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Review Article

A Modern Guide in the Management of Endodontically Treated Posterior Teeth

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Abstract

Decision-making in the management of posterior endodontically treated teeth (ETT) is still considered a challenge for the clinician. The development of adhesion has led to a paradigm shift in the restorative treatment options. Restorations which depend on mechanical retention are not the only restorations currently available. Adhesive restorations are gaining more popularity due to their conservative nature. This article aimed to provide the clinician with a modern guide for the management of posterior ETT using adhesive restorations. A method of assessment of the remaining tooth structure which places the tooth in one of the three categories was recommended, and adhesive treatment options were suggested for each category. The three categories were minimally destructed teeth, which could be managed simply through intracoronal composite resin restorations; moderately destructed teeth, which could be managed through adhesive overlays; and severely destructed teeth, which could be managed through fiber post–core–crown combination, or through endocrowns.

Keywords: Adhesive dentistry, decision-making, endodontically treated teeth

Introduction

With the vast advances in adhesive dentistry, multiple restorative treatment options are available nowadays to restore endodontically treated teeth (ETT).[1] However, determining whether cuspal coverage is needed or not, followed by selecting a suitable treatment option for each clinical situation, could be challenging for the restorative dentist.[2]

A paradigm shift in dentistry has occurred in the last decades. Conventional methods of restoring teeth, which depend on mechanical retention, are being replaced by modern methods which depend on adhesion.[3] This shift was attributed to the increased popularity of the minimally invasive dentistry philosophy, and the development of reliable adhesive systems, as well as the etchable ceramics.[4] A summary of the available conventional mechanically retained restorations and their modern adhesively retained alternatives is presented in Table 1.

The use of mechanically retained restorations is supported by long-term studies, and these restorations have demonstrated good reliability and predictability as treatment options for restoring ETT.[5,6] However, their use is not without biological cost.[7] On the other hand, the conservative nature of the adhesive restorations offers many advantages over the mechanically retained restorations.

Conservation of tooth structure

Because adhesive restorations do not require extra tooth preparation to achieve resistance and retention form, conservative preparation designs with maximal preservation of tooth structure could be used.[8] The strength and fracture resistance of the tooth has been shown to be positively related to the amount of the tooth structure remaining.[9,10] In addition, a conservative preparation will reduce periodontal problems because the margins are usually supragingival.[11,12]

Controlled mode of failure

The conservative nature of the adhesive restorations may keep the possibility of a re-intervention available once a failure occurs. Moreover, conservative restorations will reduce the risk of irreversible fractures. This will delay the restorative cycle

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Table 1: Summary of conventional and modern restorative methods

Conventional methods (mechanically retained)	Modern methods (adhesively retained)
Amalgam restorations	Composite restorations
Full- and partial-coverage crowns	Adhesive onlays and overlays
Metal post-core-crown	Fiber post-core-crown
Nayyar core-crown	Endocrowns

described by Elderton, and therefore increase the longevity of the tooth.[1,13]

Reduction in time and cost of treatment

The fabrication of a conventional crown may involve many clinical and technical steps, such as crown-lengthening procedure, post cementation, core fabrication, and temporization, which would increase the time and cost of treatment.[14] Many of these steps could be avoided through the use of adhesive methods, where the retention of the restoration is dependent on adhesion rather than mechanical retention.[15]

The survival and success of ETT is significantly influenced by the choice of appropriate restorations. Many studies have reported full cuspal coverage to be the treatment of choice for posterior ETT.[5,6] The rationale behind providing full-coverage crowns is the protection of ETT from potential future cracks and fractures. This is due to the reduced structural integrity and stiffness associated with the loss of tooth structure in ETT.[16] However, recently, few studies in the literature have reported good longevity for posterior ETT when restored with direct intracoronal restorations without the provision of cuspal coverage, specifically for teeth with limited amounts of structural loss.[17,18] Therefore, using a full-coverage crown where it could have been avoided might be considered an unnecessary removal of valuable tooth structure which could have been otherwise preserved.[19]

A recent systematic review has found insufficient evidence to compare full cuspal-coverage restorations to direct restorations when used for restoring ETT and suggested that the clinicians should make their clinical decisions based on their own clinical experience.[20] In order to assist the clinicians in the decision-making process, decision flowcharts based on prosthodontic principles for restoring ETT were suggested previously.[21] Although such flowcharts were considered helpful by many clinicians, they do not fulfill the modern requirements of conservative adhesive dentistry and do not include the adhesive restorative options currently available.[1] More recently, an online tool has been developed to facilitate access to summaries of the available evidence to help dentists in decision-making regarding the need for cuspal coverage or intracoronal restorations.[22] However, this tool still did not incorporate a guide to aid in choosing between mechanically retained and adhesive restorations.

Therefore, the aim of the current article was to provide the restorative dentist with a simple evidence-based modern guide for the decision-making process in the management of posterior ETT. The guide offers a method of assessment and categorization of the remaining posterior tooth structure and suggests adhesive restorative treatment options for each category.

Restorative Decision-making Protocol

The protocol starts with an assessment of the amounts of tooth structure loss and an assessment of any modifying factors which lead to unfavorable occlusal loading. This is followed by choosing a suitable conservative treatment option for each clinical situation.

Step 1: Assessment of the amount of tooth structure loss and any modifying factors

The assessment should be done after removal of any caries or old restorations and after finishing an endodontic access cavity when needed. This is an essential step because the type of definitive restoration chosen to restore the tooth will be influenced by the amount of tooth structure remaining after tooth preparation.[23] Understanding which part of the tooth structure is most important in keeping its fracture resistance and stiffness is fundamental for an accurate assessment of the strength of the remaining tooth structure.[1,24]

The marginal ridges

The marginal ridge has been shown to be critical in the maintenance of tooth stiffness and limiting excessive cuspal deflection.[16,25,26] It was found that the loss of tooth stiffness was 20% for an occlusal cavity, compared to 45% for a mesio-occlusal (MO)/disto-occlusal (DO) cavity and 63% for a MO-distal (MOD) cavity.[16] In another investigation to evaluate the effect of different thicknesses of the marginal ridge on fracture strength of endodontically treated maxillary premolars with DO cavities restored with intracoronal composite resin restorations, it was reported that a marginal ridge thickness of >1 mm preserved the fracture resistance of the teeth. Whereas, a 0.5-mm marginal ridge thickness led to a significant reduction in the tooth fracture resistance compared to the level of intact teeth.[27] The removal of both marginal ridges in MOD cavity preparation produced a dramatic increase in cuspal deflection compared to MO/DO cavity preparation.[25,28]

The buccal and palatal/lingual axial walls

The wider the cavity preparation, the thinner the remaining axial walls' thickness. The remaining wall thickness was reported to be an important factor in the resistance to fracture under occlusal load.[29] An axial wall thickness of <2 mm was noted to reduce the tooth resistance to fracture in endodontically treated premolars, and it was suggested that cuspal coverage would be needed to improve the fracture resistance.[30]

The endodontic access cavity

A reduction of only 5% of tooth stiffness was measured by Reeh *et al*. when a conservative endodontic access cavity was carried out before or after any restorative preparations, whereas a wider occlusal cavity was associated with 20% reduction in tooth stiffness.[16] An endodontic access cavity and an occlusal cavity surely will involve removal of the same tooth structure. However, the difference in reduction of the tooth stiffness was reported to be fourfold for an occlusal cavity compared to an endodontic access cavity. This significant difference was attributed to the possibility of greater encroachment of an occlusal cavity preparation on the marginal ridge area compared to an endodontic access cavity.[16] Similar results were reported in another study, which found that the fracture resistance of teeth with conservative access cavities alone was close to that of an intact tooth.[31] However, another study reported an increase of 2–3 folds of cuspal deflection when an endodontic access cavity was carried out for MO/DO and MOD cavities. This increase in cuspal deflection in the ETT was attributed to the increased depth associated with an access cavity preparation.[28] The contrasting findings between these studies could be attributed to the difference in the amount of tooth structure removed during the access cavity preparation. Studies which were based on conservative endodontic access cavities prepared within the confines of the occlusal cavity floor, with dentine remaining between the access opening and both proximal boxes, showed reduced loss of stiffness.[16,31] Whereas, studies in which the endodontic access included removal of the dentin between the pulp chamber and the proximal boxes showed increased loss of stiffness.[28]

As previously mentioned, many studies in the literature reported higher risk of fracture for ETT and better survival rates with cuspal coverage.[5,6,32,33] However, these studies did not take into account the amount of remaining tooth structure prior to providing cuspal coverage. ETT with a MOD cavity will have higher risk of fracture than ETT with just an occlusal cavity.[16] Therefore, managing both with cuspal coverage could be considered an overtreatment and an unnecessary removal of tooth structure. Because the strength and fracture resistance of the tooth has been shown to be positively correlated with the amount of tooth structure remaining, more conservative treatment options should be selected for ETT.[9,10,18]

A simple classification, which was recently suggested, could be followed to give an initial assessment of the tooth condition. The classification sets the posterior teeth into one of the three categories depending on the amount of tooth structure lost. The three categories were referred to as minimally destructed teeth, moderately destructed teeth, and severely destructed teeth.[34]

Minimally destructed ETT were defined as teeth with an occlusal cavity or a MO/DO cavity with thick remaining axial walls (≥2 mm). This category of teeth does not necessarily require cuspal coverage to have good longevity. A few clinical studies supported this decision. In one retrospective clinical study, endodontically treated molars with occlusal cavities restored with intracoronal restorations were reported to have 78% survival rate over 5 years.[17] Good survival rates for endodontically treated premolars with minimal MO/DO cavities were reported over 3 years without the need for cuspal coverage.[18] Other studies reported similar findings for ETT with three axial surfaces when restored adhesively with composite resin restorations.[35] These clinical findings were also supported by *in vitro* studies.[16,31]

Moderately destructed ETT were defined as teeth with a MO/DO cavity with thin remaining axial walls (<2 mm) or a MOD cavity. The teeth in this category have reduced fracture resistance due to the amount of tooth structure lost and would probably benefit from cuspal coverage. This clinical decision was supported by multiple studies in the literature.[5,16,28-31]

Severely destructed ETT were defined as teeth with tooth structure loss beyond a MOD cavity. The teeth in this category would have suffered from large amount of tooth structure loss and would definitely benefit from cuspal coverage. Cuspal coverage in these clinical cases would also facilitate the reestablishment of the lost occlusal anatomy.[34]

Following choosing the best matching category for the posterior tooth in question, an account for key modifying factors, which lead to unfavorable occlusal forces, should be made. The first modifying factor is parafunctional habits which subject the tooth to increased occlusal forces, such as bruxism. People who grind their teeth can subject their teeth and restorations to significant amount of destructive occlusal forces.[36] Parafunctional habits should be taken into consideration when a decision is made about the need for cuspal coverage and the restorative material which could withstand such forces.

The second modifying factor is lateral occlusal forces. Lateral occlusal forces are more destructive to the tooth than axial occlusal forces.[37] When testing premolars using different loading directions, premolars which were subjected to lateral occlusal loads were at higher risk of fracture than those subjected to axial occlusal loads.[38] This factor could be crucial for the longevity of ETT and their restorations, which should be considered in the decision-making process.[39]

The third modifying factor is the number of proximal contacts for the tooth. Having proximal contacts was reported to favorably dissipate the occlusal load to the adjacent teeth. Therefore, ETT with only one proximal contact or without adjacent proximal contacts are subjected to unfavorable distribution of occlusal forces. This has been shown to impact the survival rates of ETT.[19]

Any of these modifying factors might alter the clinical decision regarding the most appropriate treatment option. A tooth which falls under the minimally destructed category might be considered for cuspal coverage in the presence of any of these modifying factors. Now that an assessment has been made of the amount of tooth structure loss and the key modifying factors, the next step would be to select the most appropriate treatment option.

Step 2: Choosing a conservative treatment option for each clinical situation

Depending on the category selected for the tooth, the most conservative treatment option which provides the tooth with predictable longevity should be selected. In addition, the most esthetic treatment option should also be considered if the tooth falls in the esthetic zone.[1] It is also important to keep in mind that teeth with subgingival cavities due to caries or fractures are usually difficult to restore with adhesive restorations. This is attributed to the difficulty in achieving good isolation to obtain a dry field necessary for the bonding procedure. In these situations, the clinician should opt for a mechanically retained restoration. Otherwise, clinical crown-lengthening procedure might be considered to improve the margin location and facilitate the bonding procedure.

Minimally destructed teeth

As mentioned previously, minimally destructed teeth have sufficient tooth structure to survive without the need for cuspal coverage. Therefore, they can be managed through intracoronal composite resin restorations with good longevity.[17,18] However, in the presence of a modifying factor leading to an increase of the occlusal loads, a clinical decision for the need of cuspal coverage should be considered. An example of a minimally destructed premolar tooth is presented in Figure 1a. Assessment of this endodontically treated mandibular second premolar reveals a DO cavity and axial wall thickness (≥2 mm). There were no lateral forces on the tooth and the patient had no parafunctional habits. This tooth was managed through an intracoronal composite resin restoration [Figure 1b].

Moderately destructed teeth

Moderately destructed ETT would benefit from cuspal coverage. They could be managed through mechanically retained indirect restorations such as partial-coverage or full-coverage crowns.[5,6,34] They could also be managed through adhesively retained restorations such as adhesive onlays or overlays.[1,40]

An onlay is defined as a partial-coverage restoration that restores one or more cusps and adjoining occlusal surfaces or the entire occlusal surface, and is retained by mechanical or adhesive means. Thus, an onlay by its definition can refer to a restoration that covers part of, or the entire, occlusal surface. However, the term onlay is commonly used in the literature and by clinicians to refer to a partial cuspal-coverage restoration, whereas the term overlay is used to refer to a full cuspal-coverage restoration. Other terms are found in literature for the adhesive cuspal coverage restorations, such as additional overlay, occlusal-veneer (overlay-veneer) and long-wrap overlay.[41] However, they are basically referring to adhesive overlays with various preparation designs to accommodate different clinical situations. For example, an occlusal-veneer (overlay-veneer) is an adhesive overlay which covers the occlusal surface and extends to the entire buccal surface for esthetic reasons.

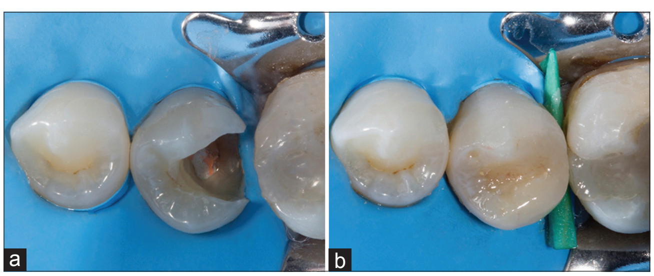

Figure 1: (a and b) An example of the assessment and management of minimally destructed premolar tooth. (a) Clinical assessment of the endodontically treated mandibular second premolar revealed a distoocclusal cavity and axial walls thickness (≥2 mm). This tooth was categorized as minimally destructed tooth. (b) In the absence of any modifying occlusal factors, the minimally destructed mandibular second premolar was restored with an intracoronal composite resin restoration

Adhesive indirect restorations have the advantage of providing cuspal coverage, while preserving the maximum amount of tooth structure.[7] Because different adhesive overlay designs were suggested in literature, the design which conserves the maximum amount of tooth structure, without compromising the predictability or the esthetic outcome of the restoration, should be selected.[1,42,43]

There are different materials available for adhesive overlays, such as gold, composite resin, and ceramic materials. The adhesive gold overlays are minimally invasive indirect restorations, which offer the advantage of being biologically conservative of the tooth tissue.[44] The gold overlays were reported to have 89% survival rate over 5 years.[45] However, patients might object to the metal color, especially if the tooth lies in the esthetic zone of the patient.

The indirect resin composite overlay offers a biologically conservative and esthetic option. However, its clinical performance in the posterior dentition is still questionable.[46] A failure rate of 21% over 3 years was reported when used in posterior teeth in parafunctional patients.[47] However, more recent studies are reporting more favorable results.[48-50] The choice between a direct or indirect composite resin restoration can be affected by various factors such as the size of the restoration, cost, number of visits, number of restorations, and the operator's skill in building large composite resin restorations.[51] However, both treatment options were shown to perform similarly in a 5-year randomized controlled trial.[49]

Indirect ceramic restorations are considered an excellent restorative option for patients with high esthetic demands.[52] Compared to a conventional full-coverage crown, the indirect ceramic overlays preserve significant amounts of tooth structure.[7] Short- and long-term data for different ceramic materials used for adhesive overlays have reported excellent results as cusp-replacing restorations.[53-55] An etchable ceramic is used for adhesive ceramic overlays, and most commonly, the second generation of lithium disilicate ceramics (IPS e.max press, Ivoclar Vivadent, Schaan, Lichtenstein, Germany) is selected. It presents improved esthetic and physical properties compared to its predecessors.[56]

Examples of two moderately destructed teeth are presented in Figure 2a.[3] Assessment of the first and second mandibular molars revealed ETT with DO and MO cavities, respectively. Some of the remaining axial wall thicknesses were found to be <2 mm. There were no lateral forces on the teeth, and the patient had no parafunctional habits. These teeth can be managed through indirect adhesive ceramic overlays [Figure 2b and c].

Severely destructed teeth

These teeth have suffered considerable amount of tooth structure loss. In addition to the necessity of cuspal coverage, such teeth usually require some sort of intraradicular retention to help retain the restoration.[57] Restoring such teeth with the mechanical methods will be through metal post, core, and full-coverage crowns.[21] The Nayyar technique followed by a full-coverage crown could also be used. In this technique, the restorative core material fills the pulp chamber and extends 2–3 mm into the coronal root canals.[58] Both of these treatment options will have better longevity and predictability if enough tooth structure was available to provide a ferrule.[59] In the absence of adequate tooth structure, clinical crown-lengthening procedure might be needed to obtain sufficient tooth structure to provide the necessary ferrule effect.[60] These conventional treatment options have been shown to be reliable clinically; however, they are not without a biological cost.[5] The full-coverage restoration leads to removal of significant amount of tooth structure, which is already scarce in such cases. In addition, such treatments are usually associated with an increase in the cost and time of treatment.[1]

The management of severely destructed ETT using the adhesive methods could be through the use of fiber post, core, and partial- or full-coverage crowns. The fiber posts unlike the metal posts depend on adhesion to the root dentine for its retention and have similar modulus of elasticity to that of dentine. They have been reported to decrease the incidence of catastrophic failures because their failure mode does not usually lead to a root fracture.[61] This is in contrast to metal posts, in which root fractures are more common.[62,63] Therefore, the use of fiber posts is associated with more favorable types of failure and a higher chance of keeping the teeth restorable following failure.[64-67]

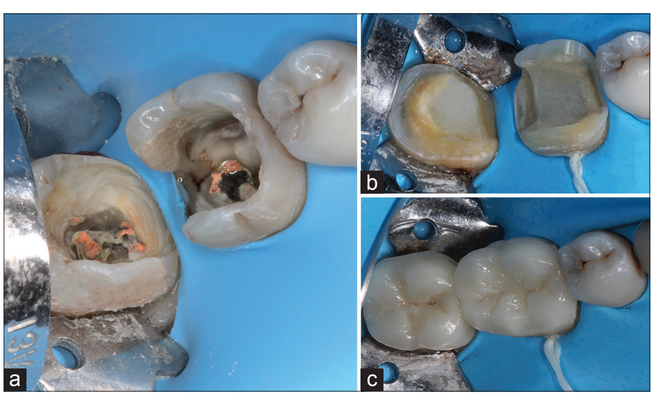

Figure 2: (a-c) An example of the assessment and management of moderately destructed molar teeth. (a) Assessment of the amount of remaining tooth structure of the mandibular first and second molar teeth categorized them as moderately destructed teeth. (b) Following composite resin core buildup, preparations for two adhesive overlays were carried out. (c) The moderately destructed mandibular molars were restored with indirect adhesive ceramic overlays

The management of severely destructed ETT using adhesive methods could also be through the use of endocrowns. This treatment modality was originally referred to as the mono-block porcelain technique by Pissis.[68] Later on, the term Endocrown was introduced by Bindl and Mörmann.[69]

Multiple definitions of endocrowns have been suggested; however, there are currently no consensus in literature about their definition.[70] An endocrown is basically a type of restoration for ETT that consists of a core and a crown as a single unit, and extends into the pulp chamber.[68,69] Retention is mainly obtained through adhesive resin cement (micro-mechanical retention). Extra retention and stability is provided through the pulp chamber's axial walls (macro-mechanical retention).[71] Consequently, materials with the capability of bonding through resin cement to the tooth structure have been selected for use in endocrowns such as glass ceramic materials (feldspathic ceramic) and, more recently, lithium disilicate ceramic and computer-aided design-computer-aided manufacturing composite materials.[70,72]

Although less commonly used compared to other treatment options, the unique design of endocrowns provides this type of restoration with many clinical advantages. It has a conservative preparation design which preserves maximum amount of tooth structure. It avoids the need for a post, which would reduce the risk of vertical root fracture and incidental root perforations.[63,73] Unlike the conventional post, core, and crown system, the endocrown does not need 1–2 mm of supragingival sound tooth structure to provide a ferrule. This will reduce the need for clinical crown-lengthening procedure and its associated disadvantages, such as the extra cost and time, the increased morbidity, the unnecessary bone removal from the adjacent teeth, and the possibility of loss of interdental papilla. Consequently, the use of endocrowns will generally decrease the number of visits and the cost of treatment.[1]

The endocrown restorations have recently been reported in a systematic review with favorable results:[74] three clinical trials and five *in vitro* studies were included, and a meta-analysis was performed. The clinical trials reported a success rate varying from 94% to 100% for endocrowns,[69,75,76] and the meta-analysis of the *in vitro* studies revealed no statistically significant differences in their survival compared to conventional treatments in posterior teeth.[74] In a more recent retrospective study which assessed 99 endocrowns up to 10 years with a mean observational period of 3.7 years, the survival and success rates of endocrowns were 99.0% and 89.9%, respectively, whereas the corresponding 10-year Kaplan–Meier-estimated survival and success rates were 98.8% and 54.9%, respectively. The main failures reported were periodontal disease, debonding, minor chipping, recurrent caries, and major fractures.[70]

Even though endocrowns have been reported consistently in literature to provide the molar teeth with good survival and success rates, they do not seem to be as consistent for premolar teeth. Bindl *et al*.[77] reported a higher failure rate of endocrowns for premolars than for molars, whereas Belleflamme *et al*. reported no difference in endocrown survival rates for premolars and molars.[70] This lack of consistency could be due to the fact that premolars have less bonding surface than molars, and that premolars have a big crown height-to-crown base ratio, which might cause occlusal forces to apply higher leverage on them compared to molars.[63,77] In addition, premolars are generally more likely to be subjected to lateral forces during mastication than molars.[63] Therefore, an endocrown for premolar teeth needs to be further tested before it can be recommended with confidence, and a fiber post–core–crown could be considered the best treatment option available for the severely destructed premolar teeth.[64] A fiber post and core system has been recommended for the management of maxillary and mandibular premolar teeth in many studies.[64,65,78]

An example of a severely destructed molar is presented in Figure 3a. Assessment of this first mandibular molar revealed an ETT with tooth structure loss beyond an MOD cavity. There were no lateral forces on the tooth, and the patient had no parafunctional habits. This tooth was managed adhesively through an endocrown [Figure 3b-e]. This will avoid the need for a post and core, avoid the need for clinical crown-lengthening procedure to provide a ferrule effect, and avoid further reduction of the remaining axial wall thickness.

A flowchart of the protocol suggested in this article is presented in Figure 4. The protocol includes assessing the

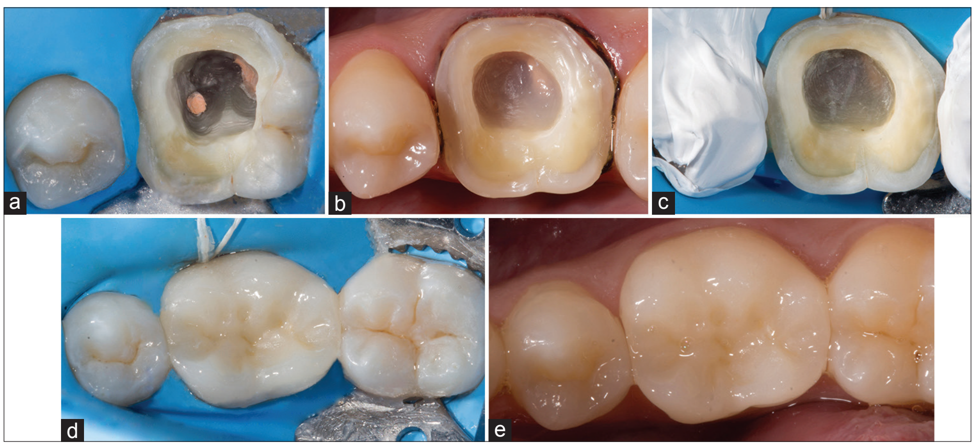

Figure 3: (a-e) An example of the assessment and management of severely destructed molar tooth. (a) Assessment of the amount of tooth structure loss of the mandibular first molar categorized it as a severely destructed tooth. (b) Pulp floor was sealed, and a conservative preparation for an endocrown was carried out. (c) Preparation for the endocrown bonding procedure under rubber dam isolation. (d) The endocrown bonding procedure to mandibular first molar. (e) The endocrown 1 week following the bonding procedure to the mandibular first molar

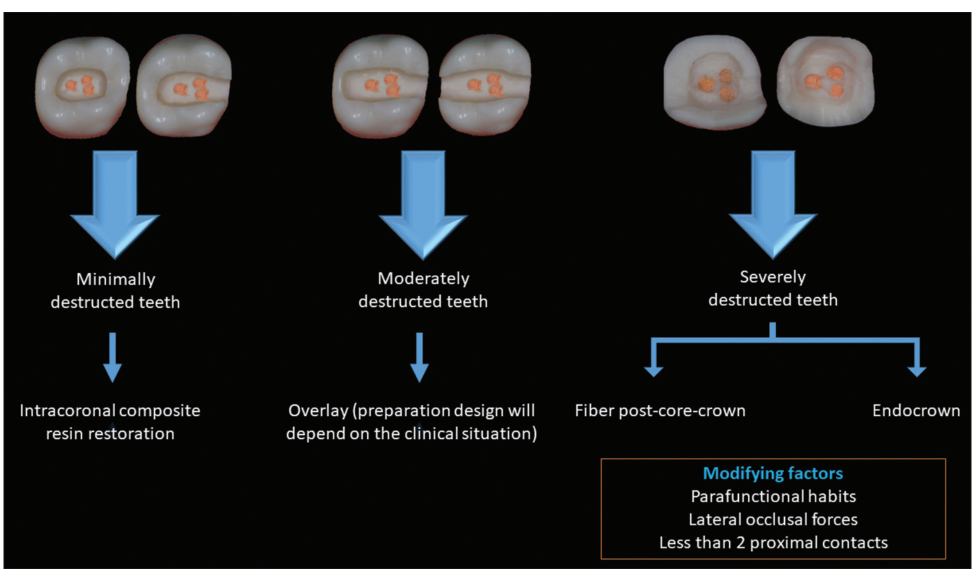

Figure 4: Flowchart for the decisionmaking process for restoration of posterior endodontically treated teeth using adhesively retained restorations

severity of tooth structure loss and assigning it to one of the three categories, followed by selecting the most conservative appropriate treatment option while keeping the key modifying factors in mind.

Conclusions

- Minimally destructed ETT (teeth with an occlusal cavity or an MO/DO cavity with thick axial walls [≥2 mm]) could be restored using intracoronal composite resin restorations
- Moderately destructed ETT (teeth with an MO/DO cavity with thin axial walls [<2 mm] or an MOD cavity) could be restored using adhesive onlays/overlays
- Severely destructed ETT (teeth with structure loss beyond an MOD cavity) could be restored using fiber post–core–crown or endocrowns
- Modifying factors (bruxism, lateral occlusal forces, or < 2 proximal contacts) should be taken into consideration during the decision-making process.

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Conflicts of interest

There are no conflicts of interest.

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