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Management of Cracked and Weakened Endodontically Treated Teeth Using Fiber-reinforced Composites: A Case Series

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Restoring endodontically treated teeth (ETT) that exhibit cracks, enlarged roots, or weakened root walls is a frequent challenge in dental practice. The present study describes three cases in which contemporary restorative techniques were employed and suggests that applying Ribbond tape (RT) to ETT can improve fracture resistance and better prevent the propagation of cracks compared with traditional methods. Although extensive *in vitro* research has been conducted on fiber-reinforced composites, studies evaluating the clinical use and durability of fiber-reinforced composites to restore ETT are limited. This report strictly adhered to the case report (CARE) guidelines, and the treatments were initiated only after signed informed consents were obtained from the patients. Therefore, the old restorations were removed from the teeth that required intervention and composite resin core build-up was created, followed by endodontic treatments or retreatment. Subsequently, the endodontic accesses were reinforced with RT. The protective restorations were performed and bonded. The two-year follow-ups showed that the patients had complete remission of signs and symptoms, and they remain under monitoring. The study emphasizes the importance of internal reinforcement of ETT and strengthening weakened walls with a resin core build-up reinforced with fibers like RT. This approach enhances mechanical retention, inhibit fracture propagation, and establish a strong chemical bond between RT and resin. It is suggested to be a promising strategy for increasing the longevity and strength of the teeth, providing a conservative and effective alternative to traditional methods.

Keywords: Biodentine; Cracked Tooth; Endodontics; Flexural Strength; Onlay; Polyethylene Ribbond Fiber; Root Canal

Introduction

Restoring endodontically treated teeth (ETT) with cracks, dilated roots, or weakened root walls is a complex and frequent task in dental practice [1]. These teeth often lose tissue due to caries, endodontic access, instrumentation, installation of metallic posts, and extensive restorations. These procedures can lead to the loss of important anatomic components and structures, such as enamel and marginal ridges, respectively [2, 3]. As a result, these teeth are significantly more prone to fracture than teeth with pulp vitality [2, 3].

Previous studies have shown that root canal treatment does not intrinsically cause the weakening of the tooth, as the tooth's stiffness is only reduced by 5% [4]. However, the absence of a marginal ridge may result in 46% loss of dental stiffness. In comparison, a mesio-occlusal-distal cavity preparation results in an average loss of 63% in the relative stiffness of the cusps [4-6]. Other factors that can negatively influence the fracture strength of ETT are chemicals and intracanal medications used between sessions, which can modify the structural composition [7, 8].

Currently, the survival of cracked teeth (CT) with root canal treatment is linked to the effectiveness of the endodontic treatment as the remaining tooth is carefully evaluated; the position of the tooth in the arch, the patient's occlusal pattern, as well as the initial and final restorative planning, which are essential for treatment success [1, 9]. When these parameters are not evaluated, the tooth may become more susceptible to fractures and other mechanical complications [10]]. In this sense, direct or indirect adhesive onlay or full coverage restoration is suggested for protecting CT [1, 10-12].

Similarly, well-established adhesive dentistry, which involves effective resin adhesive systems and composites, makes it possible to create more conservative, resistant, and highly esthetic restorations that are less expensive and can be performed in a single session [13-15]. However, there are several disadvantages in extensive restorations, such as stress caused by the polymerization shrinkage of the composite resin, that still need to be resolved [16, 17]. From this perspective, fiber-reinforced composites (FRC) in ETT should be used in contemporary restorative techniques, such as the Ribbond tape (bondable reinforcement ribbon) (Ribbond THM, Ribbond Inc, Seattle, USA) (RT), which can improve fracture resistance and better prevent crack propagation compared with traditional methods [18-21].

Ribbond tape is a fiber material composed of high strength, elastic, translucent and biocompatibile polyethylene [22]. It is treated with cold gas plasma to enhance its adhesion to synthetic materials [23]. This material effectively transfers forces throughout its plot without transferring stress to the composite resin [24]. It also hinders crack propagation by providing a strong chemical bond between the fibers and the resin matrix [20]. Due to its high flexibility, this material is ideal for stabilizing ETT and strengthening complex restorations [25].

Although extensive in vitro research on FRC has been carried out, more clinical studies should report the initial and final restorative treatment of endodontically treated CT with RT [26-29]. These cases aim to reveal innovative and effective strategies for restoring endodontically treated and structurally compromised CT reinforced with RT.

Cases Reports

The case report (CARE) guideline is a consensus-based clinical case reporting guideline development [30].

In all three cases, the clinical findings, pulp and periapical diagnoses, treatment plan and prognosis were previously explained to the patients. The treatment was carried out after the agreement and signing of the informed consent for all patients. The procedures were performed with an operating microscope (DF Vasconcellos, SP, Brazil).

Case 1

A 53-year-old female patient presented with chewing difficulties, as well as pain upon apical palpation and percussion in the right upper first molar (#16). The patient's medical history was typical. Clinical examination revealed restoration in mesio-occlusal-disto-palatal composite resin without cuspid protection. An edematous (swollen) area was observed in the apical region associated with the mesial root. Upon clinical examination of the right upper first molar (#16), palpation revealed tenderness in the apical region, percussion elicited significant discomfort, and gingival probing showed a depth of 3 mm with no signs of periodontal pocketing. No periodontal probing depth greater than 3 mm was detected. Radiographic images revealed the presence of periapical radiolucent lesions around the mesial, distal and palatal roots, with severe pulpal chamber atresia (Figure 1A). In the cone-beam computed tomography (CBCT), sagittal and frontal sections confirmed areas of periapical hypodensity around all roots. Hyperdense content was observed in the maxillary sinus region, and sinus disease of dental origin was suggested due to communication of the apex of the mesial root with the maxillary sinus (Figure 1B, 1C). Based on clinical, radiographic, and tomographic data, the tooth was diagnosed with pulp necrosis, symptomatic apical periodontitis, and probable inflammatory sinusopathy.

Initially, the patient received 2% Mepivalem (DLApharma, SP, Brazil) for anesthesia. The tooth was isolated with rubber dam. The restoration was partially removed, and crack lines were observed at the base of the buccal and palatal cusp (Figure 1D, 1E). Structural analysis revealed that the intercuspid isthmus was wider than 2.0 mm, the cavity was deeper than 4.0 mm, two marginal ridges were absent, and buccal and palatal cusps had a thickness of less than 2.0 mm.

A core build-up was created to promote the internal reconnection of the dentin walls and limit bacterial infiltration [21, 26]. Through this core build-up, minimally invasive access was achieved to start endodontic therapy in order to provide pain relief to the patient. The canals were identified and shaped with Race Evo rotary files (Dentaire, La Chaux-de-Fonds, Switzerland) (Figure 1F). Lastly, the root canals were filled with a calcium hydroxide intracanal dressing (UltraCal XS) (Ultradent Products, SP, Brazil). After one week, the patient returned and inflammatory signs had completely disappeared. The intracanal dressing was removed, and the root canals were filled with gutta-percha and bioceramic cement. Biodentine repair cement (Septodont, Saint-Maur-des-Fossés, France) was placed 2.0 mm beyond the orifice entrance of the canals to seal and reinforce this area (Figure 1G) [28, 31, 32].

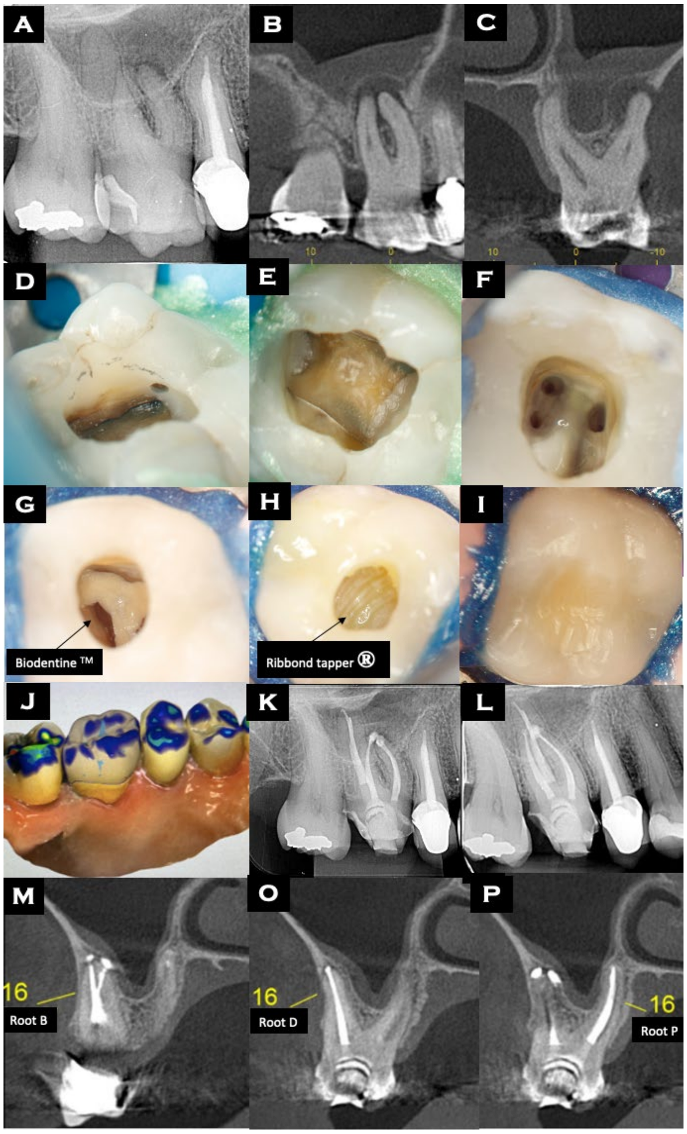

Figure 1. *A)* Initial periapical radiographic image of upper right first molar; *B, C)* Images of sagittal and frontal tomographic sections, respectively; *D, E)* Crack lines were identified at the base of the vestibular and palatal cusps; *F)* The canals were identified and formatted; *G)* Seal and reinforcement 2.0 mm beyond the orifice of the canals with Biodentine; *H)* RT with a thickness of 3 mm was previously cut, immersed in the Clearfil SE Bond, and inserted into the resin layer; *I)* Placement of RT; complete sealing of the access cavity with Ultradent resin; *J)*. Digital restoration models (overlay type) in palatal and occlusal views; *K)* Post-treatment radiographic image; *L)*. 24-month follow-up radiographs; *M-P)* Tomographic follow-up showing periapical repair and significant regression of the maxillary sinus disease

After the Biodentine was set, the endodontic cavity was cleaned, and the walls were again prepared with a spherical multilaminated drill. Clearfil SE Bond (Kuraray Medical, Osaka, Japan) was applied following manufacturer's instruction. A thin layer of the Grandioso fluid resin Heavy Flow (Voco, Cuxhaven, Germany) was deposited on the floor of pulp chamber with a thickness of 0.5 mm and photoactivated for 20 sec (Valo Grand Ultradent Products, SP, Brazil). A new horizontal increment of the regular composite resin (Forma; Ultradent Products, SP, Brazil) was inserted. Five millimeters of RT (Oraltech, Washington, USA) with a thickness of 3 mm which was previously cut and immersed in Clearfil SE Bond, was inserted into the resin layer (Figure 1H). This set was again photoactivated for 40 sec. Two-millimeter increment of the Forma composite resin was placed until the cavity was entirely sealed (Figure 1I). This internal reinforcement increases mechanical strength and rigidity by distributing stress to the tissues under load.

An onlay restoration was milled using computer-aided design/computer-aided manufacturing made from an E-MAX block (Ivoclar Vivadent Ltda, SP, Brazil). Then, the restoration was immediately cemented with Variolink II dual-polymerization cement (Ivoclar Vivadent, SP, Brazil) in order to externally reconnect all cusps and prevent crack propagation (Figure 1J) [1, 11, 33]. A final radiographic image was obtained (Figure 1K).

After 24 months, the patient returned for clinical radiography and tomographic follow-ups (Figures 1L-P), exhibiting excellent periapical repair, no inflammation, and a significant reduction in maxillary sinus issues.

Case 2

A 47-year-old female patient complained of pain in the upper right first molar when chewing. Upon clinical examination of the right upper first molar (#16), palpation revealed tenderness in the apical region, percussion elicited significant discomfort, and gingival probing showed a depth of 3 mm with no signs of periodontal pocketing. The radiographic image revealed radiolucency around the apex of the mesial root (Figure 2A). An amalgam restoration (CLASS I) with a large extension and several cracks on the occlusal surface was observed, extending along the marginal ridges and buccal and palatal developmental grooves (Figure 2B). The response to bite test was positive, but the response to thermal and electrical sensibility tests was negative. The occlusal interference in laterality involving the upper right first and second molars was verified. Additionally, wear was observed on the restorations of the antagonist teeth. Tomographic images confirmed the presence of a hypodense area, which suggests apical periodontitis (Figure 2C).

In this case, the treatment consisted of identifying the direction, location, and extent of the cracks. After removing the amalgam restoration, the remaining dentin was weakened

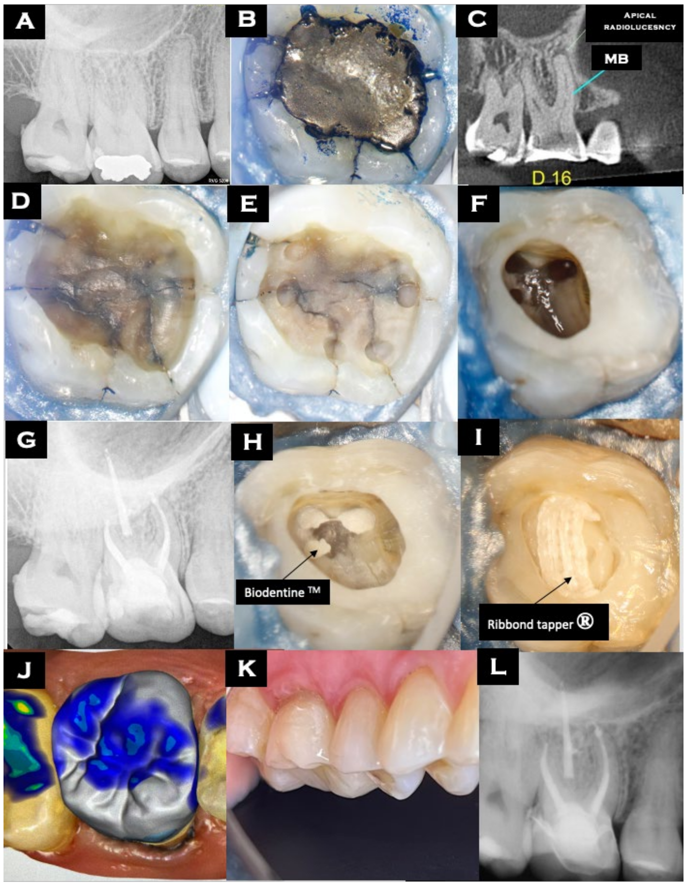

***Figure 2**. A) Preoperative radiograph of right maxillary molar; B) Pre-operative photography showing the occlusal restoration of great extension in amalgam and cracks in different directions and extensions using of methylene blue dye; C) Images of the frontal tomographic section showing a small hypodense area at the apex of the mesial root; D) Several crack lines in different directions and extensions were identified; E) Cleaning of cracks with ultrasonic tips and stabilizing them with a small cavity at their end; F) Resin core build-up was created, and the root canals were formatted G) Final radiography was taken; H) The canal orifices were reinforced with BiodentineTM 2 mm beyond the intraradicular cracks; I) A thin layer Flow composite resin was applied to the pulp chamber floor, 2 mm composite resin Forma was placed, and RT with the bond agent was inserted, touching the vestibule-occlusal-palatine faces; J) Digital cavity preparation and restoration images through CAD/CAM system; K) Photograph of the overlay restoration of element 16 already cemented with dual cement Variolink II; L) Periapical radiographic examination 2 years after treatment*

(Figures 2D, 2E). As in the previous case, an adhesive core build-up was created, and root canal treatment was performed (Figures 2F, 2G). The orifice of the canals was reinforced up to 2.0 mm inside the root with Biodentine (Figure 2H). Ribbond tape was inserted into a thin layer of flow composite resin to make contact with the buccal-occlusal-palatal faces. The endodontic access cavity was filled with regular composite resin, and the final radiograph was obtained (Figure 2I).

A preparation for an overlay restoration was done, scanned, and designed using computer-aided design/computer-aided manufacturing (CAD-CAM) system (Figure 2J). The restoration was milled from an E-MAX ceramic block (IPS E-MAX CAD; Ivoclar Vivadent, Schaan, Liechtenstein), finished, polished,adjusted, and bonded with dual resin cement Variolink II (Variolink Esthetic LC, Ivoclar Vivadent, Schaan, Liechtenstein) (Figure 2K). The occlusion was checked, and necessary adjustments were made before the patient was dismissed. After two years, the patient was asymptomatic, without clinical or radiographic signs of treatment failure (Figure 2L).

Case 3

A 32-year-old female patient reported pain in the right mandibular tooth upon chewing. In the clinical examination of the right mandibular molar (#46), palpation indicated tenderness in the apical region, percussion resulted in a positive response with pain, and gingival probing revealed a depth of 2 mm with no significant periodontal issues. Radiographic images revealed apical radiolucency in mesial and distal roots. This tooth had previously received endodontic treatment, with incompletely sealed canals, where a distal intraradicular threaded radiopaque post and a broken metal fragment in the middle third of the mesial root was present (Figure 3A, 3B). Radiographic and tomographic images confirmed the presence of a hypodense area, which suggests apical periodontitis (Figure 3C). Clinically, an onlay restoration with satisfying esthetics and marginal adaptation was observed.

In this case, the tooth was accessed through the existing restoration. The intraradicular post was carefully removed, and a radiograph was obtained (Figure 3D). The metal fragment was removed with ultrasonic inserts (Figure 3E). Then, endodontic retreatment was implemented, and the canals were carefully shaped (Figure 3F).

Multilayers with different materials were used for cavity sealing, including Biodentine and RT, to address the intraradicular crack and dentin fragility around the distal orifice (Figure 3G-J). Final radiographs were obtained (Figure 3K). Follow-up examinations at 24 months revealed significant healing in the periapical region without clinical signs of pain and probing depth (Figure 3L).

Discussion

Despite the increase in the use of all-ceramic restorations, metal restorations and metal-cast ceramic crowns with custom or

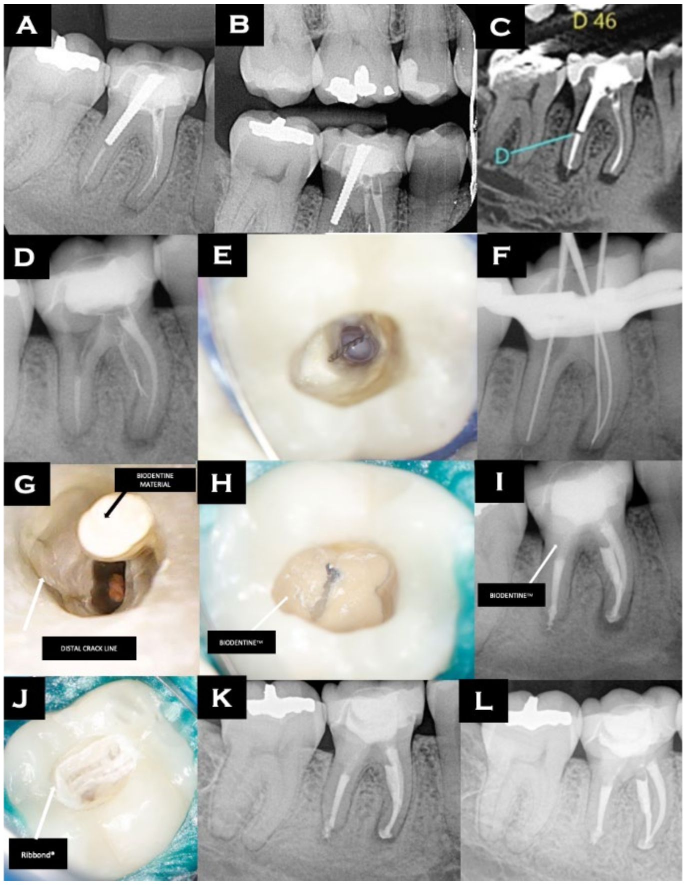

***Figure 3**. A, B)* The Periapical and bitewing preoperative radiographic of first right mandibular molar reveal a threaded intraradicular post in the distal root and a ruptured metal fragment in the middle third of the mesial root; *C)*. Frontal, tomographic sections show apical hypodensity in both roots; *D)*. After removing the threaded post, the radiographic image evidenced the walls' fragility; *E)*. Removal of the ruptured metal fragment in the middle third of the mesial root; *F)*. Odontometry radiography; *G, H)* Photograph of the distal and mesial orifices canals sealing with intraradicular BiodentineTM; *I)*. Periapical radiography after final obturation; *J)* Placement of a 5.0 mm piece of RT; *K)* Periapical radiographic showing the RT settled in the walls of the 46-element pulpal chamber; *L)* A periapical radiographic examination 24 months after treatment shows apical repair

prefabricated root posts continue to be widely used in ETT [2-4]. The approach of placing a post in the root has been shown to increase the tendency to fracture structurally compromised teeth [6]. However, recent studies have reported that the placement of intraradicular post is strongly associated with decreased survival in CT with root canal treatment [1, 10]. Corroborating with this approach, Wierichs *et al.* reported that for composite build-ups in ETT without post placement, high success rates were observed after up to 10 years [13]. In contrast, a systematic review and meta-analysis reported a success rate of up to 90% after 6 years for single crowns, regardless of the material used and the placement of the post [14].

Nevertheless, the choice of restorative materials significantly impacts the strength of ETT, as their mechanical properties and interactions with the remaining tooth structure can vary widely [16, 34, 35]. While conventional composite resins are widely used, they have notable limitations, including volumetric shrinkage during polymerization, which can induce stress and potentially lead to fractures in the tooth structure [17, 36]. To mitigate these issues, alternative materials such as bulk-fill composite resins have been recommended. These materials are specifically designed to enhance polymerization depth and mechanical strength, making them more suitable for larger posterior cavities [37, 38].

Additionally, the use of modern materials that employ acids to demineralize the surface, followed by the application of low molecular weight hydrophobic primers, is emerging as a practical and economically viable option for restoring ETT that require extensive restorations [16, 34]. This approach facilitates the formation of a micromechanical bond between the resin and dentin. The reinforcement of large cavities in endodontically treated posterior teeth with polyethylene fibers and bondable reinforcement materials such as short fiber-reinforced composite resin increases mechanical strength and rigidity by distributing stress to the tissues under load [25, 38-43].

The study by Eapen *et al.* [44] highlights the benefits of utilizing a two-layer restoration approach to mimic the natural behavior of enamel and dentin. This methodology provides enhanced reinforcement in ETT, resulting in a composite more resistant to high stresses. The authors recommend employing this association as a direct core building material in areas under high stress, thereby replacing invasive techniques [25, 39, 40].

In the present study, multilayers with Biodentine, RT and resin were used to seal the endodontic access cavity. These cases call attention to the internal reinforcement of endodontically treated CT and the strengthening of weakened walls by creating a resin core build-up reinforced with fibers without the need for an intraradicular post. We suggest that this reinforced core build-up internally protects CT against crack progression while promoting effective sealing between the root canal system and oral fluids [20, 27, 32]. Furthermore, cracks tend to expand in CT that are maintained between sessions with non-adhesive temporary sealing materials [1].

In a systematic review of 18 studies, the authors concluded that using FRC in ETT can increase fracture resistance compared with traditional hybrid composites. However, they point out that more well-designed randomized clinical trials are necessary to test the clinical performance of FRC compared to other restorations in ETT [25]. The mechanical advantages of FRC are flexural strength, fatigue strength, high modulus of elasticity, and bond strength [42, 43].

Among the suggested materials, composites reinforced with high molecular weight braided polyethylene fibers have gained prominence in the scientific environment, with good in vitro results [42-44]. In this sense, RT acts as a stress releasing, preventing crack propagation and improving the resistance of restored teeth, eventually leading to more favorable fracture patterns [43-48]. In a case report involving a structurally compromised molar tooth with root canal treatment, Soares *et al.* [27] reported that using FRC would be an economical and practical alternative for conserving the maximum amount of sound dentin and peripheral enamel, which is essential for maintaining marginal stability.

In the present study, the teeth were structurally compromised and had significant cracks. The use of RT served as an intracoronal reinforcement, being inserted in the horizontal and vertical positions to modify the occlusal stresses developed along the cracks and the walls of the cavity, respectively, minimizing failures through a mechanism of stress distribution and energy absorption [26, 43, 44]. Additionally, the teeth were immediately restored with a protective adhesive-bonded restoration [1, 11, 49]. Ni *et al.* [50] reinforced the need for cusp coverage in CT by investigating the biomechanical properties of fracture resistance in them using full coverage restorations made with different materials through extended finite element analysis. The authors confirmed that full-coverage di-silicate ceramic restorations significantly increased the fracture resistance of CT. In addition, the elimination of cracks can improve the fracture resistance of CT.

The strength of the present study was the use of modern technologies that facilitated all stages of treatment, from the identification of cracks, their extension, and their sealing. Additionally, all treatments were performed by the same senior professional with extensive experience in CT treatment [1, 11]. Since this is a new protocol, patients received extra guidance on the importance of clinical follow-up, obtaining radiographs, and, if possible, tomography images.

One of the main limitations of this study is the small sample size and, in a way, the follow-up time where the teeth were only followed for two years. Therefore, further studies with large sample sizes and longer preservation time are recommended. However, preliminary studies are essential to propose new treatment approaches and create hypotheses that can be tested in other more robust studies. In addition, it is crucial for dental professionals to assess each case individually and consider specific contraindications, such as allergic reactions, insufficient tooth structure, active caries, periodontal disease, and incompatibility with other materials.

Conclusion

This study underscores the significance of internal reinforcement in ETT, introducing RT as a viable approach for the conservative restoration of cracked or structurally compromised teeth. The treatment process involves several key steps: tooth preparation, core build-up with composite resin, endodontic treatment or retreatment, and if necessary, application of RT, bonding of a protective restoration, and ongoing follow-up to assess long-term effectiveness. Incorporating RT into this structured approach can improve fracture resistance and extend the durability of ETT.

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Conflict of interest

None.

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Authors' contributions

Conceptualization: KST/FFS, Methodology: KS T/FFS/FD/GB, Formal Analysis and Investigation: KST/FFS, Writing-Original draft preparation: KS T/FFS/FD/GB, Writing-review and editing: KST/FFS/FD/GB/AJLM/MGO, Supervision: KST/FFS. All authors read and approved the final manuscript.

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