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Review

Restoration of Endodontically Treated Teeth: A Review of Direct Restorative Approach

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Abstract: Many studies have been conducted on the restorative treatment of endodontically treated teeth, but there is still no consensus. At the same time, restorations of endodontically treated teeth can be very challenging. This article focuses on the characterization of endodontically treated teeth, their pre-restorative assessments and approaches for making more successful restorations with current novel direct restorative materials.

Keywords: *Endodontically treated teeth; restorative treatment; resin composites; cuspal coverage; tooth fracture; adhesive dentistry*

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1. Introduction

Microbial contamination of the root canal system and periapical tissues is the most common reason of the failure in endodontics (Saunders and Saunders, 1994; Torabinejad et al., 1990). Therefore, the root canal system should be sealed both apically and laterally appropriate root filling material in order to prevent microorganisms from reaching the root canal system. Leakage of microorganisms and tissue fluids into the root canal system can occur both apically and coronally. According to the hollow-tube theory (Rickert and Dixon, 1931), it is reported that the toxins formed as a result of the stagnation of tissue fluids at the root ends and the degradation of these fluids maintain the periapical lesion (Wu and Wesselink, 1993). Therefore, many researchers have dipped tooth roots into dyes and scored leakage from the apical to the coronal to detect apical leakage. On the other hand, some studies have reported that sterile tissue fluids cannot cause long-term inflammation, but the inflammation is associated with bacteria and their metabolic byproducts (Makkes et al., 1977; Sundqvist, 1976; Torneck, 1966). It was first reported in 1961 by Marshall and Messler that bacteria and nutrients can also reach the root canal system by coronal leakage (Marshall and Messler, 1961). In 1990, Torabinejad et al. observed bacterial products in the apex of endodontically treated teeth (ETT) without a coronal restoration after 3 months of *in vitro* storage (Torabinejad et al., 1990). Later, Ray and Trope (Later et al.,1995) conducted a very important study about the role of coronal restoration in the success of ETT. According to this retrospective study, prognosis of ETT was strongly related to the success of coronal restoration rather than the root canal treatment. This study suggests that coronal microleakage is more important than thought, contrary to common belief in endodontics.

Nowadays, it is widely accepted that the prognosis of ETT depends not only on the success of root canal treatment, but also on the success of coronal restoration. In clinical practice, the restoration of ETT is a treatment requiring complicated restorative planning. These treatments can be performed by using indirect restorative techniques or by direct restorative techniques. No matter which technique is chosen, it is known that ETT are weak and more prone to the fracture than vital teeth due to changing in the mechanical properties of dentin (Soares et al., 2007), changing in moisture content (Papa et al., 1994), and reduced levels of proprioception (Randow and Glantz, 1986). However, there are also studies advocating that ETT are not different from vital teeth in terms of fracture strength (Carvalho et al., 2018; Faria et al., 2011; Lewinstein and Grajower, 1981).

Vital teeth are generally fractured as a result of traumas caused by external impacts such as sports, falls, traffic accidents and violence (Goyal et al., 2017). However, ETT can also be fractured under the influence of occlusal function (masticatory forces). Studies have shown that ETT are more susceptible to fraction than vital teeth (González-López et al., 2006; Oskoee et al., 2009). The main reason for the increase in brittleness is the reduced coronal and radicular tissue during the caries removal (Reeh et al., 1989), previous restorations (Lin et al., 2001), intra-radicular procedures (Rao et al., 2013), preparation of the endodontic access cavity (Pantvisai and Messer, 1995; Reeh et al., 1989), and restorative procedures requiring extensive tissue removal (Mondelli et al., 1998; Pantvisai and Messer, 1995). Furthermore, an occlusal cavity preparation has been reported to adversely affect the fracture strength of the tooth between 14 to 44%, while the mesio-occluso-distal (MOD) cavity preparation decrease the fracture strength of 20 to 63% (Larson et al., 1981). The removal of marginal ridges, especially in the occlusal region during preparation, adversely affects the fracture resistance of ETT (González-López et al., 2006). In addition to this, dehydration of the remaining dentin tissue after endodontic treatment and the loss of collagen cross-links have been reported to adversely affect the fracture resistance (Oskoee et al., 2009). Therefore, it is beneficial to avoid unnecessary endodontic procedures and coronal tissue removal that violate the biomechanical balance and compromise the long-term performance of ETT (Magne and Belser, 2002).

2. Functional requirements

Studies have reported that especially teeth with narrow root structure are more prone to fracture as a result of masticatory forces (Chan et al., 1999; Tamse et al., 1998). In particular, maxillary premolar teeth are therefore more frequently fractured (Tamse et al., 1998). Chen et al. found that canine teeth are the most resistant to fractures and reported that incisors tend to fracture only after endodontic treatment (Chen et al.,1999). The force was faced by the anterior and posterior teeth is different from each other. The anterior teeth are mainly exposed to shear and laterally forces, while the posterior teeth are exposed to vertical forces. This difference also affects treatment planning depending on the function. In addition, it was determined that mandibular first molar teeth exhibited two times more fractures compared to mandibular second molar, maxillary first molar, maxillary second molar, and maxillary second premolar teeth (Chan et al., 1999).

Successful prognosis of ETT correlates with the preservation of dental tissues. Studies have shown that the longevity of the tooth will be prolonged with the conservation of healthier dental tissues (Nagasiri and Chitmongkolsuk, 2005). Costa et al. was supported this idea through their work (Costa et al., 1997). It was found that as the cavity width increased in premolar teeth prepared with MOD cavity, the fracture resistance of the tooth decreased. They also found that the fracture resistance improved significantly when the restorations were completed as onlay, including cusp of the teeth to the preparation (cuspal coverage). In a different *in vitro* study, maxillary premolars presenting only endodontic access cavity preparation were exhibited significantly greater fracture resistance compared to the MOD cavity prepared ones (Steele and Johnson, 1999).

2.1. *Treatment Planning*

Considering the increase in cuspal deflection during function after loss of dental material due to caries removal and endodontic access cavity preparation, and thus becoming more vulnerable to fractures, the question of how these teeth would be better restored may be raised. Although extensive research has been done on the restoration of such teeth, there is still no consensus. In a study about the difficulty in the treatment planning of ETT, different responses were obtained when four different specialists were asked about the treatment planning of the fracture lateral incisor (Türp et al., 2007). It is crucial in treatment planning to answer different questions, such as whether to restore the tooth by direct or indirect technique, whether to use a post or which material is preferred. Therefore, the amount of remaining dental hard tissues and the functional requirements of the tooth should be well evaluated.

2.2. *Preservation of the Coronal Tissues*

The replacement of defective restorations results in larger restorations. This phenomenon was also described by Elderton as the restoration cycle of death (Elderton, 1988). Replaced restorations may then fail again and result in loss of the tooth by performing even larger restorations or post-core restorations. Moreover, Dietschi et al. reported that cavity depth and isthmus width are major factors in determining the stiffness and fracture risk of ETT (Dietschi et al., 2007). With minimal intervention dentistry concept, preservation of dental tissues is gaining importance in the restoration of ETT (Magne et al., 2016, 2017; Yuan et al., 2016).

These treatments can be done with or without intra-canal post systems and cuspal coverage procedures. After final restoration, tooth fractures may occur due to dentinal tissue loss. For this reason, it is recommended to perform intra-coronal reinforcement to prevent tooth fractures (Ayna et al., 2010; Belli et al., 2015).

2.3. *Cuspal Coverage*

After endodontic treatment, restorations with cuspal coverage is a method used to increase the fracture resistance of teeth by reducing the stress formation. The cuspal coverage is simply the removal of the cusp tips of the tooth after the endodontic treatment to include them within the restoration limits. This procedure can be applied only to functional cusps as well as to all of them (ElAyouti et al., 2011). Many studies have evaluated the effect of cuspal coverage on fracture resistance after endodontic treatment (Bitter et al., 2010; Jiang et al., 2010; Mondelli et al., 2009; Shafiei et al., 2011).

In a previous study, the effects of cuspal coverage on fracture resistance of premolar teeth were investigated. The researchers were reported that 2 mm of reduction in cusps was significantly increased fracture resistance compared to the standard MOD cavity preparation (Mondelli et al., 2009). In a more recently published study, investigators were found that teeth with 2.5 mm of cusp reduction were significantly exhibited higher fracture resistance, and remaining dentinal wall thickness had no role in this improvement (Mishra et al., 2017).

Several studies argued that cuspal coverage along with composite resins enhances the prognosis and minimizes fracture risk (Mondelli et al., 2009; Soares et al., 2008; Torabzadeh et al., 2013; Xie et al., 2012). In normal occlusion, however, some studies reported that cuspal coverage along with the proper adhesive material (Krejci et al., 2003; Mohammadi et al., 2009; Scotti et al., 2011) or if a fiber post is employed (Mohammadi et al., 2009) is unnecessary.

Many studies in the literature have reported that cuspal coverage results in better survival rates (Abu-Awwad, 2019; Aquilino and Caplan, 2002; Sorensen and Martinoff, 1984). However, these studies generally did not consider the amount of dental substance loss. ETT with a MOD cavity and ETT with an occlusal cavity would not have the same risk of fracture (Reeh et al., 1989). Therefore, applying cuspal coverage to ETT in both cases would not comply to the minimally invasive treatment concept. Therefore, overtreatment should be avoided when treating ETTs (Larson et al., 1981; Mannocci et al., 2002; Mondelli et al., 1980).

2.4. *Post Systems*

The posts are the materials used for the formation of the new coronal structure in excessive crown damage with the support of the root canal system after endodontic treatment. Nowadays, the posts are chosen to strengthen the coronal structure in direct restoration after endodontic treatment (Bitter et al., 2010; Mohammadi et al., 2009; Scotti et al., 2011). In the studies evaluating the posts for strengthening the coronal structure after endodontic treatment generally combines cuspal coverage procedure (Mohammadi et al., 2009; Scotti et al., 2011).

Studies have shown that extensively damaged teeth treated using posts are fractured in a way that can be re-treated compared to the treatments without using posts (Mohammadi et al., 2009; Scotti et al., 2011). Fractures are usually more dramatic and result in loss of teeth when the posts are not in use. In a study, no significant difference was observed between post application, cuspal coverage and the combination of these two. In addition, compared to the control group (standard MOD cavity preparation), all three methods significantly increased the fracture resistance (Mohammadi et al., 2009). In another *in vitro* study, which is investigating the influence of the post length, it was reported that the post lengths did not affect the fracture type of the restored teeth, but a significant increase in fracture strength was observed for the use of both post lengths (Scotti et al., 2011).

Generally, posterior ETTs do not require post placement for retention of core build-up restorations in the presence of sufficient intact tissue (Suksaphar et al., 2017). Cagidiaco et al. (2007) and Mannocci et al. (2002) reported 100% survival rate against fracture with the fiber post placement. Dammascke et al. (2013) stated that the fracture rate in direct composite restorations lowers with the post placement. Scotti et al. (2015) also reported that the fiber post application significantly improved the clinical outcome. There are also laboratory studies supporting these findings (Nam et al., 2010). From these findings, post placement in posterior ETTs with excessive substance loss may be beneficial.

2.5. *Fiber Splints*

Fibers are light permeable, aesthetic and easy to apply materials that generally made of polyethylene fiber and glass fiber. Since they are biocompatible, they can be used safely. Fibers are used for splinting of teeth in periodontal and orthodontic treatments, strengthening of direct composite restorations, adhesive bridges in the absence of a single tooth, reinforcing the bases of removable prostheses (Belli et al., 2006; Vallittu, 2018).

After the endodontic treatment, fibers can be used in the restoration of the teeth with composite resin to strengthen the coronal structure. In direct composite restorations, the fiber splint is placed inside the restoration or the cusps are splinted together by the fiber strip (Akman et al., 2011; Manzoor et al., 2018; Oskoee et al., 2009; Tayab and Shetty, 2015; Vallittu, 2018).

2.6. *Restorative Material Choice*

Fractured posterior tooth is a most common clinical problem in restorative dentistry. Fracture resistance of restored teeth depends on the type of restorative material used, the anatomy of the tooth, the position of the tooth in the occlusion, the size of the cavity preparation and the width of the isthmus (Trope et al., 1985). Therefore, if there is no dentine support underneath the cusp, onlay restorations should be preferred. Cuspal coverage of the working cusp should be considered to distribute occlusal forces and to improve bond strength (Christensen, 2012). Dental fracture in restored posterior teeth represents a common clinical problem (Omer et al., 2019). The cusp height should be reduced by cuspal coverage to eliminate higher stress over teeth. However, direct restorations with cuspal coverage enhances fracture resistance against compressive forces (Lin et al., 2008).

2.7. *Direct Restorative Materials*

A recent finite element analysis (FEA) study reported that working cusp reduction enhances the biomechanical properties of dental restoration complex, consequently providing better prognosis (Kantardžić et al., 2012). In an *in vitro* study, researchers did not find a significant difference between direct or indirect approaches when restoring ETT with composite resin (Plotino et al., 2008). In a different study, researchers were suggested that the prognosis of direct restoration depends on the material choice (Torabzadeh et al., 2013). Further, in a more recent *in vitro* study, researchers were concluded that cuspal coverage with an amalgam and composite resin combination exhibited no difference (Shafiei et al., 2011). Restorative materials chosen for the restoration of ETT requires adequate retention and strength to maintain and protect the remaining dental structures against occlusal forces. Different types of direct restorative materials can be selected as final restoration in which include amalgam, glass-ionomer cement, or composite resin to maintain teeth and restore the function.

Amalgam was preferred due to its resistance to masticatory forces in the posterior region. However, amalgam cannot bond to dental tissues and requires additional cavity preparations that weaken dental tissues to provide mechanical retention (Varga et al., 1986). On the other hand, adhesive restorative materials have aesthetic properties and adequately bond to dental hard tissues without excessive cavity preparation (Assif et al., 1993; Baraban, 1972; Cho et al., 1999).

When endodontic success is mentioned, different results are seen in studies comparing amalgam and composite restorations (Shu et al., 2018). The contradictory findings of the studies conducted in different years can be explained by the developments in composite materials and application techniques (Göhring and Peters, 2003). According to a systematic review, the composites still have a lower longevity and a higher risk of secondary caries than amalgams (Moraschini et al., 2015). Considering that the condition in periapical tissues is related to the success of coronal restoration (Göhring and Peters, 2003), improvements in restorative materials will increase the success of endodontic treatment.

Composites and adhesive systems are widely used because of their aesthetic properties, their ability to bond to enamel and dentin, and theoretically increasing the integrity of the dental restoration complex (Ergücü and Türkün, 2007; Schirrmeister et al., 2009). Many studies have compared different restorative materials and their use (Monga et al., 2009; Soares et al., 2008). In an *in vitro* study, it was reported that composite resin restorations applied to MOD cavities prepared for maxillary premolar had no more reinforcing effect than MOD amalgam restorations performed without adhesive application (Stampalia et al., 1986).

Composite resins have been modified many times in order to eliminate the clinically felt deficiencies since the 1960s. Previously, modifications were made on the filler particles of the material to obtain materials with better mechanical properties that possess high fracture resistance and better polishability (Sakaguchi and Powers, 2012). Later on, it was aimed to reduce the polymerization shrinkage, which is seen as the cause of post-operative sensitivity, microleakage and cuspal deflection (Dayangac, 2011). Today, many new restorative materials are made available to dentists in parallel with the development of adhesive technology. As a result of the above-mentioned goals, fiber-reinforced composites, silorane-based composites and bulk-fill composites are in use by dentists.

Resin composite restorations can increase the durability of the remaining dental tissues of ETTs based on the adhesive concept realized by the adhesion of dental hard tissues and restorative material (Dietschi et al., 2011; Mincik et al., 2016). In an *in vitro* study, the fracture strength of ETT, which was restored with resin composite, was found to be similar to that of the intact tooth (Ausiello et al., 1997). According to some retrospective studies, ETTs restored with resin composite showed a higher survival outcome than amalgam-restored ETTs (Hansen, 1988; Mannocci et al., 2005; Nagasiri and Chitmongkolsuk, 2005). However, long-term degradation of the hybrid layer is still a concern (Hashimoto et al., 2003). This degradation adversely affects the fracture strength of ETTs restored with resin composite in the long-term (Opdam et al., 2014).

2.8. *Fiber-Reinforced Composites*

Based on the idea that a restorative material capable of dissipating or absorbing stress in high stress areas (e.g. posterior region) will protect the tooth tissues (Fráter et al., 2014), various improvements have been made to the inorganic phases of the resin composite materials. As a result of these improvements, seromers obtained by adding ceramic and fiber-reinforced composites obtained by adding fiber were found (Garoushi et al., 2007; Zandinejad et al., 2006).

In simple terms, a composite structure consisting of fibers held together by a resin matrix is called fiber-reinforced composites. All fiber materials are filamentous materials that can be silanized by OH^- ions on their surfaces, thus good adhesion can be achieved with the resin matrix as a result of this silanization. They were first developed in the 1960s to strengthen the methacrylate base of removable protheses. It was found that the material improved on flexural strength, fatigue resistance, elastic modulus and bond strength by adding fibers to the restorative material structure (Zhang and Matinlinna, 2012). Furthermore, it has been reported that the presence of fiber in the composite structure stops the progression of the crack during fracture process (Braga and Ferracane, 2004; van Dijken and Sunnegårdh-Grönberg, 2006; van Heumen et al., 2009; Manhart et al., 2004). Moreover, fiber reinforcement between the restorative material and dentin changes the fracture line, causes repairable fractures, saving the remaining dental tissues (Belli et al., 2005; Belli et al., 2006), and improves the restorability of ETT after failure (Shafiei et al., 2014).

It is thought that the use of a material more similar to dentine tissue to restore missing dental tissues biomimetically would prevent the progression of cracks due to the forces encountered during the function. As a result of this idea, the most recent composite material is everX Posterior (GC Corporation, Tokyo, Japan). This material is a condensable fiber-reinforced composite material produced to mimic the stress absorbing property of dentin and dentinoenamel junction. In addition, this material is designed as a single layer substrate material consisting 7.2% of short fibers by volume and requires the application of a conventional composite resin on top layer (Garoushi et al., 2008; Garoushi et al., 2015).

In an *in vitro* study, direct onlay restorations with conventional composite and fiber-reinforced composites were compared. As a result, the fracture resistance of the fiber-reinforced composites was found to be higher and when applied in combination with the conventional composite, it increased the fracture resistance of the traditional composite (Garoushi et al., 2008). Nevertheless, cuspal coverage with direct composite restorations appears to be a safe in extensive substance loss (Mondelli et al., 2009; Plotino et al., 2008)

2.9. *Silorane-Based Composites*

A monomer called silorane has been developed to reduce polymerization shrinkage in composite resins. Silorane takes its name from the siloxane and oxirane functional groups. While siloxane imparts a high hydrophobic property to the structure, cycloaliphatic oxirane, a cyclic ether, improves the durability of the material by exhibiting ring polymerization and reducing polymerization shrinkage (Sakaguchi and Powers, 2012). The water absorption and related discoloration of the material are low due to the hydrophobic properties of siloxane (Zimmerli et al., 2010).

Silorane composites exhibit low polymerization shrinkage and high strength compared to methacrylate composite resins (Eick et al., 2002). Nowadays, these materials are not widely used for reasons such as their application with a special adhesive system and their limited indication for only posterior teeth due to low color choices. There are many studies in the literature on silorane-based composites. A systematic review of these studies concluded that silorane-based composite resins did not show a significant superiority compared to methacrylate-based composite resins and should have long-term clinical follow-up (Maghaireh et al., 2017). Moreover, silorane-based composite resins showed similar clinical performance as conventional composites (Magno et al., 2016). Although Lien and Vandewalle (Lien and Vandewalle, 2010) reported the compressive strength and the microhardness of the restorative materials to be low, silorane-based composites markedly increase the fracture resistance of ETT (Shafiei et al., 2014) and decrease cusp fracture in MOD cavities (Palin et al., 2005). Fiber reinforcement had no effect on the fracture resistance of the restoration, whereas the use of a nano-ionomer core under the silorane-based restoration exhibited an improvement in terms of fracture resistance (Shafiei et al., 2014).

2.10. *Bulk-Fill Composites*

One of the recent developments in composite resins is the production and launch of bulk-fill composites to the dental market. Conventional composite resins are introduced into the cavity by the incremental technique, thereby allowing the light used in the polymerization to better penetrate into the material and reduce the polymerization shrinkage stress (El-Safty et al., 2012). The incremental technique has disadvantages such as the presence of air bubbles between the composite layers, inadequate bonding of the two layers, and long operating time (Garapati et al., 2014).

The major advantage of bulk-fill composite resins is that they can be placed in a single increment (bulk) of 4 to 6 mm thickness and exhibit low polymerization shrinkage (El-Damanhoury and Platt, 2014; Monterubbianesi et al., 2016). Other advantages include shorter application time, ease of application, good adaptation of the composite to the cavity, adequate wear resistance to masticatory forces, adequate radiopacity, good polishing and aesthetic properties (El-Damanhoury and Platt, 2014; Monterubbianesi et al. 2016). In another study, in cavities lined with SDR (Dentsply Caulk, Mildford, DE, USA), cuspal deflection is reduced markedly (Moorthy et al., 2012). SDR results in reduced polymerization shrinkage in comparison to Filtek Supreme Flow (3M, St. Paul, MN), Esthet X Flow (Dentsply Caulk, Mildford, DE, USA), nano-hybrid, microhybrid, and silorane-based composites (Ilie and Hickel, 2011).

3. Clinical Considerations

The treatment of ETTs without diffuse destruction is usually performed with direct composites (Baratieri et al., 2000). Some authors suggest that cuspal coverage, direct and indirect restorations show similar clinical outcome, and therefore direct restorations should be preferred because their cost and time efficiency (Angeletaki et al., 2016; da Veiga et al., 2016; Fennis et al., 2014). On the other hand, the skill level and accuracy of the clinician is of great importance in the application of direct restorations and affects the outcome of restorative treatment (Laske et al., 2016). For example, there are some risks in the direct restorative techniques, such as polymerization shrinkage, technical sensitivity, incompatible proximal contact, micro leakage and secondary caries formation (Alshiddi and Aljinbaz, 2016; Bianchi et al., 2013).

The first factor that should be evaluated in the conservative treatment of ETTs is the present state of the teeth. According to the recently published study, by evaluating the loss of substance, we can simply divide the ETTs into three categories: minimally destructed, moderately destructed, and severely destructed (Abu-Awwad, 2019).

Minimally destructed ETTs are teeth with only endodontic access cavity or where only one of the marginal ridges is missing (MO or DO cavities) with the support of axial walls of sufficient thickness (≥2 mm). There is no need for cuspal coverage in the conservative treatment of ETTs in this category. Nagasiri and Chitmongkolsuk (2005), reported that minimally destructed ETTs had a survival rate of 78% after 5 years of follow-up in their retrospective clinical study. Mannocci et al. (2002) also reported that the premolars with minimally destruction had a high survival rate in 3-year clinical follow-up. Similar supportive findings have been reported in both clinical (2013) and laboratory (Reeh et al., 1989; Steele and Johnson, 1999) studies. Unlike the minimally destructed ETTs, the ETTs are defined as moderately destructed if they do not have axial walls of sufficient thickness (<2 mm) or have lost both of its marginal ridges (MOD cavity). Cuspal coverage results in successful clinical outcomes for this category (Pantvisai and Messer, 1995; Reagan et al., 1989; Reeh et al., 1989; Scotti et al., 2011, 2013; Sorensen and Martinoff, 1984; Steele and Johnson, 1999). Severely destructed ETTs are cases where there is more substance loss than the MOD cavity. These ETTs would benefit from the cuspal coverage procedure; besides intraradicular retention should be considered (Afrashtehfar et al., 2017).

On the other hand, failure of restorative treatment may be influenced by localization of ETT in occlusion. In a long-term clinical study, mandibular premolar and anterior teeth both in maxillary and mandibulary have been reported to have longer survival outcomes (Cheung and Chan, 2003). In the same study, it was reported that molar teeth had lower survival rates. In another study on direct restorations, it was reported that molar teeth (5.2%) have a higher annual failure rate than premolar (4.0%) and anterior teeth (4.4%) (Laske et al., 2016).

Another controversial issue on the treatment of ETT is the use of posts. *In vitro* studies have shown that the use of fiber post improves the fracture strength of ETT (Abduljawad et al., 2016). Furthermore, in a clinical study, the survival rate of post-treated teeth (94.3%) was significantly higher than that of unused teeth (76.3%) (Guldener et al., 2017). In spite of this, some authors state that preparing a post space may increase the risk of root fracture (Faria et al., 2011; Göhring and Peters, 2003). In addition, Belleflamme et al. (2017), concluded in their 10-year retrospective study that practitioners should consider the endocrowns instead of the post and core approach to restore severely destructed ETTs. Therefore, it would be appropriate to avoid post use except severely destructed ETT, parafunction or excessive lateral forces.

Conclusion

It has been demonstrated in many scientific studies that ETT are more prone to fracture than vital teeth. This fact should not be ignored in the choice of restorative approach and material. Direct restorative approaches can be applied safely for the teeth that do not show excessive substance loss after endodontic treatment.

It has been shown that the ideal stress distribution is achieved by using materials that can be attached to dental tissues in the direct restorations to be applied after endodontic treatment. In addition, it is reported that the modulus of elasticity of the restorative material to be used should be close to the dental tissues in order to reduce the amount of stress due to masticatory forces for the remaining dental tissues. In the light of this information, it could be concluded that the most ideal restorative material to be applied after endodontic treatment would be composite resins, in particular fiber-reinforced composites.

It is observed that cuspal coverage, post system applications and fiber splint applications increase the fracture resistance of ETT and provide more ideal stress distribution. It has also been reported that fractured tooth tissues can be restored if fiber post systems or fiber-reinforced composites were used. In conclusion, the prognosis of ETT would be increased when the intra-coronal reinforcement done.

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Conflict of Interests

Author declares no conflict of interests.

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