Universidad Europea

# GRADUATION PROJECT

## Degree in Dentistry

# FIBER-REINFORCED DENTAL COMPOSITE RESIN: A REVIEW OF RESISTANCE

**Madrid, academic year 2025/2026**

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## RESUMEN

**Introducción:** Los composites reforzados con fibras han sido introducidos en odontología restauradora con el objetivo de mejorar la resistencia mecánica de las restauraciones directas, especialmente en dientes posteriores con pérdida estructural significativa; **Objetivos:** El objetivo de este trabajo fue analizar la evidencia científica disponible sobre el comportamiento mecánico de los composites reforzados con fibras en restauraciones directas, comparándolos con los composites convencionales, evaluando la influencia de las características de las fibras y determinando las situaciones clínicas en las que su utilidad es limitada; **Métodos:** Se realizó una revisión documental sistematizada basada en una estrategia PICO. Se seleccionaron estudios clínicos e in vitro publicados entre 2015 y 2025 que evaluaban propiedades mecánicas como resistencia a la fractura, resistencia a la fatiga y comportamiento flexural; **Resultados:** Se incluyeron diez estudios (tres ensayos clínicos y siete estudios in vitro). Los resultados mostraron que los composites reforzados con fibras presentan mayor resistencia a la fractura y mejor comportamiento frente a cargas elevadas, especialmente en cavidades extensas. Sin embargo, en restauraciones conservadoras no se observaron diferencias significativas frente a composites convencionales. La efectividad del refuerzo depende de factores como el tipo de fibra, su orientación y su interacción con la matriz resinosa; **Conclusiones:** Los composites reforzados con fibras mejoran el comportamiento mecánico en dientes estructuralmente comprometidos y favorecen patrones de fractura más reparables. No obstante, su beneficio es limitado en situaciones de bajo estrés mecánico, por lo que su uso debe indicarse de forma selectiva.



## PALABRAS CLAVES

Odontología, Composite reforzado con fibras, restauraciones directas, resistencia a la fractura, comportamiento mecánico.

## ABSTRACT

**Introduction:** Fiber-reinforced composites have been introduced in restorative dentistry to improve the mechanical performance of direct restorations, particularly in posterior teeth with significant structural loss; **Objectives:** The aim of this study was to analyze the available scientific evidence on the mechanical behavior of fiber-reinforced composites in direct restorations, comparing them with conventional composites, evaluating the influence of fiber characteristics, and identifying clinical situations in which their usefulness remains limited; **Methods:** A systematized literature review was conducted based on a PICO strategy. Clinical and in vitro studies published between 2015 and 2025 were included, focusing on mechanical properties such as fracture resistance, fatigue resistance, and flexural behavior; **Results:** A total of ten studies were included (three randomized clinical trials and seven in vitro studies). Fiber-reinforced composites showed improved fracture resistance and better performance under high mechanical loads, particularly in large restorations. However, no significant differences were observed in conservative restorations. Their effectiveness depends on factors such as fiber type, orientation, and interaction with the resin matrix; **Conclusions:** Fiber-reinforced composites improve mechanical behavior in structurally compromised teeth and are associated with more favorable, repairable fracture patterns. However, their benefit remains limited under low mechanical stress, and their use should be considered selectively.

## KEYWORDS

Dentistry, Fiber-reinforced composite, direct restorations, fracture resistance, mechanical behavior.

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# 1. INTRODUCTION

A fiber-reinforced dental composite is fundamentally a restorative material where fibers are integrated into a resin matrix to boost its mechanical performance(1,2) creating a synergistic combination of polymer and reinforcing fibers(3). These fibers establish an internal framework that not only strengthens structurally compromised teeth but also helps prevent the occurrence of fractures(4,5). By providing this internal reinforcement, the material offers crucial stability in cases where the remaining tooth structure is weak or where conventional composites fall short in terms of mechanical reliability (4,6). This enhanced resilience makes fiber-reinforced composites particularly valuable in clinical settings that demand superior strength, better force distribution, and improved long-term durability compared to standard resins (2).

The restorative dentistry has undergone a gradual yet profound transformation over the past few decades (7). For a long time, the field was dominated by metallic materials like amalgam (7,8). However, as patient expectations shifted and dentistry embraced more conservative philosophies, the drawbacks of traditional metal restorations became increasingly apparent(7). The need for more aesthetic and biocompatible solutions led to the development of early resin composites (7,9). Their ability to be shaped directly within the cavity, along with shades and translucency mimicking natural enamel, marked a significant advance (9,10).

A natural tooth depends on the interplay between enamel and dentin to effectively distribute and absorb chewing forces(5). Conventional resin composites however do not replicate the supportive tolerance of natural dentin (4,5) Consequently in situations with significant tooth structure loss these materials are prone to marginal wear, gradual weakening under repeated stress, and eventual fracture(2,5),that explain why bulk fracture and secondary caries were the leading causes of failure in posterior composite restorations (5,8).

The concept of using fibers to strengthen materials did not originate in dentistry; it was borrowed from engineering and architecture(5). The dental field adapted this principle, recognizing its potential to improve how restorative materials manage the mastication forces (2,5). Early applications included reinforcing adhesive bridges, periodontal splints, and various prosthetic frameworks(1,3). The first true fiber-reinforced composites appeared in the 1960s (3), As interest grew, people started thinking about adding fibers directly into the composite material, although this change came with many practical challenges. (3,5).

Today, fiber-reinforced composites are a common choice for posterior teeth with substantial structural loss, such as those with deep MOD cavities or multiple missing cusps(5,11,12). A wealth of laboratory studies confirms that restorations with fiber reinforcement are more resistant to fracture and can withstand cyclic loading for longer durations(2,6,13,14). While research has expanded rapidly, the body of evidence is still not very clear. A focused review is therefore essential to organize the current knowledge, clarify the practical value of fiber reinforcement resistance and permit clinicians to make well-informed evidence-based decisions (2).

## 1.1. Theoretical Framework

### 1.1.1. Definition and concept of fiber-reinforced composite resins

Fiber-reinforced dental composite resins consist of structural fibers embedded within a resin matrix. This creates an internal framework that fundamentally alters the material's response to mechanical stress during function(1,3,14). The fibers serve to redirect and diffuse occlusal forces throughout the composite, which diminishes the localized stress peaks that can initiate internal defects(15). This reinforcement mechanism relies on the efficient transfer of stress from the polymer matrix to the much stronger fibers, they also act as a crack stopper to stop propagation(3,5). The integration of these fibers not only enhances stiffness but also helps maintain the restoration's dimensional stability under the pressures of mastication (3) and conferring excellent fatigue resistance (12). Because of these advantages they can offer more predictable outcomes and enhanced durability, especially in structurally compromised posterior teeth (2,14).

This internal support system provides stability precisely when the remaining tooth structure is weakened or when conventional composites lack sufficient mechanical reliability (4,6). They are used whenever a direct restoration must provide superior strength, force management, and longevity (2). By incorporating fibers they offer a level of support that more closely mimics the natural function of dentin(5,15).

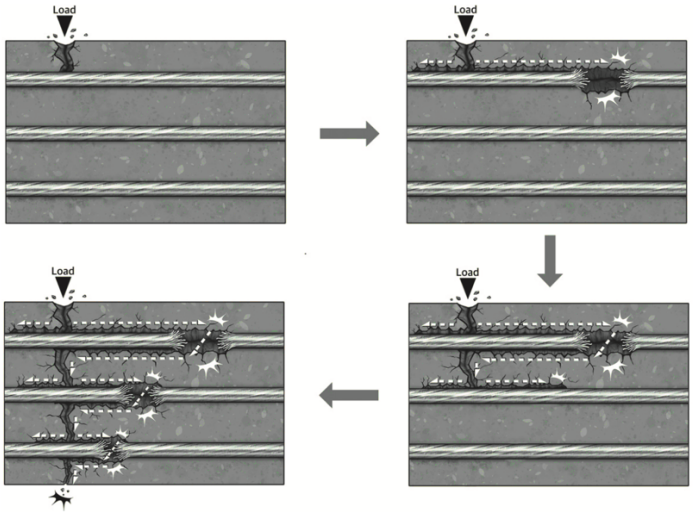



***Fig.1 :*** Crack diversion mechanism in fiber-reinforced composite restorations. Adapted from (15)

### 1.1.2. Evolution of restorative materials in dentistry

The field of restorative dentistry has experienced a slow but clinically significant evolution over recent decades(7). For many years, metallic materials like amalgam were the usual approach thanks to their robust clinical performance and long-term survival rates that were often comparable or superior to other options(7,8). Their long standing popularity was also strengthened by their proven durability and ease of use making them the first choice for posterior teeth (7). However, despite their proven track record, metallic materials presented significant limitations. Their most apparent disadvantage was their lack of aesthetics which clashed with rising patient demands for natural looking restorations(7). Furthermore, their placement necessitated invasive cavity designs with mechanical undercuts. It represented a real contrast to the conservative adhesive principles of modern composites (7). As patient expectations and clinical philosophies evolved towards tooth preservation, the incompatibility of metal restorations became harder to overlook. This shift in thinking fueled the adoption and continuous refinement of resin-based composites, which are more aligned with the demands of modern conservative dentistry (7,9).

### 1.1.3. Development and advantages of resin-based composites

With the dental shift towards more aesthetic and biological approaches, early resin composites presented themselves as a revolutionary alternative(7). The integration of inorganic fillers like glass ceramics and zirconia has significantly improved their mechanical properties and stability, enhancing their clinical performance and aesthetic qualities (16) They also conducted in an era of more conservative dentistry, as their retention relies on adhesive bonding rather than mechanical preparations. Recent advancements in nanotechnology have led to the development of composites with superior aesthetic properties and improved polishability, making them ideal for anterior restorations (17). The evolution of resin-based composites has also incorporated bioactive glass particles to stimulate remineralization and metal oxide nanoparticles to prevent bacterial colonization, reflecting a shift towards multifunctional restorative materials (16). As these materials continued to evolve, their formulations became more stable and easy to use leading to their widespread adoption in clinical practice (7,9).

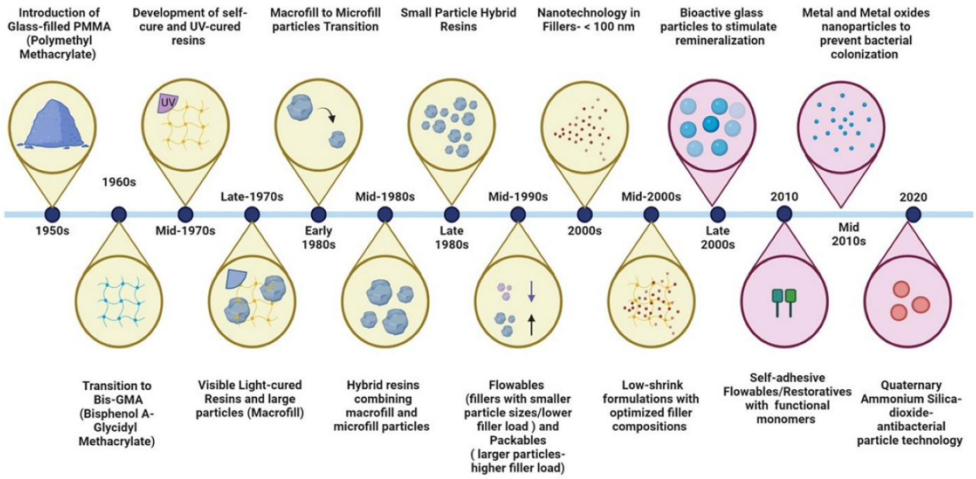



***Fig.2:*** The evolution of dental composite materials from the 1950s to the 2020s. Adapted from (16)

1.1.4. Mechanical limitations of conventional composite restorations

While resin composites solved the aesthetic problem, clinicians quickly realized that this was not enough for long-term success (7). The dentin, in particular, provides an essential supportive core that is vital for stability (5). Conventional resin composites simply do not offer the same level of support or fracture tolerance as dentin(4,5). When a large amount of tooth structure is missing these materials tend to wear at the margins after repetitive loading and are susceptible to fracture (2,5). These failure modes are frequents in clinical follow-ups and are a primary reason for the replacement of large composite restorations in molars (5). It became evident that a successful restoration required a material that could withstand daily functional forces.

| Failure Cause | Frequency (%) | Composite Type Used |
|---|---|---|
| **Bulk fracture (6,8)** | 8–18% | Conventional PFC (Particulate Filler Composite) |
| **Secondary caries (8,15)** | 6.6–38% | PFC and bulk-fill composites |
| **Marginal wear / degradation (8,9)** | ≈8.2% | Micro-filled or hybrid composites |
| **Debonding (adhesive failure)(8,18)** | High | Non-reinforced or self-adhesive composites |

***Table 1****: Main causes of failure of conventional composite restorations* in posterior composite restorations

### 1.1.5. Introduction of fiber reinforcement in dentistry

The idea of using fibers for reinforcement is not native to dentistry but was adopted from engineering and architecture(5). Dentistry recognized that this same principle could be applied to help restorative materials better handle with occlusal forces(2,5). A major challenge was adapting a concept designed for large scale applications to the small dimensions of dentistry restoration so this process required significant adjustments(3,5). Initially, fibers found their place in dentistry as reinforcement for removable dentures, adhesive bridges, and periodontal splints where their performance clearly demonstrated their potential (1,3). By the 1990s, the application of fiber-reinforced composites had expanded to include fixed prosthodontics (3).

With growing interest, it became logical to try to incorporate them directly into the composite resin. This transition was not very easy, factors like fiber length, orientation, position within the resin, and the quality of the bond between fiber and matrix all had to be perfect (3,5). Overcoming these obstacles made the transition from external frameworks to integrated fiber-reinforced composites a significant challenge(3). Clinicians needed a material that delivered the benefits of fiber reinforcement without adding complexity to the procedure, a need that drove the development of modern and user friendly materials (5).

Common fibers used in dentistry include glass, carbon, aramid, polyethylene, and ceramic fibers, each providing distinct advantages in composite reinforcement(4). Glass fibers are widely used due to their excellent biocompatibility, aesthetic translucency, and high tensile strength, making them particularly suitable for anterior restorations. Carbon fibers offer superior stiffness and mechanical strength but are limited by their dark color. Aramid fibers (Kevlar) provide exceptional impact resistance and toughness. Polyethylene fibers contribute high ductility and prevent catastrophic fracture. Ceramic fibers, including zirconia-based options, combine high hardness with good aesthetic compatibility, though they exhibit more brittle behavior during handling (4).

### 1.1.6. Current clinical relevance and need for evidence review

Today, fiber-reinforced composites are frequently selected for posterior teeth that have suffered significant structural loss, such as deep MOD cavities or teeth missing one or more cusps(5,11,12,18). A common clinical approach is a layering technique where a short fiber-reinforced composite acts as a dentin substitute which is then overlaid with a conventional composite to replace the enamel layer

(5). Restorations built on a fiber foundation exhibit less cusp flexure under load and maintain better overall stability, a critical advantage in molars subjected to high masticatory stress (12,14). Another key advantage lies in their failure mode. When a fracture does occur in a fiber-reinforced restoration it tends to be less catastrophic. Instead of propagating uncontrollably, cracks are arrested or slowed by the fiber network leading to failures that are more manageable clinically and less damaging to the remaining tooth. Modern fiber-composites are also less technique-sensitive and easier to handle than older continuous-fiber systems, which translates to reduced chairside time. These materials also expand the possibilities for direct restorations. In cases where an indirect restoration like a ceramic onlay might traditionally be indicated, the added strength from a fiber-reinforced base can make a direct approach a viable more conservative alternative (3). Beyond fillings these composites are used for periodontal splinting, fixed bridgework, and denture reinforcement (2,3). Glass fibers are often preferred for their good aesthetics, corrosion resistance, high toughness, and biocompatibility (1), but other types, including carbon, aramid, and polyethylene, are also available, each offering unique properties(1,19).Current research continues to explore how fiber parameters such as length, aspect ratio, volume, and orientation influence the material overall performance (11). It is known that fiber orientation has a major impact on mechanical behavior, for example unidirectional fibers provide maximum strength along a single axis whereas bidirectional fibers offer more balanced properties(3,5). The ultimate effectiveness of the reinforcement hinges on the fiber load, the quality of the fiber-matrix bond, fiber orientation relative to functional loads, and their position within the final restoration (2). Although research on fiber-reinforced dental resins has grown exponentially, the evidence can still be complex to navigate. It is therefore crucial to have a focused review that structures this knowledge, defines the practical value of fiber reinforcement, and helps clinicians make confident evidence-based decisions. By offering this clarity, this review aims to contribute to a more accurate and clinically relevant understanding of their role in contemporary restorative dentistry.

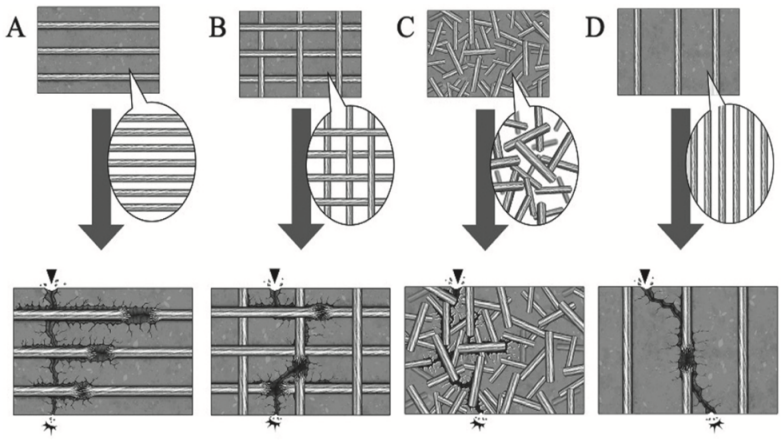


***Fig.3 :*** Reinforcing efficiency of fibers with different orientations relative to crack propagation. Adapted from (15)

(A) Unidirectional fibers perpendicular to the crack path show maximum reinforcement.

(B) Bidirectional fibers provide intermediate reinforcement.

(C) Randomly oriented fibers provide multidirectional reinforcement.

(D) Unidirectional fibers parallel to the crack path provide minimal reinforcement.

### 1.1.7. Justification

Fiber reinforced dental composites are advancing quickly and offer great potential for better dental restorations. However, the current research is often inconsistent and varied, making it hard to know how effective they really are in practice. While these materials promise stronger and longer-lasting results, the variety in research methods and findings means we need a thorough review. This review aims to gather current research to better understand how fiber reinforcement affects important outcomes like fracture resistance and long-term stability. By pulling together all the available data, this review gets to provide a comprehensive foundation for making evidence-based decisions regarding the application of these composites. Moreover, there aren't many articles focusing on the use of fibers in direct restorations on natural teeth without endodontic treatment. This review will specifically focus on it. As dentistry moves towards more conservative and personalized treatments, understanding the true benefits and limitations of fiber-reinforced composites is crucial.

## 2. OBJECTIVE

**Primary objective:**

To review the current scientific evidence on the resistance of fiber-reinforced composite resins used in direct dental restorations and to understand how these materials respond to functional stresses compared with conventional non-reinforced composites.

**Secondary objectives:**

- To examine the different types of fibers used in these materials and analyze how their nature, orientation, and distribution influence their mechanical resistance and overall behavior.
- To determine in which situations their usefulness remains limited.

## 3. MATERIALS AND METHODS

This study was carried out as a systematized documentary review, using the basic structure of a systematized literature review following PRISMA guidelines. The aim was simply to organize the literature in a clear way, following the same steps for searching, selecting and analyzing the studies. In this review, I focused on research that evaluates how fiber-reinforced composite resins perform when used in direct dental restorations**.** Studies related to endodontic posts or root reinforcement were not included, focusing only on restorative procedures. The review focused on identifying how the presence of fibers influences the resistance of the material and whether this makes a real difference compared to conventional composites. The main objective of this review was to analyze the evidence available on the resistance properties of these materials such as fracture toughness**,** flexural strength, and fatigue resistance and to compare them with standard non-reinforced composite resins. To see if fiber reinforcement provides a measurable advantage in direct restorations, and in which situations this extra resistance could be useful in clinical practice.

To organize this review clearly, the research question was developed using the PICO framework. This method helps create specific questions and improves how the literature search is planned. By dividing the topic into key elements, PICO made it easier to identify the exact information needed from the studies.

Based on the main objectives of this study, the following research question was formulated:

"In human teeth restored with direct composite resins, how does the use of fiber-reinforced composite resins compared to conventional non-fiber-reinforced composites can affect the resistance properties such as fracture resistance, flexural strength, and fatigue resistance?"

| P (Population) | I (Intervention) | C (Comparison) | O (Outcome) |
|---|---|---|---|
| Human teeth restored with direct composite resins. | Fiber-reinforced composite resins. | Conventional (non-fiber-reinforced) composite resins. | Resistance properties (fracture resistance, flexural strength, fatigue resistance, etc.). |

***Table 2** : Research Question (PICO)*

Before starting the search, inclusion and exclusion criteria were chosen to avoid bias in selecting the articles. These criteria were set based on the topic and objectives of the review.

Eligibility Criteria

Inclusion:

- In vitro human studies or in vivo human studies evaluating resistance of fiber-reinforced composite resins.
- In direct restorations.
- Studies comparing fiber-reinforced composite with conventional composites.
- Articles in English or Spanish.
- Published from 2015 to 2025.
- Full text accessible for title, abstract, and full-text screening
- Studies reporting measurable mechanical resistance outcomes, such as fracture resistance, flexural strength, modulus of elasticity, crack propagation behaviors and fatigue resistance.
- Clinical trials, randomized controlled experiments, prospective or retrospective cohorts
- Control group restored with a conventional (non-reinforced) composite resin under the same testing conditions.
- Publication in peer-reviewed journals ensuring scientific reliability.
- No time restriction of publication for the introduction section

Exclusion:

- Studies focused on endodontic posts or root reinforcement.
- Case reports, reviews, editorials, systematic reviews, meta-analyses.
- Studies without measurable resistance outcomes.
- Studies evaluating fiber-reinforced composites only in prosthodontics, periodontal splints, or orthodontic applications.
- Studies including indirect restorations, CAD/CAM technique, or luting materials.
- Case reports, editorials, opinion papers, letters

Search Strategy Databases:

To make sure no important study was missed, the search was done using the main biomedical databases. These databases were chosen so the review could include as much relevant literature as possible**: PubMed, MEDLINE, Scopus.**

Only primary studies that met the inclusion criteria were included and the extra articles were found by checking manually. The search was completed between October and December 2025.

To find the good articles, it was important to use the good MeSH terms combined with free-text keywords to select only relevant articles focused on the topic.

| PICO Element | Free-Text Terms | MeSH Terms (Medical Subject Headings) |
|---|---|---|
| **P – Population** | "Human teeth", "extracted teeth", "posterior teeth", "direct restorations", "posterior composite restorations", "Class II restorations", "MOD restorations" | *Dental Restoration, Permanent* [MeSH], *Dental Cavity Preparation* [MeSH] |
| **I – Intervention** | "Fiber-reinforced composite", "fiber reinforced composite resin", "short fiber composite", "short fiber-reinforced composite", "SFRC", "glass fiber composite", "fiber reinforced dental resin" | *Composite Resins* [MeSH], *Glass Fibers* [MeSH], *Dental Materials* [MeSH] |
| **C – Comparison** | "Conventional composite", "non-reinforced composite", "nanohybrid composite", "microhybrid composite", "control composite resin" | *(No specific MeSH )* |
| **O – Outcomes** | "Fracture resistance", "flexural strength", "fatigue resistance", "mechanical resistance", "modulus of elasticity", "crack propagation", "load to fracture", "fracture toughness" | *Mechanical Phenomena* [MeSH], *Stress, Mechanical* [MeSH], *Elasticity* [MeSH], *Materials Testing* [MeSH], *Tensile Strength* [MeSH], *Fatigue* [MeSH] |

***Table 3**: Search Strategy Terminology Based on the PICO Model*

The table below presents the MeSH terms and free-text keywords derived from the PICO question, which were used to structure and optimize the literature search.
These terms were used to run the database search. The studies obtained were then screened according to the PRISMA shown below.

A total of 141 records were identified After removal of 60 duplicates, 81 records remained for screening.
The search strategy combined both free-text terms and MeSH terms and was structured around the PICO question**.** ("fiber-reinforced composite" OR "short fiber composite" OR "fiber reinforced resin" OR "fiber reinforced composite") AND (restoration OR posterior OR cavity OR "Class II") AND ("fracture" OR "fracture resistance" OR "flexural strength" OR "fatigue" OR "mechanical") NOT ("fiber post" OR "post and core" OR Endodontics).

After reviewing titles and abstracts, 55 studies were excluded because they did not match the focus of the review. The remaining 29 studies were examined and 19 were excluded for the following reasons: indirect restorative techniques (n = 8), studies involving endodontically treated teeth (n = 4), material-based studies without direct (n = 5) and publications that were not primary research (n = 3). In total**,** 10 studies met all the inclusion criteria and were incorporated into the qualitative synthesis.

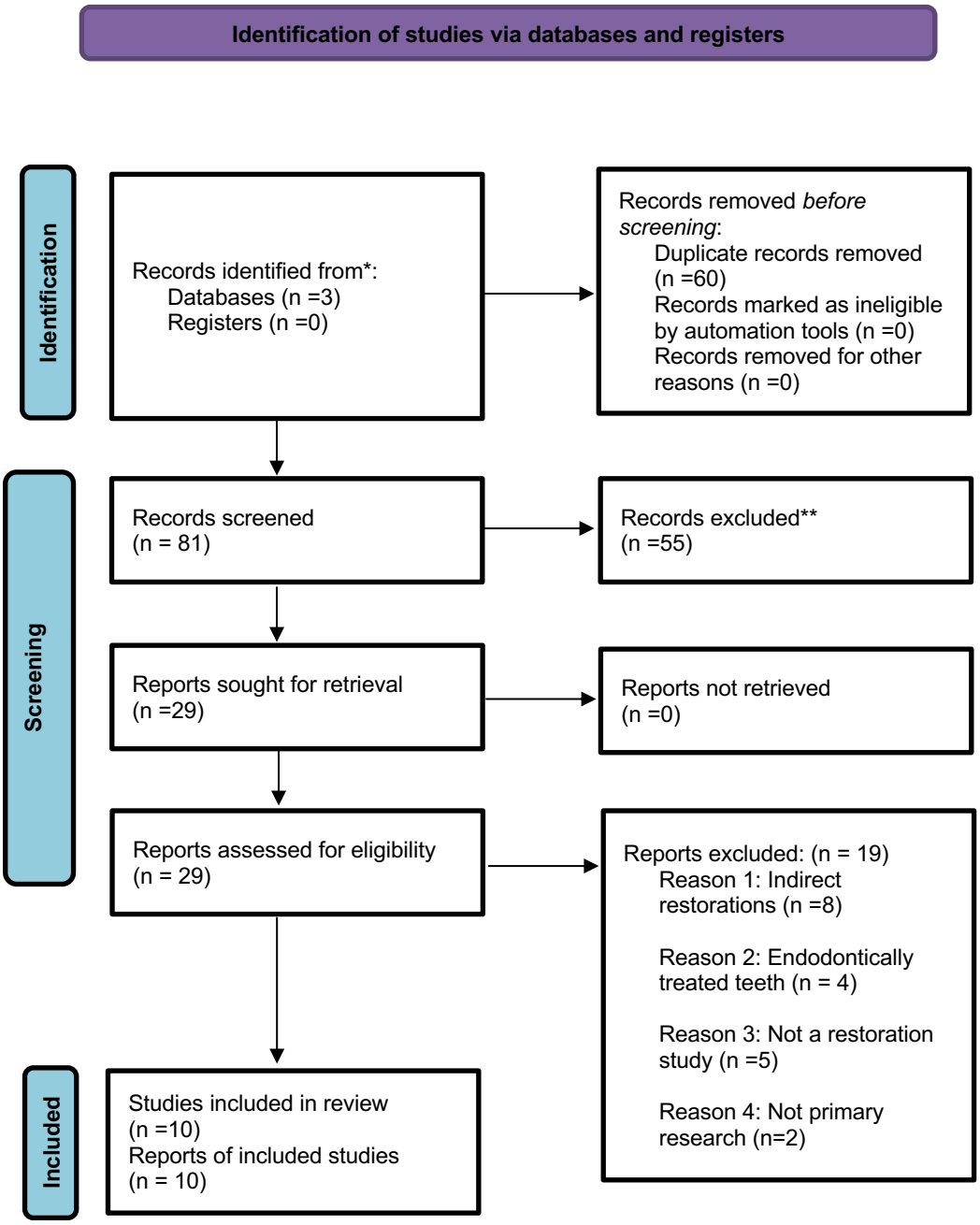



***Figure 4***: Prisma Flow diagram of study selection

*Consider, if feasible to do so, reporting the number of records identified from each database or register searched (rather than the total number across all databases/registers). /
**If automation tools were used, indicate how many records were excluded by a human and how many were excluded by automation tools.
Figure 1. Study selection process illustrated using the PRISMA 2020 flow diagram (adapted from Page et al., 2021).

Data Extraction: For the articles that were included, the information was noted in a clear and simple way so they could be compared easily.
The details noted for each study were:

- Authors, year of publication and country.
- Type of study.
- Type of fiber-reinforced composite and the conventional composite used as control.
- Characteristics and type of cavity or restoration investigated.
- Mechanical outcomes measured, such as fracture resistance or flexural behavior.
- The main results reported by the authors.

Using the same set of items for all the articles helped to organize the information clearly and to understand the differences between the restorative approaches tested.

Data Synthesis: Because the studies used different experimental arrangements, testing methods and restorative designs, the results were brought together through a narrative description rather than a statistical combination.

The synthesis compares how the different fiber-reinforced composites performed in direct restorations and how they behaved relative to conventional materials. A meta-analysis was not carried out, as the variability between studies did not allow for a reliable quantitative pooling of the data.

Expected Outcome : The objective is to offer a clear and structured overview of how fiber-reinforced composites perform in direct restorations, based on the available evidence.
By bringing the findings together, the review helps identify when fiber reinforcement provides an actual advantage, where its limits appear, and which aspects should be explored further in future research

# 4. RESULTS

4.1 Overview of Included Studies

A total of 10 studies were included in the present review, including seven in vitro experimental investigations and three randomized clinical trials. The in vitro studies primarily examined the mechanical performance of short fiber-reinforced composite materials in extracted premolars and molars restored with standardized cavity preparations, mainly large (MOD) cavities. In addition, some investigations addressed other clinical situations such as non-carious cervical lesions and incisal edge restorations. The outcomes evaluated across these studies mainly involved fracture resistance, flexural strength, fatigue behavior, and fracture pattern. The randomized clinical trials assessed the clinical performance and survival of fiber-reinforced composite restorations placed in posterior teeth. These studies explored the use of short fiber-reinforced composite materials either as a reinforcing base, as a bulk restorative material, or in combination with conventional resin composites, and compared them with restorations performed without fiber reinforcement. These studies allow a direct comparison of the reported results and provide a basis to answer the objectives of the present review.

| Study | Study Design | Model | Restoration Type | Fiber Type | Control Composite | Main Outcomes |
|---|---|---|---|---|---|---|
| **Mohamed et al., 2025 cl (20)** | Randomized Clinical Trial (18 months) | Human vital posterior teeth | Class II MOD | Short glass fiber (everX Posterior); Polyethylene (Ribbond Ultra) | Filtek Z250 (nanohybrid composite) | Clinical performance (USPHS) |
| **Kaya et al., 2023 (21)** | Randomized Clinical Trial (24 months) | First permanent molars (MIH) | Selective caries removal | Flowable short glass fiber (everX Flow) | Equia Forte HT (glass hybrid) | Restoration retention rate |
| **Abd ElAziz et al., 2024(22)** | Randomized Clinical Trial (18 months) | Premolars and molars | Class II (no proximal coverage) | Flowable short glass fiber (everX Flow) | G-ænial Posterior (microhybrid composite) | Clinical performance (marginal integrity, survival) |
| **Pierce et al., 2025 (23)** | In vitro | Extracted mandibular molars | Cuspal-coverage restorations | MS-SFRC (everX Flow); Polyethylene (Ribbond) | Filtek Supreme Ultra (nanofill composite) | Fracture resistance; Failure mode |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Magne & Milani, 2023 (24)** | In vitro (fatigue + static) | Extracted maxillary molars | Large MOD with undermined cusps | Short glass fiber base (everX Flow) | Gradia Direct (microhybrid composite) | Fatigue survival; Fracture resistance |
| **Qiu et al., 2025 (25)** | In vitro | Standardized resin bar specimens | Flexural strength bars (20×3×3 mm) | Unidirectional & woven quartz fibers | Beautifil II (giomer); Beautifil Flow Plus (flowable composite) | Flexural strength |
| **Jadhav et al., 2024 (26)** | In vitro | Extracted maxillary incisors | Incisal build-up | Polyethylene (Ribbond) | Filtek Z250 (nanohybrid composite) | Load-bearing capacity; Failure pattern |
| **Oksanen et al., 2025 (27)** | In vitro | Extracted premolars and molars | Wide MOD | Micrometer-scale & hybrid SFC (everX Flow/Posterior) | G-ænial Universal Injectable (injectable composite) | Fracture resistance |
| **Hazar & Hazar, 2024 (28)** | In vitro | Extracted maxillary premolars | Wedge-shaped NCCLs | Flowable short glass fiber (everX Flow) | SDR flow+ (bulk-fill); Universal Injectable (injectable composite) | Fracture resistance; Failure pattern |
| **Fráter et al., 2021 (29)** | In vitro (fatigue + static) | Extracted mandibular molars | Deep MOD cavities | Flowable short glass fiber core (everX Flow) | G-ænial Posterior (packable microhybrid composite) | Fatigue resistance; Load-bearing capacity; Failure mode |

***Table 4**: The main characteristics of the included studies*

Randomized clinical trials mainly evaluated restoration retention, marginal integrity, survival rates, and overall clinical performance over follow-up periods ranging from 18 to 24 months (Mohamed et al., 2025; Kaya et al., 2023; Abd ElAziz et al., 2024)(20–22).

Experimental in vitro studies focused on fracture resistance under static and cyclic loading, fatigue survival, flexural strength, load-bearing capacity, and fracture patterns, particularly the prevalence of repairable versus catastrophic failures (Fráter et al., 2021; Magne & Milani, 2023; Oksanen et al., 2025; Hazar & Hazar, 2024; Qiu et al., 2025; Jadhav et al., 2024) (24–29).

4.2 Mechanical Resistance Outcomes

| Study | Mechanical Test | Fiber-Reinforced (Mean ± SD) | Conventional (Mean ± SD) | Significant Difference? |
|---|---|---|---|---|
| **Mohamed et al., 2025 (20)** | Clinical evaluation (USPHS) | Satisfactory performance (Alpha/Bravo ratings) | Comparable performance (Filtek Z250) | No ($p > 0.05$) |
| **Kaya et al., 2023 (21)** | Clinical survival (24 months) | 93.5% ± 4.4 SE | 77.4% ± 7.5 SE | Yes (Retention $p = 0.016$) |
| **Abd ElAziz et al., 2024 (22)** | Clinical evaluation | Alpha ratings > 90% | Alpha ratings > 87% | No ($p > 0.05$) |
| **Pierce et al., 2025 (23)** | Fracture load (N) | 1112.9 ± 249.3 N | 651.7 ± 228.3 N | Yes ($p < 0.011$) |
| **Magne & Milani, 2023 (24)** | Accelerated fatigue (cycles) | Higher fatigue survival (mean not reported) | Poorest survival; catastrophic failures | Yes ($p < 0.001$) |
| **Qiu et al., 2025 (25)** | Flexural strength (MPa) | 459.69 ± 46.61 MPa | 107.02 ± 13.68 MPa | Yes ($p < 0.001$) |
| **Jadhav et al., 2024 (26)** | Load-bearing capacity (N) | 702.5 ± 20.66 N | 501.8 ± 21.45 N | Yes ($p = 0.0001$) |
| **Oksanen et al., 2025 (27)** | Fracture load (N) | 2280 ± 375 N | 1221 ± 435 N | Yes ($p < 0.05$) |
| **Hazar & Hazar, 2024 (28)** | Fracture resistance (N) | 673.787 N | 553.289 N | Yes ($p < 0.001$) |
| **Fráter et al., 2021 (29)** | Static load-to-fracture (N) | ≈ 2160 ± 643 N | 1040 ± 262 N | Yes ($p < 0.05$) |

***Table 5:*** The mechanical performance of fiber-reinforced composites compared with conventional

SD: standard deviation; SE: standard error; USPHS: United States Public Health Service criteria.
N: Newton; MPa: megapascal; p: probability value.

4.2.1: Fracture Resistance

Fracture resistance has been investigated in multiple in vitro studies focusing on both posterior and anterior restorations. Fráter et al. (2021)(29) showed that large MOD restorations reinforced with a flowable short fiber–reinforced composite (SFRC) core had a significantly greater load-bearing capacity after fatigue loading than restorations made with conventional composite alone. In addition, fractures in the fiber-reinforced groups were more often restorable. Similarly, Pierce et al. (2025) (23) reported higher fracture loads in cuspal-coverage restorations that incorporated a micrometer-scale SFRC base layered with nanofill composite. The fiber-reinforced group reached 1112.9 ± 249.3 N, whereas the

nanofill-only group showed 651.7 ± 228.3 N. In another laboratory study, Oksanen et al. (2025) (27) found that premolars restored with conventional composite demonstrated fracture resistance values of 481 ± 159 N. In contrast, plain SFC restorations reached 1735 ± 533 N. For molars, hybrid SFC restorations achieved even higher values, up to 2280 ± 375 N. Hazar and Hazar (2024) (28) evaluated NCCL restorations and reported fracture resistance values of 673.787 N for everX Flow™, compared with 553.289 N for injectable composite and 497.368 N for SDR® flow+. For anterior restorations, Jadhav et al. (2024) (26) observed that incisal build-ups reinforced with a single fiber exhibited higher load-bearing capacity (702.5 ± 20.66 N) than non-reinforced composite restorations (501.8 ± 21.45 N).

#### 4.2.2: Flexural Strength

Flexural strength was assessed using standardized bar-shaped specimens in laboratory settings. Qiu et al. (2025) (25) reported a mean flexural strength of 116.80 ± 11.45 MPa in the non–fiber-reinforced control group. In comparison, fiber-reinforced specimens reached values as high as 459.69 ± 46.61 MPa. The authors noted that both fiber orientation and placement technique significantly affected the results. Other laboratory findings have also indicated that fiber positioning plays an important role in mechanical behavior under bending forces.

#### 4.2.3: Fatigue Resistance

Fatigue performance under cyclic loading has mainly been examined in posterior restorations. Fráter et al. (2021) (29) subjected restorations to up to 25,000 loading cycles and found no statistically significant differences in survival rates between groups. Nevertheless, restorations reinforced with fibers demonstrated greater load-bearing capacity after fatigue testing compared to conventional composite restorations. Pierce et al. (2025) (23) , after thermocycling and cyclic fatigue procedures, similarly reported higher fracture loads in fiber-reinforced groups than in non-reinforced controls. Clinical investigations by Kaya et al. (2023) (21) and Abd ElAziz et al. (2024) (22) also reported favorable short-term outcomes, with high retention and survival rates of fiber-reinforced posterior restorations over follow-up periods ranging from 18 to 24 months.

4.3 Structural and Biomechanical Implications of Fiber Reinforcement

| Study | Fiber Nature | Architecture / Orientation | Distribution Pattern | Reinforcement Mechanism | Biomechanical Implication |
|---|---|---|---|---|---|
| **Mohamed et al., 2025 (20)** | Short glass fiber composite; Ultra-high molecular weight polyethylene | Random; Leno-weave structure | Bulk dentin replacement or cavity wall lining | Improved stress redistribution | Limited additional benefit in moderate cavities |
| **Kaya et al., 2023 (21)** | Flowable short glass fiber | Random | Core base covered with microhybrid composite | Enhanced energy absorption capacity | Improved restoration retention |
| **Abd ElAziz et al., 2024 (22)** | Flowable short glass fiber (200–300 micrometers) | Random | Dentin replacement including proximal wall | Load transfer through fiber network | Comparable behavior in Class II restorations |
| **Pierce et al., 2025 (23)** | Micrometer-scale short glass fiber; Nanometer-scale fiber; Polyethylene fiber | Random; Bidirectional | Dentin base or crisscross reinforcement | Crack bridging and energy dissipation | Most effective under high occlusal load |
| **Magne and Milani, 2023 (24)** | Flowable short glass fiber | Random | Floor base reinforcement | Slowing of fatigue crack propagation | Relevant in large mesio-occluso-distal cavities |
| **Qiu et al., 2025 (25)** | Quartz fiber reinforcement | Unidirectional or woven | Strategic placement within restoration | Directional tensile reinforcement | Strength gain dependent on fiber orientation |
| **Jadhav et al., 2024 (26)** | Polyethylene fiber | Leno-weave structure | Localized palatal reinforcement layer | Improved tensile stress control | Effective in incisal composite build-ups |
| **Oksanen et al., 2025 (27)** | Hybrid short glass fiber | Three-dimensional random network | Monolithic or bilayer configuration | Multi-scale crack control | Improved repairability of fractures |
| **Hazar and Hazar, 2024 (28)** | Flowable short glass fiber | Random isotropic distribution | Bulk placement in cervical lesions | Redistribution of wedge-shaped stress | Beneficial in non-carious cervical lesions |
| **Fráter et al., 2021 (29)** | Short glass fiber | Random | Bulk dentin core under composite overlay | Enhanced fatigue resistance | Indicated for deep mesio-occluso-distal cavities |

***Table 6:*** Effect of Fiber Characteristics on Mechanical Behavior

### 4.4 Situations in Which the Usefulness of Fibers Remains Limited

Some of the included studies reported situations in which fiber reinforcement did not provide a statistically significant advantage. In a randomized clinical trial on posterior Class II restorations, Mohamed et al. (2025) (20) found no significant superiority of fiber-reinforced composite compared with conventional composite after 18 months. Similarly, Abd ElAziz et al. (2024) (22) reported no significant differences between reinforced and non-reinforced restorations in posterior Class II cavities. Laboratory studies also showed that the reinforcing effect was not always consistent. Pierce et al. (2025) (23) observed that improvements in fracture resistance depended on the fiber configuration, and not all tested systems demonstrated superior performance. Qiu et al. (2025) (25) reported that mechanical behavior was influenced by fiber orientation, with no increase in strength when the fibers were not properly aligned. Kaya et al. (2023) (21) evaluated fiber-reinforced restorations in MIH-affected molars and reported improved retention compared with glass hybrid restorations. Hazar and Hazar (2024) (28) reported increased fracture resistance in non-carious cervical lesion models under laboratory conditions. Jadhav et al. (2024) (26), Oksanen et al. (2025)(27), Fráter et al. (2021)(29), and Magne and Milani (2023) (24) described improvements in load-bearing capacity, fatigue resistance or fracture patterns in in vitro models

### 4.5 Synthesis of Findings

Ten scientific articles evaluated the mechanical resilience of fiber-reinforced composite resins in direct restorations, comparing them against traditional particulate-filled materials. It includes three randomized clinical trials and seven in vitro investigations.

Fracture resistance is the most studied mechanical property among these articles. In scenarios involving large mesial-occlusal-distal cavities or those requiring cusp coverage, the results typically showed that using a short fiber-reinforced composite core produced higher mean fracture loads than using conventional resins alone. Also, several lab studies highlighted that fiber-reinforced groups showed a significantly higher percentage of restorable fracture patterns compared to unreinforced controls. Testing on standardized beam specimens demonstrated that fiber could add superior flexural strength compared to standard materials. The presence of these reinforcing fibers also contributed to higher fracture toughness and a greater ability to arrest crack propagation within the restoration. Fatigue resistance was another key focus, with protocols involving cyclic loading and artificial aging simulations. These studies revealed that restorations featuring a fiber-reinforced base maintained a stronger load-bearing capacity after simulated functional wear than those made only of conventional composite. The three randomized clinical trials analyzed the performance of posterior direct

restorations under actual intraoral conditions. Key outcomes monitored during follow-up included restoration survival rates, fracture frequency, and specific failure modes. While fiber-reinforced composites generally displayed distinct fracture behaviors and structural integrity, the magnitude of these differences compared to conventional resins varied across the clinical data.

# 5. DISCUSION

The main objective of this review was to assess the performance of fiber-reinforced composites in direct restorations through three specific aims: to determine whether these materials offer greater resistance to functional stresses compared with conventional composites, to examine how fiber characteristics affect their mechanical behavior, and to identify clinical situations in which their use may be limited.

## 5.1 Resistance of fiber-reinforced composite resins to functional stresses compared with conventional composites.

The findings of this review indicate that the mechanical advantage of fiber-reinforced composites is not consistent and seems to depend on the level of functional stress as well as the amount of remaining tooth structure. Although several in vitro studies have reported higher fracture resistance with fiber reinforcement, this effect appears more nuanced when fatigue is considered. For instance, Fráter et al. (2021) (29) did not find significant differences during cyclic loading that simulated mastication. However, once specimens were loaded to failure after fatigue, fiber-reinforced restorations withstood higher loads. This suggests that fiber reinforcement may not prevent fatigue damage itself but could delay the onset of catastrophic failure, which remains clinically relevant. The amount of structural loss appears to play a central role in this behavior. When most of the tooth structure is preserved, enamel and dentin already provide sufficient rigidity to distribute occlusal forces. Under these conditions, conventional composites seem to perform adequately. This is in line with the clinical observations of Abd ElAziz et al. (2024) (22), who reported no significant differences in survival between reinforced and non-reinforced restorations in Class II cavities with intact marginal ridges.

In contrast, the situation changes in larger cavities such as mesio-occluso-distal restorations. In these cases, stress concentration is higher and cuspal deflection becomes more significant. Fiber-reinforced composites therefore appear to provide a more meaningful biomechanical contribution. Their internal structure may help redistribute stresses and reduce the risk of catastrophic fracture. The influence of fibers on crack propagation is particularly relevant here. By acting as internal barriers within the resin matrix, they can deflect or slow down crack growth. This does not prevent cracks from forming but may limit their progression and delay structural failure.

Another aspect to consider is the formation of defects during polymerization. Mohamed et al. (2025) (20) observed fewer polymerization-related cracks in fiber-reinforced composites. These early defects can act as stress concentrators over time. Reducing their formation may therefore provide a more stable structural starting point, especially in deep cavities where polymerization stress is higher.

Finally, fiber reinforcement seems to influence not only resistance but also the way restorations fail. According to Magne and Milani (2023) (24), fiber-reinforced restorations are more likely to exhibit repairable fractures, whereas conventional composites tend to result in more catastrophic failures. Clinically, this is a relevant finding, as it allows preservation of tooth structure and may improve long-term management of the restoration.

### 5.2 Influence of fiber type, orientation and distribution.

The findings of this review suggest that the mechanical behavior of fiber-reinforced composites does not depend simply on the presence of fibers, but rather on how well they interact with the resin matrix.

The limited improvement reported with polyethylene fibers by Pierce et al. (2025) (23) points to the importance of the fiber–matrix interface. Although these fibers have high tensile strength, their reinforcing effect seems to be reduced when adhesion to the resin is insufficient. In such cases, stress transfer remains limited, which compromises their overall contribution to the material's mechanical performance. In contrast, glass fibers tend to provide more consistent reinforcement. This is likely related to their ability to bond chemically with the resin matrix through silane coupling agents. As a result, stress transfer is more efficient, and the mechanical response of the composite becomes more predictable. Fiber length and distribution also appear to influence clinical behavior. Short fiber-reinforced composites have shown favorable results in several studies, probably because they adapt more easily to complex cavity geometries and reduce the risk of void formation during placement. Long-fiber systems, on the other hand, may offer greater reinforcement under ideal conditions, but their clinical use can be more demanding and less reliable in irregular cavities.

Fiber orientation is another factor that should be considered. According to Qiu et al. (2025) (25), properties such as flexural strength are strongly influenced by fiber alignment. While unidirectional fibers can improve resistance along specific stress directions, achieving optimal orientation in clinical situations is not always feasible. For this reason, randomly oriented short fibers may represent a more practical solution. Their distribution allows stresses to be dissipated in multiple directions and reduces technique sensitivity during placement. However, fiber content must be carefully controlled. An excessive amount of fibers may disrupt the continuity of the resin matrix and negatively affect the overall integrity of the material.

### 5.3 Clinical situations with limited usefulness

Overall, the benefits of fiber-reinforced composites appear to depend on the specific clinical context.

When mechanical stresses are low and enough tooth structure is preserved, the advantage of fiber reinforcement appears limited. This is typically the case in small Class I cavities or Class II restorations with intact marginal ridges. Clinical studies by Abd ElAziz et al. (2024) and Mohamed et al. (2025) (20,22) reported similar performance between fiber-reinforced and conventional composites in these conditions, suggesting that additional reinforcement may not be necessary. In contrast, their use seems more appropriate in situations where the risk of fracture is higher. This includes large posterior restorations with significant loss of tooth structure, as well as patients exposed to increased occlusal loads. In these cases, the additional reinforcement provided by fibers may contribute to improved mechanical behavior. Beyond mechanical considerations, other factors may influence their clinical use. Esthetic limitations remain an issue, as these materials are often available in a limited range of shades and may present higher translucency. This can restrict their indication in highly visible areas. In practice, they are more frequently used as dentin-replacement materials or as internal reinforcement layers rather than as definitive restorative surfaces.

The interpretation of these findings should also consider the limitations of the available evidence. Most of the studies included in this review were conducted in vitro, and clinical data are still limited, particularly in terms of long-term outcomes. As a result, the behavior of fiber-reinforced composites over extended periods, especially in challenging conditions such as deep subgingival cavities, remains insufficiently documented. From a practical point of view, simplified systems such as pre-mixed short fiber-reinforced composites appear to offer a better balance between performance and ease of use. In contrast, more complex techniques involving manual fiber placement may be more technique-sensitive and are likely better reserved for specific situations where maximum reinforcement is required. However, some limitations must be considered. A considerable heterogeneity of study designs was observed, with differences in methodologies, materials, and outcome measures, which limits direct comparison between studies. Moreover, the predominance of in vitro studies represents an important limitation, as laboratory conditions do not fully reflect the complexity of the oral environment. In addition, the lack of long-term clinical trials reduces the ability to draw definitive conclusions regarding the durability and clinical performance of these materials. Therefore, further well-designed clinical studies with longer follow-up periods are needed to strengthen the current evidence

## 6. CONCLUSIONS

1. Fiber-reinforced composites can improve fracture resistance in large posterior restorations with significant structural loss, while their benefit appears limited in smaller restorations with preserved tooth structure.

2. Their mechanical behavior is influenced by fiber characteristics and orientation. Glass fiber-reinforced composites provide more consistent results, whereas short-fiber systems offer better clinical applicability. Unidirectional fibers tend to enhance resistance, while multidirectional configurations are associated with more favorable and repairable fracture patterns.

3. Overall, fiber-reinforced composites should be mainly considered in situations with increased fracture risk rather than as a routine alternative to conventional composites. However, their clinical use is still limited by factors such as esthetic constraints and the lack of long-term evidence, especially in complex conditions like deep subgingival restorations or high occlusal load scenarios.

## 7. SUSTAINABILITY

Fiber-reinforced composites contribute to sustainability in restorative dentistry through social and economic aspects. From a social perspective, their use may help preserve natural dentition for a longer period by reducing the risk of catastrophic failures that often lead to tooth extraction. In many cases, when failure occurs, it tends to be more repairable, allowing maintenance of oral function and reducing the physical and psychological impact associated with tooth loss.

From an economic point of view, these materials are associated with a higher initial cost compared with conventional composites. However, their use in structurally compromised teeth may reduce the need for repeated treatments over time. This can decrease the number of clinical interventions, limit time away from daily activities, and contribute to a more efficient use of healthcare resources.

Despite these advantages, their application should be carefully considered. The higher upfront cost may limit accessibility for some patients, and their use is more justified in situations where a clear mechanical benefit is expected. Therefore, a selective and evidence-based approach is recommended to maximize both clinical outcomes and sustainability.

## 8. REFERENCES


1. Safwat EM, Khater AGA, Abd-Elsatar AG, Khater GA. Glass fiber-reinforced composites in dentistry. Bull Natl Res Cent. 2021;45:190. doi:10.1186/s42269-021-00650-7.

2. Escobar LB, Pereira da Silva L, Manarte-Monteiro P. Fracture resistance of fiber-reinforced composite restorations: a systematic review and meta-analysis. Polymers. 2023;15(18):3802. doi:10.3390/polym15183802.

3. Vallittu PK. An overview of development and status of fiber-reinforced composites as dental and medical biomaterials. Acta Biomater Odontol Scand. 2018;4(1):44-55. doi:10.1080/23337931.2018.1457445.

4. Alla RK, Sanka GSSJ, Saridena USNG, Ramaraju AV, Raju MAKV, Mantena SR. Fiber-reinforced composites in dentistry: enhancing structural integrity and aesthetic appeal. Int J Dent Mater. 2023;5(3):78-85. doi:10.37983/IJDM.2023.5303.

5. Garoushi S, Gargoum A, Vallittu PK, Lassila L. Short fiber-reinforced composite restorations: a review of the current literature. J Investig Clin Dent. 2018;9(3):e12330. doi:10.1111/jicd.12330.

6. Albar NHM, Khayat WF. Evaluation of fracture strength of fiber-reinforced direct composite resin restorations: an in vitro study. Polymers. 2022;14:4339. doi:10.3390/polym14204339.

7. Ferracane JL. A historical perspective on dental composite restorative materials. J Funct Biomater. 2024;15(7):173. doi:10.3390/jfb15070173.

8. Bhagwat S, Mandke L, Vandekar M, Basmatkar N, Pawar A, Khatri R. Longevity of amalgam versus composite resin restorations in permanent posterior teeth: a systematic review. Cureus. 2025;17(7):e88836. doi:10.7759/cureus.88836.

9. Zhou X, Huang X, Li M, Peng X, Wang S, Zhou X, Cheng L. Development and status of resin composite as dental restorative materials. J Appl Polym Sci. 2019;136:48180. doi:10.1002/app.48180.

10. 10. Alsharif SO, Arifin Z, Ishak BM, Arriffin AB. An overview on dental composite restorative "white filling". Ann Fac Eng Hunedoara Int J Eng. 2010;8(2):95-100.

11. Jakab A, Palkovics D, Szabó VT, Szabó B, Vincze-Bandi E, Braunitzer G, et al. Mechanical performance of extensive restorations made with short fiber-reinforced composites without coverage: a systematic review of in vitro studies. Polymers. 2024;16:590. doi:10.3390/polym16050590.

12. Garoushi S, Mangoush E, Vallittu PK, Lassila L. Short fiber reinforced composite: a new alternative for direct onlay restorations. Open Dent J. 2013;7:181-185.

13. Kamourieh N, Faigenblum M, Blizard R, Leung A, Fine P. Fracture toughness of short fibre-reinforced composites—an in vitro study. Materials. 2024;17:5368. doi:10.3390/ma17215368.

14. Mohammadipour HS, Farajzadeh M, Toutouni H, Gazerani A, Sekandari S. Fracture resistance of fiber-reinforced vs conventional resin composite restorations in structurally compromised molars: an in vitro study. Int J Dent. 2025;2025:5169253. doi:10.1155/2025/5169253.

15. Alshabib A, Jurado CA, Tsujimoto A. Short fiber-reinforced resin-based composites (SFRCs): current status and future perspectives. Dent Mater J. 2022;41. doi:10.4012/dmj.2022-080.

16. Alluhaidan T, Qaw M, Garcia IM, Montoya C, Orrego S, Melo MA. Seeking endurance: designing smart dental composites for tooth restoration. Designs. 2024;8:92. doi:10.3390/designs8050092.

17. Cangul S, Adiguzel O. The latest developments related to composite resins. Int Dent Res. 2017;7:32-41. doi:10.5577/intdentres.2017.vol7.no2.3.

18. Tsertsidou V, Mourouzis P, Dionysopoulos D, Pandoleon P, Tolidis K. Fracture resistance of class II MOD cavities restored by direct and indirect techniques and different materials combination. Polymers. 2023;15:3413. doi:10.3390/polym15163413.

19. Butterworth C, Ellakwa AE, Shortall AC. Fibre-reinforced composites in restorative dentistry. Dent Update. 2003;30:300-306. doi:10.12968/denu.2003.30.6.300.

20. Mohamed MH, Abouauf EA, Mosallam RS. Clinical performance of class II MOD fiber reinforced resin composite restorations: an 18-month randomized controlled clinical trial. BMC Oral Health. 2025;25:159. doi:10.1186/s12903-025-05521-5.

21. Kaya R, Sen Yavuz B, Kodaman Dokumacigil N, Kargul B. A randomized clinical trial of short fiber reinforced composite and glass hybrid restoration for molars affected by molar hypomineralization. Pediatr Dent. 2023;45(4):292-298.

22. Abd ElAziz RH, Abd ElAziz SA, Abd ElAziz PM, Frater M, Vallittu PK, Lassila L, et al. Clinical evaluation of posterior flowable short fiber-reinforced composite restorations without proximal surface coverage. Odontology. 2024;112:1274-1283. doi:10.1007/s10266-024-00905-5.

23. Pierce AL, Kosaraju A, Gedge JL, Vandewalle KS. Fracture resistance and failure modes of cuspal-coverage restorations using fiber-reinforced and non-fiber-reinforced materials: an in vitro study. J Contemp Dent Pract. 2025;26(1):4-9. doi:10.5005/jp-journals-10024-3806.

24. Magne P, Milani T. Short-fiber reinforced MOD restorations of molars with severely undermined cusps. J Adhes Dent. 2023;25:99-106.

25. Qiu S, Zhou Y, Tang M, Jiang LP, Sano H, Carvalho RM, et al. The impact of using two fiber-reinforced composites with different placement methods on the flexural strength of two resin materials: an in vitro study. BMC Oral Health. 2025;25:1006. doi:10.1186/s12903-025-06450-z.

26. Jadhav GR, Mittal P, Shinde S, Al-Qarni MA, Al-Obaid M, Abullais SS, et al. Biomimetic approach to strengthen the incisal fracture composite build-up: an in vitro study. BMC Oral Health. 2024;24:42. doi:10.1186/s12903-023-03679-4.

27. Oksanen V, Bijelic-Donova J, Vallittu PK, Lassila L, Garoushi S. Two different short fiber-reinforced resin composites for extensive MOD cavities in premolars and molars. Clin Oral Investig. 2025;29:462. doi:10.1007/s00784-025-06562-4.

28. Hazar A, Hazar E. Effect of composite resins with and without fiber-reinforcement on the fracture resistance of teeth with non-carious cervical lesions. J Appl Biomater Funct Mater. 2024;22:22808000241303327. doi:10.1177/22808000241303327.

29. Fráter M, Sáry T, Vincze-Bandi E, Volom A, Braunitzer G, Szabó BP, et al. Fracture behavior of short fiber-reinforced direct restorations in large MOD cavities. Polymers. 2021;13:2040. doi:10.3390/polym13132040.