiva ha perimitido enforques más conservadores mediante restauraciones indirectas; **Objectivos:** El objectivo de este estudio es evaluar el rendimiento clínico, el comportamiento mecánico y la longevidad de las restauraciones indirectas adhesivas en dientes posteriores tratados endodónticamente y comparalas con los restauradores convencionales; **Metodología:** Se realizó una revisión de la literatura utilizando bases de datos como PubMed, MEDLINE y Detistry & Oral Sciences Source. Los estudios fueron seleccionados según criterios de inclusíon predefinidos, centrándose en dientees posteiores tratados endodónticamente restaurados con técnicas indirectas adhesivas. Se incluyeron tanto estudios clínicos como estudios in vritro; **Resultados:** Los estudios analizados muestran que la restauraciones indirectas adhesivas, incluyendo inalys, onlays, overlays y endocoronas presentan resulatados favorablesen términos de resistancia a la fractura, distribución de tensiones y preservación de la estructura dental. Varios estudios reportan un rendimiento comparable o superior al de las coronas completas convencionales. Sin embargo, los resultadosvarían en función del material restaurador, el diseño de a preparación y el protocolo adhesivo; **Conclusiones:** Las restauraciones indirectas adhesivas representan una opción fiable y míimamente invasiva para restauración de dientes posteriores tratados endodónticamente. Aunque no sustituyen completamente a las técnicas convencionales, ofrecen ventajas significativas en situaciones clínicas específicas. Se requieren más estudios clínicos a largo plazo para establecer protocolos estandarizados.

PALABRAS CLAVE

Odontología; dientes tratados endodónticamente; restoraciones adhesivas; onlays; dientes posteriores.

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1. INTRODUTION

1.1 Restoration of endodontically treated teeth (ETT)

1.1.1. Posterior endodontically treated teeth and their challenges

Posterior teeth play a fundamental role in mastication and maintaining the overall equilibrium of the oral cavity. Primarily responsible for grinding food, they also support the vertical dimension of occlusion and contribute to the stability of the bite. When these teeth undergo endodontic treatment, their biochemical behavior is altered, predisposing them to structural weakening and an increased risk of fracture under functional load (1).

This weakening is mainly due to the cumulative loss of hard tissue resulting from caries, access cavity preparations and previous restorative procedures, which collectively reduces the overall structural strength of the tooth. Moreover, the tooth endures an alteration in dentin composition and microstructure such as decreased moisture and a lower modulus of elasticity further compromising the mechanical behavior of the tooth (2). Posterior teeth are particularly vulnerable because of their complex morphology and exposure to high occlusal stresses (2)

As a result, one of the main causes of failure in ETT is the development of non-restorable fractures in the coronal portion of the tooth (3). The preservation of tooth structure is therefore a critical factor for clinical success. An adequate restorative approach should aim not only to restore morphology and function but also to reinforce the weakened tooth, ensuring its long term biomechanical stability (3).

1.1.2. Historical approach to ETT restoration

In this context, the coronal restoration of ETT plays a crucial role in enhancing their long-term survival. Direct restoration techniques for posterior teeth have traditionally been considered the simplest and most efficient approach, offering satisfactory aesthetics and adequate mechanical

properties. Historically, it was also widely believed that ETT required the placement of a root canal post and full coverage crown for adequate reconstruction. Posts were thought to retain the core and provide additional support for the crown, while the crowns were intended to protect weakened cusps from fracture and restore masticatory function. Studies have shown that cuspal coverage could increase the survival rate of non- vital posterior teeth by up to six times. Consequently, for many years, full crowns were considered the gold standard (4). However, these traditional approaches also had limitations. The preparation required removal of a lot of tooth structure, which could further weaken the tooth and increase the risk of fracture. In cases where teeth exhibit extensive loss of coronal structure the mechanical properties of restorations must be reinforced to ensure durability and functional stability. These considerations have prompted the development of more conservative restorative strategies, emphasizing adhesion and the preservation of tooth structure over purely mechanical retention (5).

1.2. Evolution toward adhesive and conservative dentistry

1.2.1. Advances in adhesive dentistry

With the continues development in dental materials and technologies, indirect restorative techniques have received increasing attention and have become the focus of more extensive research. Among these, adhesive indirect restorations for posterior teeth have attracted particular interest, especially for the restoration of endodontically treated teeth, as they allow a more conservative approach while achieving satisfactory mechanical and esthetic performances (6). The emergence of adhesive dentistry in the late 20th century marked a fundamental shift from traditional, mechanically retained restorations toward adhesive based techniques, enabling stronger integration between restorative materials and dental tissues (7).

1.2.2. From direct to indirect adhesive restorations

The transition from direct to indirect adhesive restorations was driven by both material limitations and clinical challenges of conventional techniques. While direct composite restorations are widely

used for their simplicity, their polymerization shrinkage, limited wear resistance and technique sensitivity often compromise marginal adaptation and longevity in extensive posterior cavities (8).

Indirect adhesive restorations , on the other hand, offer several advantages, including improved reproduction of occlusal morphology, proximal contact adaptation and a significant reduction in polymerization shrinkage as the material is cured outside the oral cavity before cementation (9). These properties contribute to better marginal sealing, reduced postoperative sensitivity and improved biomechanical performance, especially in endodontically treated posterior teeth, where the remaining structure is already weakened (10).

ETT present several biological and structural alterations that compromise their mechanical behavior. The loss of neurovascular bundle following root canal treatments leads to the absence of proprioception and pulpal sensitivity, making these teeth less responsive to thermal stimuli and early signs of recurrent caries (11). This sensory loss, combined with the lack of internal vascularization, contributes to progressive dentin dehydration and changes in collagen cross-linking, reducing tissue resilience and increasing susceptibility to fracture under occlusal loading (10). Beyond biological factors, the biomechanical integrity of ETT is significantly affected by the amount of remaining tooth structure. Structural loss occurring before and during treatment weakens cupsal stiffness, alters stress distribution, and represents one of the main predictors of failure in posterior teeth (12). For these reasons, ensuring adequate coronal seal and selecting a restorative approach that compensates for the compromised dentin and reinforced the residual structure are essential for long term survival (13).

Although traditional full coverage crowns or post and core restorations have demonstrated long term clinical reliability, their preparations often require excess removal of sound tooth structure, which contradicts the modern principles of minimally invasive dentistry. The development of adhesive indirect techniques thus represents a shift towards restorations that aim to reinforce rather than replace the remaining dental tissues (10).

1.3. Classification of indirect adhesive restorations

1.3.1. Inlay, Onlay, Overlay, Endocrown & modern variants

Bonded restorations can be classified according to the extent of the tooth structure they replace and the area of cuspal coverage: Inlay, Onlay, Overlay, Endocrown… These are partial coverage restorations are designed to restore one or more missing cusps and the corresponding occlusal surfaces, with retention achieved through adhesive techniques (4).

An inlay, is an indirect restoration fabricated outside the oral cavity, without covering any cusps (14). It is cemented into the tooth and is typically indicated for medium class II cavities in which buccal and lingual walls remain intact (9).

An onlay, is a partial coverage restoration that includes at least one cusp (14). Onlays are recommended for teeth with moderate loss of cupsal structure, helping to restore form and function while conserving sound tissue (9).

An overlay can be considered a specific type of onlay that provides complete coverage of all cusps. Adhesively bonded overlays are commonly indicated in cases of extensive loss of tooth structure, providing complete protection of the remaining tooth structure and enhanced stress distribution (15).

An endocrown is a full cusp coverage indirect restoration specifically designed for endodontically teeth. It integrates the crown and core into a single monolithic structure that is retained by adhesive bonding within the pulp chamber. The internal extension into the pulp chamber provides additional surface area for adhesion and mechanical stability (16). This concept preserves sound dentin and offers a conservative alternative to traditional post and full coverage crowns, combining simplicity of design with favorable mechanical performance (9).

Beyond these classical categories, newer minimally invasive variants have been introduced in adhesive dentistry. Tabletop restorations, used mainly in posterior teeth with advanced occlusal wear, provide full occlusal coverage while preserving axial walls and offer a conservative option for managing worn dentition (17). Veneerlay restorations combine characteristics of veneers and onlays, extending over functional cusps to enhance strength and esthetics while maximizing enamel preservation (17). These hybrid designs illustrate the continuous evolution of partial coverage adhesive restorations toward increasingly conservative and biomimetic approaches (17).

1.3.2. Clinical and functional advantages

Adhesive indirect restorations offer several clinical and functional advantages over conventional techniques. Their adhesive nature not only ensures reliable retention but also promotes biomechanical harmony with the remaining tooth structure. Unlike conventional crowns that rely on extensive tooth reduction for micromechanical retention, adhesive restorations achieve retention through micromechanical and chemical interactions between the restorative material and the tooth (18).

Adhesive techniques create a monoblock effect enhancing the continuity between the prepared tooth and the restoration forming: a strong bong. This unified behavior mimics the natural tooth biomechanics leading to improved load transfer and increased fracture resistance of endodontically treated teeth (16,18).

1.4. Restorative materials for adhesive indirect restorations

Indirect adhesive restorations can be fabricated from several classes of materials. Each material presents specific mechanical, optical and adhesive properties that influence its clinical use and longevity. A practical classification includes glass-based ceramics, reinforced ceramics, indirect resin composites and hybrid CAD/CAM resin matrix materials.

Glass-based ceramics, such as feldspathic porcelain and leucite reinforced ceramics are valued for their translucency, esthetics and chemical stability in the oral environment. However, their relatively low flexural strength and fracture toughness limit their indications in high stress clinical situations particularly in post endodontic treated posterior teeth, where occlusal loads are significant (19,20).

In contrast, lithium disilicate ceramics represent the most widely used glass ceramic material for posterior adhesive restorations due to its combination of high flexural strength and esthetic qualities. Their mechanical reliability and adhesive potential makes them the preferred material for onlay, overlays and endocrowns in more demanding clinical situations (19).

Indirect resin composites and hybrid CAD/CAM materials represent a newer category of restorative options that are particularly relevant for posterior endodontically treated teeth. These materials exhibit an elastic modulus close to that of dentin, which allows them to absorb masticatory stresses more effectively and reduce the risk of fracture (20). Their lower stiffness may help distribute occlusal loads more homogeneously within the tooth restoration complex, a property that can be advantageous in the structurally compromised ETT.

Zirconia based ceramics, belonging to the polycrystalline ceramic family, are increasingly indicated for posterior ETT because of their exceptional flexural strength and fracture toughness (19). Although zirconia is less translucent than glass ceramic, recent formulations with enhanced translucency have improved its esthetic potential. Zirconia is an excellent option for posterior indirect restorations of ETT where functional demands are high (21).

1.5. Adhesive interface and cementation

Beyond the selection of restorative materials, the success and longevity of adhesive indirect restorations depends critically on the quality of the adhesive interface and the resin cementation protocol.

Because indirect restorations involve both restorative surface and a prepared tooth substrate, the adhesion protocol is very technique sensitive. It requires multiple sequential steps for the conditioning of each surface, making it susceptible to contamination by moisture or saliva and thus compromising bond integrity if not properly managed (22).

1.5.1. Resin cements

Resin cements play a fundamental role in the retention and long-term stability of indirect adhesive restorations. They are generally classified into total-etch, self-etch and self-adhesive system, each differing in their interaction with enamel, dentin and restorative materials (23). Total-etch and self-etch resin cements usually provide the highest and most durable bond strengths, especially when used with glass ceramics or resin-based CAD/CAM materials, while self-etch adhesive resin cements simplify clinical procedures but often yield lower adhesion values. In posterior ETT where

both, structural compromise and high functional demands coexist, the selection of resin cement capable of achieving a strong and stable adhesive interface is particularly important (23,24).

1.5.2. Surface conditioning protocols

Because indirect adhesive restorations require bonding to both the restorative material and the tooth substrate, each surface must be conditioned using a specific protocol. The treatment depends on the microstructure and chemical composition of the restorative material.

Etchable glass ceramics, such as lithium disilicate, are etched with hydrofluoric acid followed by silane to achieve micromechanical and chemical adhesion (25). Polycrystalline ceramics like zirconia require airborne particle abrasion and the application of an MDP containing primer, since they do not respond to hydrofluoric acid etching (26). Indirect resin composites and hybrid CAD/CAM materials are generally sandblasted and treated with silane or universal primer to enhance micromechanical interlocking and chemical coupling. On the tooth side, adhesion is achieved either through a total-etch or self-etch approach, depending on the resin cement selected (20,27)

Table 1. Surface treatment protocols for indirect restorative materials used in posterior endodontically teeth (22,28).

Material type	Surface conditioning	Primers/ coupling agent	Adhesive mechanism
Etchable ceramics (LDS)	Hydrofluoric acid etching (5–10%) 20 s	Silane coupling agent	Micromechanical retention and siloxane chemical bonding
Non etchable ceramics (Zr, Alumina)	Sandblasting with 50 µm Al_2O_3 for 10s	MDP containing primer (10-MDP)	Phosphate zirconium oxide chemical bonding
Indirect resin composite, hybrid CAD/CAM	Sandblasting with 50 µm Al_2O_3 for 10s	Silane coupling agent	Micromechanical interlocking and silane coupling

Tooth substrate (enamel, dentin)	37% orthophosphoric acid (15–30 s)	Adhesive resin / bonding agent	Resin infiltration and hybrid layer formation

1.5.3. Clinical importance of adhesive interface

Proper adhesion and cementation remain the foundation of the biomechanical success of restorative procedures in posterior ETT, where the remaining structure is often compromised, and occlusal loads are high. The integrity of the adhesive interface largely determines how stresses are distributed across the tooth restoration complex and strongly influences the restoration's longevity and failure behavior (29). Although the detailed bonding and cementation protocols are not the main focus of this study, understanding their roles provides important context for evaluating the clinical performance of adhesive indirect restorations in structurally compromised ETT. (20)

2. OBJECTIVE

The primary objective of this study is to evaluate and synthesize the available scientific evidence regarding the clinical performance, mechanical behavior, longevity of adhesive indirect restorations (inlay, onlay, overlay and endocrown) compared with conventional restorative techniques in endodontically treated posterior teeth.

3. MATERIALS AND METHODS

3.1. Research question (PICO)

The research question was formulated following the PICO framework to ensure a structured and focused approach to the literature review.

- P (Patient/Population): Endodontically treated posterior teeth, which frequently present substantial loss of tooth structure and require restorations capable of withstanding high occlusal forces.
- I (Intervention): Adhesive indirect restorations, including inlays, onlays, overlays, endocrowns… fabricated from different materials and places using adhesive cementation protocols.
- C (Comparison): Conventional restorative approaches such as direct composite restorations, full-coverage crowns or non-adhesive techniques used to restore posterior ETT.
- O (Outcome): Mechanical performance, clinical longevity, survival rates, failure modes and esthetic outcomes of the restorations.

Based on these parameters, the research question guiding this review was: In patients with endodontically treated posterior teeth, does restoration with adhesive indirect restorations such as inlay, onlay, overlays or endocrown (I) compared with conventional restorative techniques (C) result in improved mechanical performance, clinical longevity, and esthetic outcomes (O)?

3.2. Eligibility criteria

This review included primary research that evaluated indirect adhesive restorations placed on endodontically treated posterior teeth. Articles comparing different indirect restorative materials or techniques, and those reporting relevant outcomes such as clinical performance, longevity, mechanical behaviors or esthetics, were included. Clinical studies and laboratory investigations published in English between 2000 and 2025 were considered.

Secondary literature such as systematic review, meta- analyses, narrative reviews, expert opinions and articles lacking primary data were excluded. Studies focused exclusively on root posts or core materials without evaluating the coronal indirect restoration were excluded from this research, as well as publications without full text available.

3.3. Sources of information

The bibliographic search was carried out using major scientific databases relevant to dental research. The primary sources of information were MEDLINE complete (EBSCOhost) and PubMed, which provided access to peer reviewed biomedical and dental literature. To complement the search, Google Scholar was consulted to identify grey literature and additional primary studies not indexed in traditional databases.

3.4. Search strategy

A structured search was conducted using the advanced search functions of MEDLINE complete and PubMed. Search terms were developed form the PICO components and combined using Boolean operators. The exact search used for MEDLINE Complete was: (Posterior teeth OR Molars) AND (Indirect restorations OR Inlays OR Onlays OR Overlays OR Endocrown) AND (Adhesive OR Bonding OR Resin composite) AND (Clinical performance OR Longevity) and was performed on 18/10/25. The corresponding PubMed query, adapted to PubMed field indexing, was: (((Posterior teeth OR Molars) AND (Indirect restorations OR Inlays OR Onlays OR Overlays OR Endocrown)) AND (Adhesive OR Bonding OR Resin composite)) AND (Clinical performance OR Longevity) and was on conducted on 02/12/25. Additional records were identified through grey literature searches using Google Scholar.

3.5. Study selection

All studies found during the search were examined first by title and abstract, and then through full text evaluation. Duplicate records were removed during the initial phase. Articles that were unrelated to indirect adhesive restorations in posterior ETT or that did not meet the predefined eligibility criteria were excluded. The final set of eligible studies was included for data extraction, with the selection process illustrated in the PRISMA flow diagram provided in the results section.

3.6. Data extraction

Data form the included studies were collected and organized in a structured table. The information collected included the author, year of publication, study design, type of tooth evaluated, restorative material, type of adhesive indirect restoration and main clinical or mechanical outcome reported. These data were synthesized in the result section.

4 RESULTS

The study selection process is presented in figure 1 using a PRISMA flow diagram. The search strategy identified a total of 430 records across the selected databases. After removal of duplicates, 72 studies remained and were screened based on title and abstract. Articles that did not meet the predefined inclusion criteria were excluded. The full texts of the remaining studies were then assessed for eligibility, resulting in the selection of 10 studies included in the qualitative synthesis.

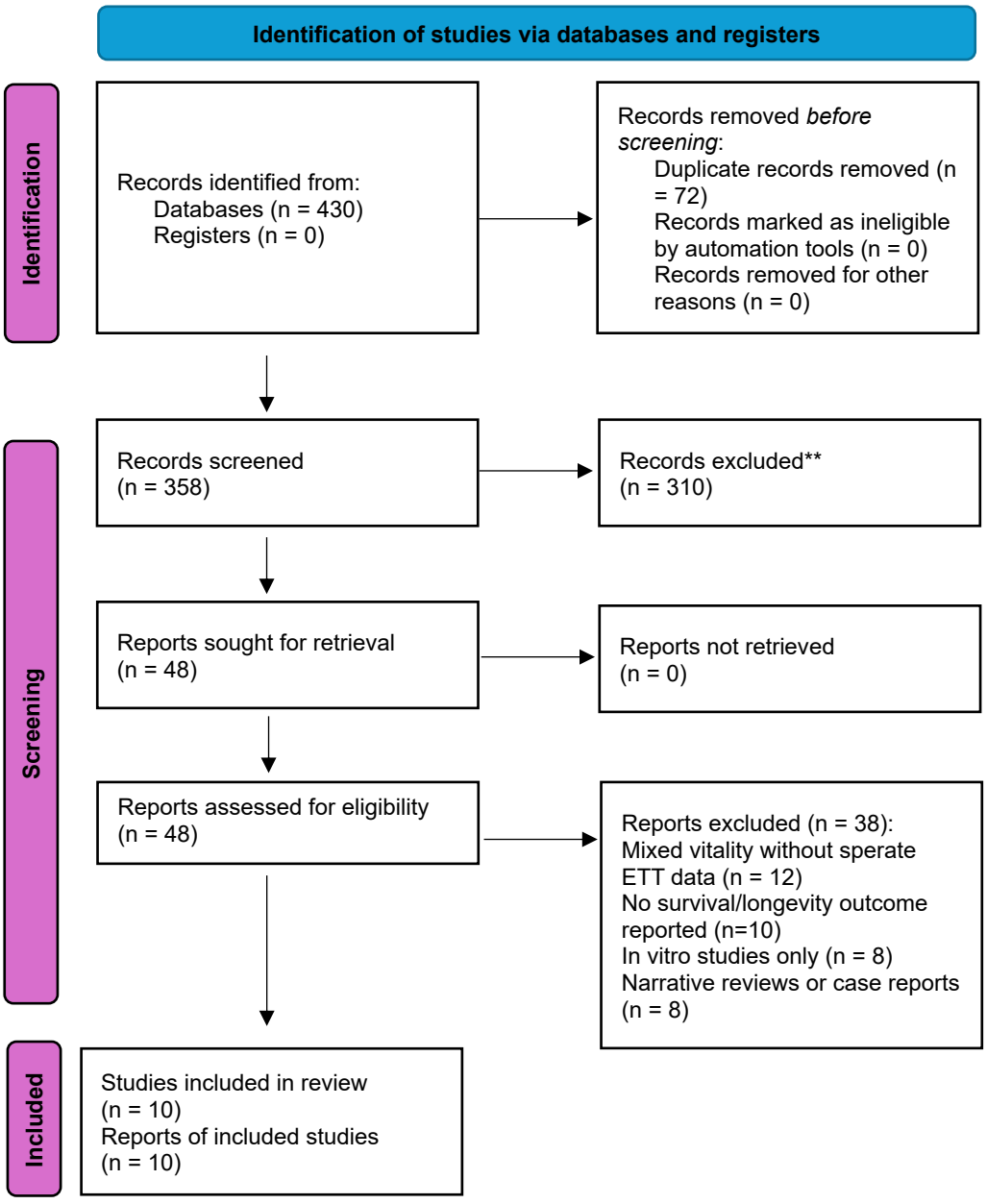


Figure 1. PRISMA flow diagram of the study selection process.

The following studies were published between 2015 and 2025 and comprised systematic reviews and meta-analysis, randomized clinical trials, retrospective clinical studies and one in vitro investigation. All articles focused on endodontically treated posterior teeth and evaluated adhesive indirect restorations, either alone or in comparison with conventional restorative approaches. Follow up periods ranged from short term evaluation to long term analysis up to 20 years. The main characteristics and outcomes of these studies are summarized in table 2.

Table 2. Characteristics and main outcomes of included studies evaluating adhesive indirect restorations in endodontically treated posterior teeth.

Study (author /year)	Study design	Population	Restauration type	Comparator	Follow-up	Outcomes	Main findings
de Kuijper et al., 2023 (30)	Systematic review and meta- analysis (22 studies: 2RCTs, 3 prospective, 17 retrospective)	Endodontically treated posterior teeth	Direct composite resin restorations	Indirect restorations	Primarily short-term evidence (2.5-3 years)	Tooth survival and restorative success	Short- term finding indicate no statically significant difference between direct and indirect restorations in terms of tooth survival or restorative performance.
Dioguardi et al., 2021 (31)	Systematic review and meta- analysis	Endodontically treated posterior teeth	Indirect adhesive restorations (including inlays, onlays, overlays and endocrown)	Conventional restorative approaches (including full crowns and direct restoration)	Follow – up periods varied among included studies (short- and medium-term data)	Clinical performance, survival rate and failure patterns	Indirect adhesive restorations demonstrated favorable survival rates and clinical performance. Partial adhesive restorations, particularly endocrowns and overlays, were reported as reliable alternatives to

							conventional full coverage crowns in ETT posterior teeth.
Fouda et al., 2024 (32)	Randomized control clinical trial	Endodontically treated posterior teeth	Indirect adhesive restorations (CAD/CAM partial coverage restorations)	Conventional full-coverage crowns	Medium term follow - up	Survival rate, complication rate and failure patterns	No statically significant difference in survival rate between partial adhesive restorations and full- coverage crowns were observed during the follow-up period. Partial coverage restorations demonstrated comparable clinical performance, suggesting they may represent a conservative and reliable alternative for restoring endodontically treated posterior teeth.
Frankenberger et al., 2015 (33)	Randomized controlled clinical trial	Endodontically treated posterior teeth	Indirect adhesive partial restorations (ceramic inlays/ onlays)	Direct composite restorations	Long term follow - up (up to 11 years)	Survival rate and failure incidence	Long- term results showed no statistically significant difference in overall survival between indirect ceramic restorations and direct composite restorations. However, indirect restorations demonstrated slightly lower rates of catastrophic failures, suggesting a potential advantage in terms of long-term structural durability.

Elhaddad et al., 2024 (34)	Prospective clinical study	Endodontically treated posterior teeth	Indirect adhesive restorations (CAD/CAM partial coverage restorations)	Conventional full coverage crowns	Medium term follows up	Survival rate, complication rate and mechanical failure	Indirect adhesive partial restorations demonstrated survival rates comparable to full- coverage crowns. Most reported complications were minor and repairable, supporting the use of conservative adhesive restorations as a predictable alternative to conventional crowns in endodontically treated posterior teeth.
Dioguardi et al., 2022 (35)	Systematic review and meta- analysis	Endodontically treated posterior teeth	Indirect bonded adhesive restorations (including inlays, onlays, overlays and endocrowns)	-	Follow – up ranged from 2 to 30 years	Failure rate, annual failure rate and survival	Indirect bonded restorations in endodontically treated posterior teeth demonstrated favorable long-term survival, with low annual failure rates according to studies. Longer follow-up period was associated with increased failure rates, although overall outcomes supported the reliability of adhesive partial coverage restorations as a conservative treatment option.

Kontakou Zoniou et al., 2025 (36)	Scoping review	Endodontically treated posterior teeth	Endocrowns (adhesive monolithic restorations)	Conventional post and core restorations and full coverage crowns	Follow up varied among included studies (short to long term data)	Survival rate, preparation design influence and material performance	Endocrowns demonstrated high survival rates and were reported as reliable and conservative alternative to post and core supported crowns. Preparation design and restorative material influenced clinical performance, although overall outcomes supported the use of adhesive endocrowns in posterior ETT.
Lempel et al., 2019 (36)	Retrospective clinical study	Endodontically treated posterior teeth	Direct composite restorations	Vital posterior teeth	Up to 13 years	Survival rate, annual failure rate and hazard ratios	ETT restored with direct composite exhibited significantly lower long-term survival compared with vital teeth. Increased failure risk was associated with endodontic treatment and occlusal stress. These findings highlight the structural vulnerability of ETT and support the need for restorations providing cuspal coverage.
Shu et al., 2018 (37)	Systematic review and meta-analysis	Endodontically treated posterior teeth	Indirect restorations	Direct restorations	5 and 10 years follow up	Survival rates (odds ratio analysis)	Indirect restorations demonstrated significantly higher survival rates compared with direct restorations at both 5 and 10 years. The analysis favored indirect restorations in

							log- term follow up, although the overall quality of evidence was limited due to heterogeneity among included studies.
Ravasini et al., 2018 (38)	Retrospective clinical study	Posterior teeth (including subgroups of ETT)	Indirect composite restorations (inlays, onlays, overlays)	-	Up to 20 years	Survival analysis, clinical performance	Indirect composite restorations demonstrated high short- and medium-term survival rates, with gradual reduction over long term follow up. Ten-year survival exceeded 80% while 20-year survival decreased but remained clinically acceptable. Failures were mainly related to fracture and secondary caries.

4.1. Clinical outcomes of indirect adhesive restoration

4.1.1. Survival and clinical performance

Across the included studies, the primary outcomes assessed were restoration survival, success rate and incidence of mechanical complications. Most studies reported high survival rates for indirect adhesive restorations placed in posterior ETT during short to medium term follow up periods. Survival was generally defined as the absence of catastrophic failure, need for replacement or loss of retention.

4.1.2 Indirect vs direct restoration

In studies directly comparing indirect adhesive restorations with direct composite restorations, short term survival outcomes were similar, with no significant differences reported in some clinical trials. However, studies including long term follow up periods reported higher incidence of structural complications in restorations without cuspal coverage, particularly in ETT subjected to occlusal stress.

4.1.3. Indirect vs full-coverage crowns

Full coverage crowns were evaluated in several included studies, either as comparator or reference restoration. Reported survival rates for crowns were generally higher during the assessed follow up periods particularly in cases with extensive structural loss. However, adhesive indirect restorations providing cuspal coverage showed comparable survival rates in short and medium-term evaluations. Crown preparations were described as involving greater removal of remaining tooth structure compared with indirect restorations.

4.1.4. Endocrowns and cuspal coverage restorations

Endocrowns demonstrated favorable clinical performance, particularly in posterior teeth with extensive coronal tissue loss. Survival outcomes were comparable to other indirect adhesive restoration and in some studies to full coverage crowns. Onlays and overlays were frequently associated with reduced incidence of catastrophic fracture compared with intracoronal restorations.

4.1.5. Failure patterns

Complications demonstrated in the included studies primary consisted of debonding, fracture of the restorative material, marginal deterioration and secondary caries. Root fractures were less frequently described in indirect restorations. Failure type and frequency varied according to restoration design, material and duration of follow up.

5 DISCUSSION

The present review evaluated the clinical performance and longevity of adhesive indirect restorations in posterior ETT in comparison with conventional restorative approach. Overall, the evidence suggests that adhesive indirect restorations provide predictable outcomes, particularly when cuspal coverage is incorporated. Although full coverage crowns remain a well-established treatment option, contemporary adhesive strategies emphasize preservation of remaining tooth structure as a central consideration in restorative decision making.

5.1. Biomechanical vulnerability of endodontically treated teeth

Endodontically treated teeth present altered biomechanical behavior primarily due to loss of structural integrity associated with caries removal, assess cavity preparation and previous restorative procedures. The reduction of marginal ridges and peri cervical dentin significantly decreases fracture resistance, making these teeth more susceptible to cuspal deflection under occlusal loading (33,36).

The amount of remaining coronal tooth structure has been commonly recognized as a critical determinant of long-term prognosis. Multiple studies emphasized that extensive loss of coronal tissue, particularly in mesio-occlusal-distal (MOD) cavities, increases the risk of structural failure when cuspal coverage is not provided (32,35). This structural compromise rather than the endodontic procedure itself appears to be the primary factor influencing fracture susceptibility (36).

Biomechanical reinforcement through cuspal coverage has been shown to reduce stress concentration within the remaining tooth structure. Adhesively bonded restorations may contribute to stress redistribution across the restored unit, potentially limiting cracking propagation and catastrophic root fracture (33,35). This concept helps explain the improved performance observed in restorations incorporating cupsal coverage with intracoronal restorations alone (32,37).

Furthermore, the presence or absence of a ferrule has been described as an important factor influencing resistance to fracture, particularly when comparing partial adhesive restorations with

full-coverage crowns (32,33). The interaction between residual dentin thickness, preparation design and restorative material therefore plays a central role in determining clinical outcomes.

5.2. Indirect adhesive restorations: Mechanical and clinical rationale

Indirect adhesive restorations have been increasingly proposed as conservative alternatives for the restoration of posterior ETT. Unlike traditional full coverage crowns, adhesive restorations aim to reinforce the remaining tooth structure while preserving as much sound dental tissue as possible. This approach aligns with the principles of minimally invasive dentistry, which emphasize on structural preservation and biological respect for remaining tissues while maintaining adequate mechanical performance (31,35).

From a biomechanical perspective, the effectiveness of adhesive indirect restorations is largely related to their capacity to redistribute functional stresses across the bonded interface and the remaining tooth structure. When cupsal coverage is incorporated through restorations such as onlays, overlays or endocrowns, occlusal forces can be more evenly distributed along the restorative-tooth complex. This stress redistribution may help reduce localized tensile stresses that could otherwise lead to cusps fracture in structurally weakened teeth (32,33). As a result, adhesively bonded restorations may contribute not only to restoring lost tooth structure but also to reinforcing the remaining dental tissues.

Another important advantage of indirect restorations lies in their fabrication process. Laboratory fabrication or CAD/CAM technology allows improved control over restoration morphology, occlusal anatomy and material polymerization compared with direct techniques. This controlled fabrication may result in improved marginal adaptation, reduced polymerization shrinkage and enhanced mechanical properties of the restorative material (30,34). These factors may contribute to the favorable medium term survival outcomes reported in several clinical studies included in this review (31,35).

Nevertheless, the long-term success of adhesive indirect restorations remains strongly dependent on the quality and durability of the adhesive interface. Bond degradation over time, moisture contamination during bonding procedures and variability in adhesive protocols may influence restorative longevity. Consequently, while adhesive restorations offer significant advantages in

terms of tissue preservation and biomechanical reinforcement, their clinical performance remains technique sensitive and requires strict adherence to appropriate bonding protocols (34,35). Taken together, the available evidence suggests that adhesive indirect restorations may represent a valuable restorative option for posterior ETT.

5.3. Direct composite restorations: Indications and limitations

Direct composite restorations remain a commonly used treatment option for the restoration of posterior ETT due to their conservative nature, reduced treatment time and lower economic cost. When sufficient coronal tooth structure is preserved, direct restorations may provide acceptable short term clinical outcome while allowing restoration of function through a minimally invasive approach (36,37).

However, the biomechanical limitations of direct composite restorations become more evident in teeth presenting extensive structural loss. ETT frequently exhibit large cavities involving multiple cusps or loss of marginal ridges, conditions that significantly increase cupsal deflection under functional load (32,36). In such situations, intracoronal restorations alone may be insufficient to adequately reinforce weakened cusps, potentially increasing the risk of structural failure over time.

In addition, the long-term performance of direct composite restorations may be influenced by material related factors such as polymerization shrinkage, marginal degradation and occlusal wear. These phenomena may contribute to gradual deterioration of the restoration-tooth interface (36). Evidence suggests, restorative approaches incorporating cupsal coverage may provide improved biomechanical protection and greater long-term stability (32,35).

5.4. Full-coverage crowns: Longevity versus biological cost

Full coverage crowns have traditionally been considered the gold standard for the restoration of posterior ETT. Their ability to provide circumferential coverage of the remaining tooth structure offers significantly mechanical protection. Several studies included in this review reported favorable long term survival rates for crowned teeth, supporting their effectiveness in reducing the risk of catastrophic fracture in structurally compromised teeth (31,32).

One of the biomechanical benefits of full coverage crowns is related to the presence of a ferrule effect. The ferrule, defined as a circumferential band of sound tooth structure above the finish line of a crown preparation, has been shown to improve fracture resistance and distribute functional stresses more evenly along the tooth-restoration complex (32,33).

In contrast, the mechanical benefits of full coverage crowns must be considered alongside the biological cost associated with their preparation. Conventional crown preparations frequently require substantial removal of remaining dental tissue, including sound enamel and dentin. In teeth with root canals that may already present structural loss, additional removal of tooth structure may further weaken the tooth and increase the risk of unfavorable fracture patterns (33).

For this reason, contemporary restorative concepts increasingly emphasize the importance of preserving remaining tooth structure whenever possible. While crowns continue to demonstrate excellent long-term survival, their invasive preparation design has led clinicians to explore more conservative alternatives capable of providing adequate biomechanical protection while minimizing additional structural sacrifice.

5.5. Endocrowns and the shift toward conservative full coverage

In recent years, endocrowns have emerged as a conservative restorative alternative for the rehabilitation of endodontically treated teeth presenting extensive coronal tissue loss. Unlike conventional post and core restorations followed by full coverage crowns, endocrowns rely on adhesive bonding within the pulp chamber to provide macro-retention and stability, eliminating the need for intraradicular posts. This approach allows preservation of radicular dentin while simplifying the restorative procedure (35,39).

Multiple studies reported in this review reported favorable outcomes for endocrowns, particularly molars where the large pulp chamber provides sufficient bonding surface for adhesive restorations. As a result, the risk of catastrophic root fracture associated with intraradicular posts may be reduced (35). The success of endocrowns appears to depend on several clinical factors, including the amount of remaining coronal structure, the geometry of the pulp chamber and the quality of adhesive bonding. Consequently, careful case selection remains essential when considering this restorative strategy (39).

5.6. Failure patterns and clinical meaning

Beyond survival rates, the evaluation of failure patterns provides important insights into the clinical behavior of restorative strategies used for endodontically treated posterior teeth. The studies included in this review reported different types of complications, including restoration fracture, debonding, marginal degradation, secondary caries and catastrophic tooth fracture (31,35,37). These outcomes highlight that the mode of failure may vary depending on the restorative approach used as well as the amount of remaining tooth structure. Direct composite restorations were mainly associated with complications such as marginal degradation, restoration fracture or wear. Although these failures may occur more frequently in extensive damaged teeth, they are often considered repairable allowing conservative retreatment without the need for complete restoration replacement (36,37). Restorations providing cuspsal coverage, including indirect adhesive restorations and full coverage crowns, generally demonstrated lower rates of structural failure. However, when failures occur in these restorations, they may involve more severe complications such as debonding or tooth fracture, which can require more complex retreatment procedures (32,35).

From a clinical perspective, analyzing failure patterns helps better understand the behavior of different restorative approaches over time. Although survival rates are commonly used to evaluate treatment success, the type and severity should also be considered. Understanding how restorations fail may help clinicians anticipate possible complications and their management.

5.7. Clinical decision-making framework

Based on the available evidence, the selection of the restorative strategy for endodontically treated posterior teeth should consider several clinical factors, particularly the amount of remaining tooth structure, cavity configuration and functional demands. These factors play a role in determining whether a conservative intracoronal restoration or a cupsal coverage restoration is more appropriate.

When the loss of coronal tooth structure is limited and cusps remain largely intact, direct composite restorations may provide an adequate and conservative treatment option. In these situations, composite restorations directly on enamel and dentin allows preservation of remaining dental tissue while restoring function and occlusion (36,37).

However, when teeth present extensive structural loss such as large MOD cavities or significant cuspal involvement restorative strategies providing cuspal coverage may offer improved biomechanical protection. Indirect adhesive restorations, including onlays, overlays and endocrowns may allow reinforcement of weakened cusps while preserving more tooth structure compared with conventional full coverage crowns (32,35,39).

Full-coverage crowns remain a reliable restorative solution, particularly in cases of severe structural compromise or when adequate ferrule can be achieved. Their high survival rates have been widely reported in the literature, however the invasive nature of crown preparation should be considered when selecting the most appropriate treatment approach (32,35).

Therefore, rather than relying on a single restorative strategy, treatment planning should be individualized according to the structural condition of the tooth and the biomechanical requirements of each clinical situation.

5.8. Strength of evidence and methodological limitations

Although the studies included in this review provide valuable information regarding restorative strategies for posterior ETT, several methodological differences should be considered when interpreting the results. The included studies varied in terms of study design, restorative materials and follow-up periods which may limit direct comparison between outcomes.

In addition, clinical conditions such as cavity size, amount of remaining tooth structure and occlusal factors were not always standardized across studies. These variations may influence the reported survival rates and complication patterns. Therefore, while the available evidence provides useful insights, further well-designed clinical studies with longer follow-up periods are needed to strengthen the current body of evidence.

5.9. Future perspectives

Future developments in restorative dentistry are increasingly oriented toward minimally invasive treatment strategies aimed at preserving remaining tooth structure while maintain adequate biomechanical protection. In this context, adhesive restoration techniques are expected to play an increasingly important role in the management of endodontically treated posterior teeth.

Advanced in restorative materials may further improve the clinical performance of conservative restorations. The development of high-strength ceramics, hybrid CAD/CAM materials and reinforced composite systems offers promising alternatives capable of combining favorable mechanical properties with more conservative preparation designs.

In addition, the growing integration of digital dentistry may contribute to improving restorative outcomes. CAD/CAM technologies allow more precise fabrication of indirect restorations and may enhance marginal adaptation, occlusal morphology and overall restorative quality. As restorative dentistry continues to evolve, future research and clinical practice will likely focus on approaches that combine long-term mechanical reliability with preservation of dental tissues, supporting a shift toward more conservative and biologically oriented restorative strategies.

6 CONCLUSION

The restoration of endodontically treated posterior teeth remains a significant challenge due to the loss of structural integrity and altered biomechanics. Traditionally, full coverage crowns were considered the gold standard to ensure protection and longevity. However, the evolution of adhesive dentistry has introduced more conservative and biomimetic approaches.

Based on the literature analyzed, indirect adhesive restorations such as inlays, onlays, overlays and endocrown appear to offer several advantages. These include improved stress distribution, preservation of dental tissues and satisfactory aesthetic outcomes. Particularly, endocrowns and overlays have demonstrated promising clinical performance, especially in cases with extensive coronal destruction.

When compared to conventional techniques, adhesive indirect restorations may provide comparable and, in some cases, superior outcomes in terms of fracture resistance and longevity. Nevertheless, their success is highly dependent on proper case selection, the amount of remaining tooth structure, the material used, and the precision of adhesive protocols. Despite these advantages, some limitations must be considered. The available evidence remains heterogeneous and long-term clinical studies are still limited. Furthermore, the technique sensitivity of adhesive procedures may influence the final outcomes.

In conclusion, indirect adhesive restorations represent a reliable and minimally invasive alternative for the rehabilitation of endodontically posterior teeth. Their indications should still be carefully evaluated on a case-by-case basis, considering both clinical conditions and operator expertise.

7 SUSTAINABILITY

Sustainability in dentistry refers to the adoption of clinical approaches that minimize biological, economic and material impact while maintaining long-term treatment success. In the context of endodontically treated posterior teeth, adhesive indirect restorations represent a more conservative alternative compared to conventional full crowns.

These restorations preserve a greater amount of healthy dental structure which is a key principle in minimally invasive dentistry and contributes to the long-term survival of the tooth. By avoiding excessive removal of sound tissue, they reduce the need for more complex retreatments in the future.

From a material perspective, adhesive techniques may also reduce resource consumption by limiting the use of extensive prosthetic components. Additionally, their potential for repair rather than replacement further supports a more sustainable approach.

Economically, although some adhesive indirect restorations may have higher initial cost, their conservative nature and favorable clinical performance can lead to reduced long-term costs by preventing complications and extending tooth longevity.

Overall, adhesive indirect restorations align with the principles of sustainable dentistry by promoting tissue preservation, durability and efficient use of resources.

8 BIBLIOGRAPHY

1. Magne P, Belser UC. Porcelain versus composite inlays/onlays: effects of mechanical loads on stress distribution, adhesion, and crown flexure. Int J Periodontics Restorative Dent. 2003;23(6):543-543–55.

2. Reeh ES, Messer HH, Douglas WH. Reduction in tooth stiffness as a result of endodontic and restorative procedures. J Endod. 1989;15(11):512-512–6. doi:10.1016/S0099-2399(89)80191-8

3. Dietschi D, Duc O, Krejci I, Sadan A. Biomechanical considerations for the restoration of endodontically treated teeth: A systematic review of the literature—Part 1. Composition and micro- and macrostructure alterations. Quintessence Int. 2007.

4. Dioguardi M, Alovisi M, Comba A, Baldi A, Troiano G, Cadenaro M, et al. The influence of indirect bonded restorations on clinical prognosis of endodontically treated teeth: A systematic review and meta-analysis. Dent Mater. 2022;38(8):e203–19. doi:10.1016/j.dental.2022.06.018

5. Bruhnke M, Wierichs RJ, Von Stein-Lausnitz M, Meyer-Lückel H, Beuer F, Naumann M, et al. Long-term Survival of Adhesively Luted Post-endodontic Restorations. J Endod. 2022;48(5):606–13. doi:10.1016/j.joen.2022.02.006

6. Lukarcanin J, Sadıkoğlu İS, Yaşa B, Türkün LŞ, Türkün M. Comparison of Different Restoration Techniques for Endodontically Treated Teeth. Int J Biomater. 2022; 11;2022:1–7. doi:10.1155/2022/6643825

7. Fan J, Xu Y, Si L, Li X, Fu B, Hannig M. Long-term Clinical Performance of Composite Resin or Ceramic Inlays, Onlays, and Overlays: A Systematic Review and Meta-analysis. Oper Dent. 202;46(1):25–44. doi:10.2341/19-107-LIT

8. Peumans M, Bajraktarova Valjakova E, De Munck J, Bajraktarova Mishevska C, Van Meerbeek B. Bonding Effectiveness of Luting Composites to Different CAD/CAM Materials. J Adhes Dent. 2016;18(4):289-289–302. Located at: Dentistry & Oral Sciences Source; 118195172. doi:10.3290/j.jad.a36155

9. Fan J, Xu Y, Si L, Li X, Fu B, Hannig M. Long-term Clinical Performance of Composite Resin or Ceramic Inlays, Onlays, and Overlays: A Systematic Review and Meta-analysis. Oper Dent. 2021;46(1):25–44. doi:10.2341/19-107-LIT

10. Dietschi D, Duo O, Krejci I, Sadan A. Biomechanical considerations for the restoration of endodontically treated teeth: A systematic review of the literature--Part 1. Composition and micro- and macrostructure alterations. Quintessence Int. 2007;38(9):733-733–43. Located at: Dentistry & Oral Sciences Source; 36831714

11. Sedgley CM, Messer HH. Are endodontically treated teeth more brittle? J Endod. 1992 ;18(7):332-332–5. Located at: MEDLINE Complete; 1402595. doi:10.1016/S0099-2399(06)80483-8

12. Sedgley CM, Messer HH. Are endodontically treated teeth more brittle? J Endod. 1992; 18(7):332-332–5. Located at: MEDLINE Complete; 1402595. doi:10.1016/S0099-2399(06)80483-8

13. Akkayan B, Gülmez T. Resistance to fracture of endodontically treated teeth restored with different post systems. J Prosthet Dent. 2002; 87(4):431-431–7.

14. Morimoto S, Özcan M. Survival Rate of Resin and Ceramic Inlays, Onlays, and Overlays: A Systematic Review and Meta-analysis.

15. Rocca GT, Krejci I. Bonded indirect restorations for posterior teeth: From cavity preparation to provisionalization. Quintessence Int. 2007; 38(5):371-371–9.

16. Saratti CM, Rocca GT, Durual S, Lohbauer U, Ferracane JL, Scherrer SS. Fractography of clinical failures of indirect resin composite endocrown and overlay restorations. Dent Mater. 2021; 37(6):e341–59. doi:10.1016/j.dental.2021.02.002

17. Veneziani M. Posterior indirect adhesive restorations: updated indications and the Morphology Driven Preparation Technique. Int J Esthet Dent. 2017 Jan; 12(2):204-204–30.

18. Dioguardi M, Alovisi M, Troiano G, Caponio CVA, Baldi A, Rocca GT, et al. Clinical outcome of bonded partial indirect posterior restorations on vital and non-vital teeth: a systematic review and meta-analysis. Clin Oral Investig. 2021;25(12):6597–621. doi:10.1007/s00784-021-04187-x

19. O´Connor C, Gavriil D. Predictable bonding of adhesive indirect restorations: factors for success. Br Dent J. 2021;231(5):287–93. doi:10.1038/s41415-021-3336-x

20. Abad-Coronel C, Naranjo B, Valdiviezo P. Adhesive Systems Used in Indirect Restorations Cementation: Review of the Literature. Dent J. 2019;7(3):71. doi:10.3390/dj7030071

21. Zarone F, Di Mauro MI, Ausiello P, Ruggiero G, Sorrentino R. Current status on lithium disilicate and zirconia: a narrative review. BMC Oral Health. 2019;19(1):134. doi:10.1186/s12903-019-0838-x

22. Pjetursson BE, Sailer I, Makarov NA, Zwahlen M, Thoma DS. Corrigendum to “All-ceramic or metal-ceramic tooth-supported fixed dental prostheses (FDPs)? A systematic review of the survival and complication rates. Part II: Multiple-unit FDPs” Dental Materials 31 (6) (2015) 624–639.

23. van den Breemer CR, Gresnigt MM, Cune MS. Cementation of Glass-Ceramic Posterior Restorations: A Systematic Review. BioMed Res Int. 201;2015:148954–148954.

24. Radovic I, Monticelli F, Goracci C, Vulicevic ZR, Ferrari M. Self-adhesive resin cements: a literature review. J Adhes Dent. 2008;10(4):251-251–8.

25. Blatz MB. Long-term clinical success of all-ceramic posterior restorations. Quintessence Int Berl Ger 1985. 2002;33(6):415-415–26.

26. de Souza G, Hennig D, Aggarwal A, Tam LE. The use of MDP-based materials for bonding to zirconia. J Prosthet Dent. 2014;112(4):895-895–902.

27. Grzebieluch W, Mikulewicz M, Kaczmarek U. Resin Composite Materials for Chairside CAD/CAM Restorations: A Comparison of Selected Mechanical Properties. J Healthc Eng. 2021;2021:8828954–8828954.

28. Bonding Effectiveness of Luting Composites to Different CAD/CAM Materials. J Adhes Dent. 2016 ;18(4):289–302. doi:10.3290/j.jad.a36155

29. Mario D, Mario A, Allegra C, Andrea B, Giuseppe T, Milena C, et al. The influence of indirect bonded restorations on clinical prognosis of endodontically treated teeth: A systematic review and meta-analysis. Dent Mater Off Publ Acad Dent Mater. 2022;38(8):e203-e203–19.

30. De Kuijper MCFM, Cune MS, Özcan M, Gresnigt MMM. Clinical performance of direct composite resin versus indirect restorations on endodontically treated posterior teeth: A systematic review and meta-analysis. J Prosthet Dent. 2023;130(3):295–306. doi:10.1016/j.prosdent.2021.11.009

31. Dioguardi M, Alovisi M, Troiano G, Caponio CVA, Baldi A, Rocca GT, et al. Clinical outcome of bonded partial indirect posterior restorations on vital and non-vital teeth: a systematic review and meta-analysis. Clin Oral Investig. 2021;25(12):6597–621. doi:10.1007/s00784-021-04187-x

32. Fouda H, Hassanein OE, Saber S, Haridy MF, Baz ME, Ahmed HS, et al. Two-year clinical performance of indirect resin composite restorations in endodontically treated teeth with different cavity preparation designs: a randomized clinical trial. BMC Oral Health. 2024;24(1):1009. doi:10.1186/s12903-024-04725-5

33. Frankenberger R, Zeilinger I, Krech M, Mörig G, Naumann M, Braun A, et al. Stability of endodontically treated teeth with differently invasive restorations: Adhesive vs. non-adhesive cusp stabilization. Dent Mater. 2015;31(11):1312–20. doi:10.1016/j.dental.2015.08.160

34. Elhaddad EEH, Mohsen MMA, Mohamed DEE. Clinical performance and wear resistance of milled resin composite material versus direct nanohybrid bulk-fill resin composite in the restoration of endodontically treated posterior teeth over 1 year: Randomized clinical trial. J Conserv Dent Endod. 2024;27(4):400–7. doi:10.4103/JCDE.JCDE_46_24

35. Dioguardi M, Alovisi M, Comba A, Baldi A, Troiano G, Cadenaro M, et al. The influence of indirect bonded restorations on clinical prognosis of endodontically treated teeth: A systematic review and meta-analysis. Dent Mater. 2022;38(8):e203–19. doi:10.1016/j.dental.2022.06.018

36. Lempel E, Lovász BV, Bihari E, Krajczár K, Jeges S, Tóth Á, et al. Long-term clinical evaluation of direct resin composite restorations in vital vs. endodontically treated posterior teeth — Retrospective study up to 13 years. Dent Mater. 2019;35(9):1308–18. doi:10.1016/j.dental.2019.06.002

37. Shu X, Mai Q qing, Blatz M, Price R, Wang X dong, Zhao K. Direct and Indirect Restorations for Endodontically Treated Teeth: A Systematic Review and Meta-analysis, IAAD 2017 Consensus Conference Paper.

38. Ravasini F, Bellussi D, Pedrazzoni M, Ravasini T, Orlandini P, Meleti M, et al. Treatment Outcome of Posterior Composite Indirect Restorations: A Retrospective 20-Year Analysis of 525 Cases with a Mean Follow-up of 87 Months. Int J Periodontics Restorative Dent. 2018;38(5):655–63. doi:10.11607/prd.3471

39. Kontakou Zoniou A, Tzimas K, Pappa E, Rahiotis C. Clinical Performance of Endocrowns in Molars: A Scoping Review. Medicina (Mex). 2025 Aug;61(9):1562. doi:10.3390/medicina61091562