Restorative Strategies for Endodontically Treated Teeth with Extensive Structural Loss: A Narrative Review

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Abstract

The mechanical characteristics of damaged anterior teeth that have received endodontic treatment procedures may ultimately be impacted by intra-radicular restoration. With significant structural loss, fiber-reinforced composite (FRC) posts are frequently recommended as an alternative to metal posts because they possess a higher elasticity modulus, thus tending to increase the chances of root fractures. However, with continual advancements in adhesive restorations, reinforced resin composite materials have recently been offered as possible substitutes for FRC or metal posts. These alternatives provide improved bonding capabilities and can further enhance the longevity of the restoration. This narrative review aimed to accumulate data on various post and core buildup protocols as well as the effect they have on anterior teeth's fracture resistance following endodontic treatment. The findings suggest that the choice of post and core materials significantly influences the longevity and durability of the restored teeth. By evaluating different protocols, clinicians can make informed decisions to optimize treatment outcomes. We concluded that while each approach has benefits and drawbacks, all can be used effectively for post-endodontic reinforcement. Despite this, traditional fiber posts and composite cores provide higher fracture strength in comparison with the reinforced composite core material alone, particularly in situations when the coronal portion of the tooth has been severely destructed.

1. Introduction

Endodontically treated anterior teeth (ETAT), particularly upper central incisors, present unique restorative challenges due to their aesthetic importance, functional role in articulation and phonetics. Failure to restore them has not only orofacial repercussions, but also has psychological consequences owing to social discontent. Also, because the occlusal stresses experienced by endodontically treated anterior teeth are more transverse, they are more prone to fractures.[1-2]. A variety of interrelated factors must be evaluated when determining the long-term survival of teeth that have undergone endodontic treatment (Figure.1). They comprise periapical health, tooth's location within an arch, the quantity and condition of neighboring teeth, and the nature of occlusal contacts. Additionally, the degree of reduction in coronal hard tissue, the overall thickness of the surviving dentin walls, and the structural integrity of root dentin, which may be compromised by collagen degradation and reduced intermolecular cross-linking, play crucial roles. Other significant considerations (Figure.2) are the type of definitive coronal reconstruction, selection of post and core materials if post placement is warranted and the presence and quality of a

ferrule, which can enhance biomechanical stability when indicated [3]. The longevity of restored endodontically treated teeth is significantly influenced by the quantity of tooth structure that survives after endodontic treatment and post-preparation [4-6].

While metal post-and-core techniques (Table 1) have demonstrated superior resistance to fracture, they are also associated with an increased risk of catastrophic failures, particularly apical root fractures. This risk is heightened in teeth with thin residual dentinal walls, as the high rigidity of metal posts, combined with the wedging forces exerted within the root canal, may predispose the tooth to structural failure [7-10]. Since fiber post' elastic modulus is more resembling dentin's, it has been introduced to address this issue (Table 1) [4-6-11-12]. In cases of flared root canals, numerous studies have indicated that restoring the canal with single fiber post and composite core yields reduced resistance to fracture, primarily because of poor adaptation among fiber post and the canal walls. Thick layer of resin cement is produced from this mismatch, which increases the risk of polymerization shrinkage, void formation, and ultimately debonding [4-5-8-13]. Accessory or multiple fiber posts have been proposed in

such anatomically compromised canals. This technique has shown improved fracture resistance in teeth with severe structural loss or widened canals [4-8-14-15]. Nonetheless, employing multiple small-diameter posts introduces multiple interfaces between the posts and the luting resin, which may compromise the integrity of the restoration.

Additionally, the reduced strength of smaller fiber posts can be a limiting factor, often leading to fiber post fractures or debonding at the adhesive interfaces [4]. These drawbacks have led researchers to explore alternative approaches that aim to reduce dependence on prefabricated posts while enhancing adaptation and mechanical stability. The coronal tooth structure is essential for ensuring long-term function, form, and esthetics. Resin composites are commonly utilized in conjunction with FRC posts as core build-up material [16-18]. Innovations in composite chemistry have produced core-specific materials with increased filler loading for improved handling and strength [11-19-20]. With advances in adhesive dentistry and restorative materials, alternative approaches, such as fiber-reinforced core build-ups and post-free restoration strategies, have emerged. These methods aim to conserve more radicular dentin, reduce the number of interfaces within the root, enhance the repaired tooth's mechanical integrity without relying on traditional post placement [4-6-11-19-21]. In this review article, we provided a comprehensive evidence-based overview of material advancements, and clinical outcomes related to use of FRC posts and alternative post-free strategy in restoration of teeth that received endodontic therapy.

2. Fiber post

Two important goals for post and core-maintained restorations are retention along with fracture resistance, the retention of the post system should be taken into consideration by evaluating numerous aspects including A post's length, design, diameter, surface treatment, material, canal shape, as well as the luting medium and cementation process [22]. In contrast, resistance to fracture corresponds with amount of dentin that is still present [22]. Unrestorable root fractures have been linked to metal posts and cores because they possess an excessive modulus of elasticity [6-11]. Nonmetal posts, which include those made of zirconia, epoxy or methacrylate resin strengthened using either glass or quartz fibers, carbon fiber-reinforced epoxy resin posts, along with polyethylene fiber-reinforced posts, were developed in accordance with a demand for substances with mechanical qualities similar to root dentin. This enabled a transition from mechanically retained restorations to ones that are adhesively retained, & aesthetic appeal. The fundamental benefit of fiber-reinforced composite (FRC) posts (Table 1) over metal posts is that they transfer stresses to the root dentin more favorably and flex slightly under load [6-11]. Numerous investigations evaluating mechanical durability of pulpless incisors reconstructed using FRC posts have revealed fewer instances of root fractures [23-25].

Historically, lengthening post has been considered a means to improve retention. However, maintaining consistent bonding performance in the root canal apical area is difficult to achieve. This is partly owing to technical restrictions involved with adhesive methods in deep, tight locations, maintaining appropriate moisture levels, guaranteeing efficient light penetration for curing, and establishing uniform adhesive distribution are particularly challenging

[26-31]. Innovations in adhesive technologies have facilitated a transition toward more conservative and biologically compatible restorative approaches. Among these, self-adhesive resin cements have gained significant clinical acceptance owing to their streamlined application protocol and reliable bonding performance. By reducing technique sensitivity, these cements simplify clinical procedures and have demonstrated enhanced fracture resistance, particularly when paired with short fiber-reinforced composite (FRC) posts [5-32-33]. Evidence suggests that short posts limit the extent of post space preparation and conserve radicular dentin, further enhancing structural durability, higher fracture resistance and more restorable fracture pattern [34-35].

3. Core Build-Up Materials
3.1. Resin Composite

When a post is utilized, the core build-up material serves as the crucial intermediary, transferring occlusal loads from the final restoration (crown) to the post and ultimately to the root structure [36]. Simultaneously, the core must provide adequate retention and resistance form to securely anchor the definitive crown [18]. Resin composite (Table 2) is a popular core build-up material that is frequently used to reconstruct the coronal section of the endodontically treated tooth because of its mechanical compatibility with tooth structure, ease of handling and intraoral sculpting, and, most importantly the ability to bond adhesively [17-18-37]. Their modulus of elasticity and fracture toughness are similar to dentin, which supports more favorable stress distribution while also providing retention and resistance form for the final restoration [17-18-37].

3.2. Filler Reinforced Composites

Composite chemistry advancements have resulted in the development of core-specific materials with greater filler loads for better handling and strength (Table 2). These materials differ in terms of filler amount and type, viscosity, curing mode, and build-up process, amongst other factors, and their physical characteristics were studied in a variety of ways [18-38-40]. In order to guarantee full polymerization along with maximum strength, high-viscosity composite core materials have been managed utilizing an incremental approach. In an attempt to prevent air contaminants, low viscosity core build-up composites were typically produced using an automix syringe. Such materials are also capable of being utilized to simultaneously cement FRC post, in addition being able to serve as core material. They're dual-curing composites that are better suited for usage alongside fiber posts, since light curing may not be fully accomplished, so as to permit polymerization within root canal.

Clinicians have discovered when compared to high viscosity materials, low viscosity core materials are easier in preparing using diamond cutting equipment. According to Rüttermann, et al. [40] who examined physical characteristics for direct core materials, the flexural strength exhibited by high viscosity composites (Clearfil and MultiCore HB) is greater compared to that of flowable composites (Rabilda SC). This means that while a low-viscosity composite core might become easier to operate with, but endurance may be diminished. But according to some research, lower viscosity composite core materials bonded to FRC posts more strongly over hybrid composites [41-42]. Prapaporn Panitiwat et al. [18] evaluated various composite materials for core build-up

and found that higher filler content composites demonstrated superior fracture resistance. This suggests that material composition and filler characteristics directly influence clinical performance and longevity of the core restoration.

3.3. Fiber Reinforced Composites

The integration of fiber reinforcement within resin composites represents another step forward in the development of biomimetic restorative systems. Fiber-reinforced composites (FRCs) (Figure.3) and (Table 2) include discontinuous (short) or continuous fibers (e.g., glass, polyethylene, carbon, or aramid) into the resin matrix [43]. Glass fibers, particularly E-glass and S-glass, are presently used to make the majority of dental FRCs because of their transparent nature and surface chemistry, allowing adherence with the resin matrix using silane coupling agents [44-45]. The key elements that can enhance or degrade the mechanical properties of fibre-reinforced composites are aspect ratio, critical fibre length, fibre loading, and fiber orientation [20-43-46-49]. The length of fiber to diameter (l/d) proportion is referred to as the aspect ratio. It impacts fiber-reinforced materials' tensile strength and reinforcement efficiency [20-50-52]. The "critical fiber length," or the minimum length of fiber, is further associated with impact of fiber aspect ratio. It currently determined that in order to prevent fiber debonding under tensile stress, essential fiber length for improved FRCs may be fifty times bigger than fiber's diameter.

The essential fiber length must be within 750 and 900 μm since the glass fibers currently utilized in dental FRCs have a diameter of 15 to 18 μm [20-50]. Whenever the fiber length is equivalent to or higher in comparison to the critical fiber length along with the specified fiber aspect ratio, load is effectively transferred from a polymer matrix toward the fibers [11-50-53]. Appropriate load transference across the two elements is made possible by adequate adhesion in between the fiber and matrix. This guarantees that the force get transmitted to the stronger fiber, and this explains how the fiber serves as reinforcing. Addition to that, if there is poor adhesion and gaps appear inside the fiber and the polymer matrix, such vacancies might serve as early fracture points in the matrix, which would speed up material degradation. Polyethylene fibre often utilized in dental materials to enhance mechanical qualities of restorations [54]. At adhesive material interface, a polyethylene fiber efficiently modifies the behavior of stress and permits efficient force transmission [55]. A new fiber-reinforced composite restorative material called EverX Posterior recently launched for use as a reinforcement beneath conventional composites.

It incorporates short fibers and functions as a load-bearing layer under high stresses. Glass fibers are employed due to their good aesthetic qualities alongside their effectiveness in reinforcing. The millimeter-scale short fibers and the semi-IPN (semi-interpenetrating network) structure provide short fiber-reinforced composites their enhanced effect, work together to help prevent cracks from starting and spreading [56]. The millimeter-scale fibers contribute to toughening by engaging multiple mechanisms such as crack deflection, bridging, as well as blunting, which collectively lower the stress concentration at the crack tip. As cracks form, these discontinuous fibers can span across the border of the spreading crack, reducing notch sensitivity and leading to the blunting of the initially sharp fracture, thereby delaying or preventing further propagation. The varied fiber lengths within the SFRC contribute to a gradual toughening response, where shorter segments disengage and longer ones maintain load transfer [49-53-57].

Additionally, chemical modifications, such as methacrylate-based silanization of the fibers and inclusion of polymethyl methacrylate (PMMA) within semi-IPN network, improve compatibility with resin matrix and reduce stiffness, enhancing energy absorption and toughness. Notably, fracture toughness of these advanced SFRCs is comparable to that of natural dentin [58], which is essential for achieving biomechanical compatibility. This similarity not only ensures uniform stress distribution b/w restorative material and tooth structure but also reflects shared toughening mechanisms, such as crack bridging and deflection. Structurally, the short fibers in SFRCs function analogously to collagen fibers in dentin, both playing a critical role in enhancing resistance to fracture [49-58]. Sufyan Garoushi et al. [47-49] that short-fiber reinforced composites) have superior mechanical properties such as higher flexural strength and fracture toughness due to presence of optimally sized and oriented fibers. enhance restoration's ability to withstand loads, making such materials suitable not only for core build-up but potentially for post-free restoration strategies.

4. Substitution of the Fiber Post

While fiber-reinforced composite (FRC) posts have been widely adopted due to their favorable mechanical compatibility and esthetic advantages, their clinical performance is not without limitations. One of the primary challenges in using FRC posts is the mismatch between the post and canal morphology, especially in flared or oval-shaped root canals. This discrepancy often necessitates a thicker luting layer, which is more prone to polymerization shrinkage and stress development, potentially leading to debonding and loss of retention [6]. In recent years, fiber-reinforced composite materials have been investigated not only as core build-up materials but also as potential substitutes for conventional intraradicular posts (Table 2). These systems, which do not require a separate post or cementation step, aim to reduce procedural complexity, conserve tooth structure, and eliminate interfaces that could act as failure points. Such approaches align with modern adhesive dentistry principles emphasize preservation of tooth structure & enhancement of biomechanical performance.

Previous studies by Rayyan [21] and Sufyan Garoushi et al. [19], compared various techniques for intraradicular reinforcement and found superior fracture resistance when employing core material alone as post and core and this outcome was attributed to a reduced number of interfaces within the complex radicular part. These findings contradict prior research by Lippo lassila et al. [11] and study by Casanova et al. [6], which examined the fracture strength of posts and cores versus core material alone. It was concluded that, while core material alone demonstrated adequate performance a higher incidence of irreparable failure modes was experienced, particularly when compared to restorations with intraradicular posts. This shows that while post-free techniques may be viable in some circumstances, they may not have the endurance required for long-term clinical success, especially in patients with substantial coronal loss. Yet, a previous investigation by Pham KV et al. [12] found no significant difference between utilizing post and cores or not using post.
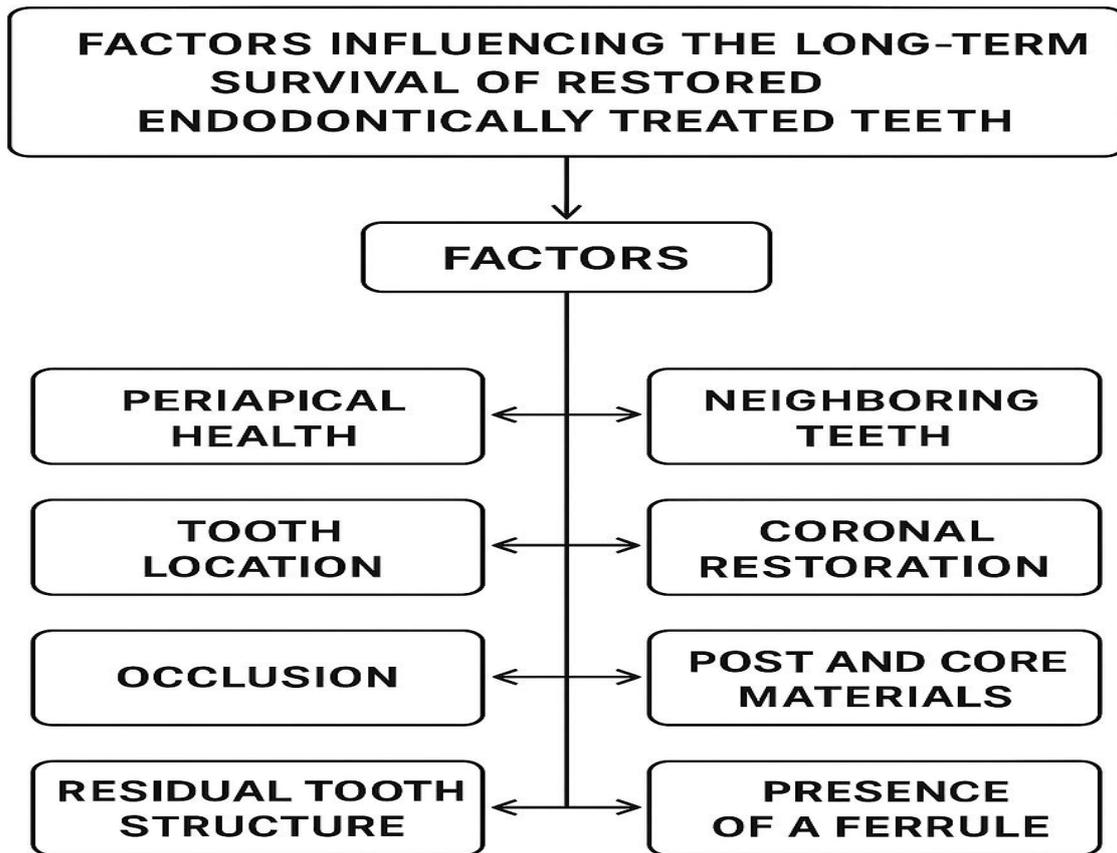
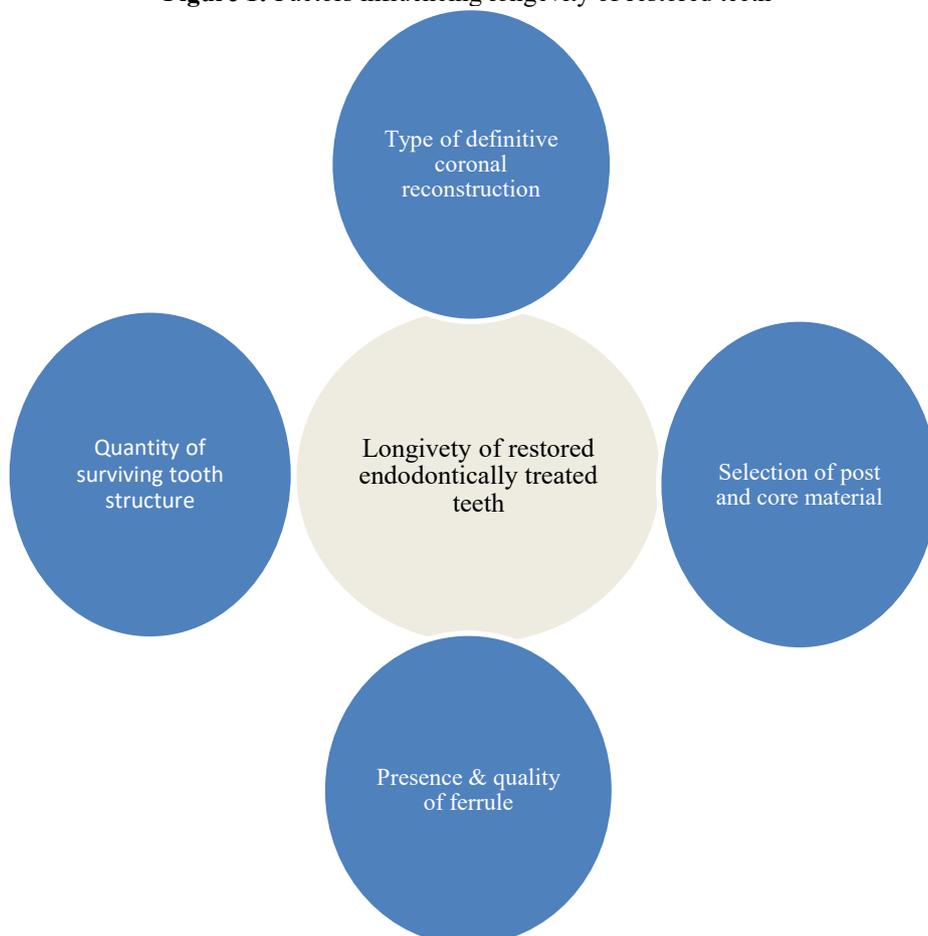**Figure 1:** Factors influencing longevity of restored teeth

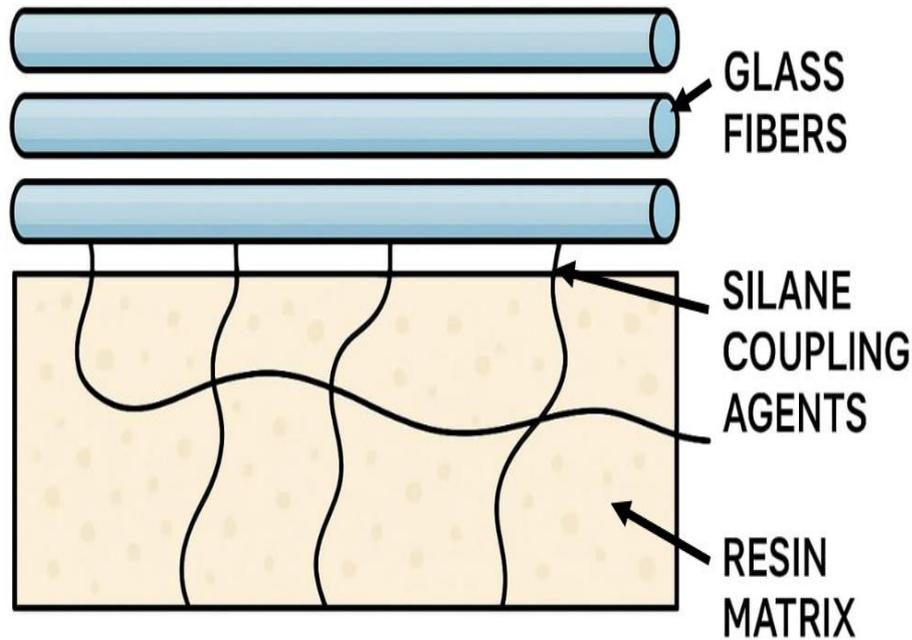**Figure 2:** Factors affecting the restoration longevity

Figure 3: Composition of Fiber-reinforced composites (FRCs)

Table 1. Comparison between the different reinforcing options of Endodontically Treated Teeth

Post Type	Advantages	Disadvantages
Metal Posts	High fracture resistance	High rigidity, risk of catastrophic root fracture, esthetics limitations
Fiber-Reinforced Composite (FRC) Posts	Elastic modulus similar to dentin; better stress distribution; esthetic	Risk of debonding in flared canals; technique-sensitive cementation
Post-Free Reinforcement (Composite Core Only)	Minimally invasive; conserves radicular dentin; eliminates interfaces	Higher incidence of irreparable failures; less evidence for long-term success

Table 2. Properties of Core Build-Up Materials

Core Material	Composition / Structure	Advantages	Limitations	Clinical Relevance
Resin Composite Eg: (Filtek Supreme XTE- 3M ESPE)	Resin-based material; modulus of elasticity similar to dentin; bonds adhesively	Easy handling and sculpting; favorable stress distribution; strong bonding	Lower strength compared to reinforced materials in large defects, polymerization shrinkage, technique-sensitive	Commonly used for core build-up with or without posts
Filler-Reinforced Composites Eg (MultiCore Ivoclar-Vivadent)	Higher filler loading; available in high- and low-viscosity; dual-cure options	Improved handling, strength, and polymerization; dual-cure ensures full setting	Low-viscosity types may show reduced endurance despite easier manipulation	Best suited for use with FRC posts; strong bond and adequate polymerization
Fiber-Reinforced Composites (FRCs) Eg: (EverX Posterior-GC)	Resin matrix reinforced with short or continuous fibers (glass, polyethylene, carbon, aramid)	Enhanced fracture toughness; biomimetic stress distribution; crack deflection prevents crack propagation	Technique-sensitive; fiber length and adhesion critical; risk of weak points with poor bonding	Suitable for post-free strategies and reinforcement in compromised teeth

5. Conclusions

The restoration of endodontically treated anterior teeth remains a complex endeavor balancing biomechanical requirements, aesthetic demands, and the imperative for minimally invasive dentistry. Each technique has its advantages and limitations, and all can be effectively utilized for restoring endodontically treated anterior teeth with normal biting conditions. However, FRC posts remain recommended choice for teeth with severely compromised coronal structure. Additionally, more research is needed to look into various core materials, designs, and ageing processes (cyclic loading) to reflect the long-term success of the restoration and for better understanding of these restorative choices.

6. Clinical Recommendations

1. For maxillary central incisors that underwent endodontic therapy with flared or irregular canals, moderate coronal loss, and normal occlusal forces, a reinforced core material used as a post-and-core system is recommended because of its superior adaptation while conservative approach.

2. FRC posts continue to be recommended in cases where coronal structure is severely compromised, and where a stable post-core foundation is essential for long-term success.

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