# Evidence-based treatment planning for the restoration of endodontically treated single teeth: importance of coronal seal, post vs no post, and indirect vs direct restoration

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Every orthograde endodontic procedure requires restoration of the coronal (access) cavity. The specific type of treatment used in individual cases greatly depends on the amount and configuration of the residual coronal tooth structure. In practice there are Class I access cavities as well as coronally severely damaged, even decapitated, teeth and all conceivable manifestations in between. The latest attempts to review results from clinical trials to answer the question of whether post placement or crowning can be recommended for the restoration of endodontically treated teeth or not are inconclusive. For dental practitioners, this is not a satisfactory result. This appraisal evaluates available evidence and trends for coronal restoration of single endodontically treated teeth with a focus on clinical investigations, where available. It provides specific recommendations for their coronal restoration to assist clinicians in their decision making and treatment planning. *(Quintessence Int 2019;50:772–781; doi: 10.3290/j.qi.a43235)*

**Key words:** coronal restoration, direct restoration, endodontically treated teeth (ETT), endodontics, fiber post, indirect restoration, seal

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This appraisal evaluates available evidence and trends for coronal restoration of single ETT with a focus on clinical investigations, where available. It provides specific recommendations for their coronal restoration to assist clinicians in their decision making and treatment planning.

## The importance of coronal restoration for endodontic treatment outcome

Leaking coronal restorations dramatically reduce the chance of endodontic treatment success. Numerous studies by renowned authors provide appropriate evidence, concluding that the coronal restoration is at least as important for apical periodontal health as the quality of the endodontic treatment itself.[1-4]

An early study on the influence of the marginal integrity of coronal restorations on endodontic treatment outcome assessed more than 1,000 teeth radiologically that had undergone endodontic treatment.[1] It was apparent that the absence of apical periodontitis was significantly dependent on the marginal integrity of the coronal restoration; 90% of endodontically sufficiently treated teeth were free of apical foci, assuming these were also restored coronally and a marginal seal achieved. The success rate dropped to 44% for coronal restorations that appeared to have marginal leakage (Fig 1).

The importance of coronal restoration is also verified by a large epidemiologic study of survival data on close to 1.5 million ETT, provided by a US dental health insurer.[2] From approximately 42,000 teeth extracted during the observation period, 85% had no proper coronal coverage and were removed at a rate six times greater than teeth that had coronal coverage. Further retrospective research is in line with this finding.[3]

A comprehensive meta-analysis of data available on the subject concluded that when either the quality of the coronal restoration or the quality of the root canal filling is completed inadequately, it is equally contributive to an unsuccessful outcome.[4] Placement of a sufficient restoration over a poorly obturated root canal, or vice versa, does not render the high degree of success associated with performing both procedures adequately.

Hence, for the best possible, meaning long-term successful, endodontic treatment, both adequate endodontic and restorative treatments are indispensable. The question remains how state-of-the-art coronal restoration can be accomplished in an endodontic context.

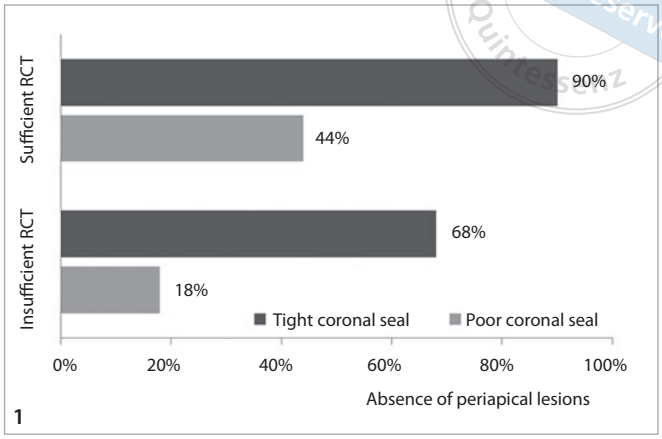



**Fig 1** Endodontic success, ie the absence of periapical lesions, depending on coronal restoration seal (tight or poor) and the quality of the root canal treatment (RCT, sufficient or insufficient). Modified from Ray and Trope.[1]

## To post or not to post, that is the question

ETT are more susceptible to fracture than vital teeth.[5] It appears that particularly the loss of marginal ridges reduces fracture-resistance.[6,7] In the case of a three-surface Class II mesio-occluso-distal (MOD) access cavity configuration, that is involving loss of both marginal ridges, coronal stiffness reduction is on average 63%.[7] To compensate for this loss of stability, it is still customary to crown ETT. A central procedure in this context is frequently placement of a post.

A root post is traditionally used primarily for improving retention of the build-up material to the residual tooth structure. Whether posts improve the time in situ of the coronal restoration or tooth, however, is a controversially discussed subject. Current reviews assess the data available on the issue.[8,9] As the authors of these reviews criticize the lack of methodic quality of the investigations under review, they are unable to provide a general recommendation for or against the use of posts. However, it is noted that there appears to be an emerging trend toward the superiority of fiber-reinforced posts.[9]

### *Post type*

Within the scope of this appraisal, a selection of the clinical trials available on the subject shall therefore be made according to the following rationale: fiber posts are based on state-of-the-art technology and the accepted standard of care. Studies and reviews confirm that:

- fiber posts exhibit relatively uniform stress distribution to the root[10]
- fiber posts have elastic moduli similar to dentin[10]
- fiber posts are easy to place, cost effective, and esthetic[10]
- glass fiber posts are associated with low catastrophic failure rates compared to other post types[11]
- glass fiber posts exhibit lower and thus superior stress peaks in finite element analysis.[12]

Based on this rationale, the appraisal at hand only takes clinical trials into consideration, which:

- deal with a "composite core with fiber post vs composite core without fiber post" scenario
- are included in the "Level I Evidence" category (that is, randomized controlled trial [RCT]) as set forth by the US Preventive Services Task Force (USPSTF).[13]

### *Premolars*

According to the recent review of trials on the topic,[8] there are three published RCTs that match the above criteria.[14-16] Conclusions from these trials can be summarized as follows:

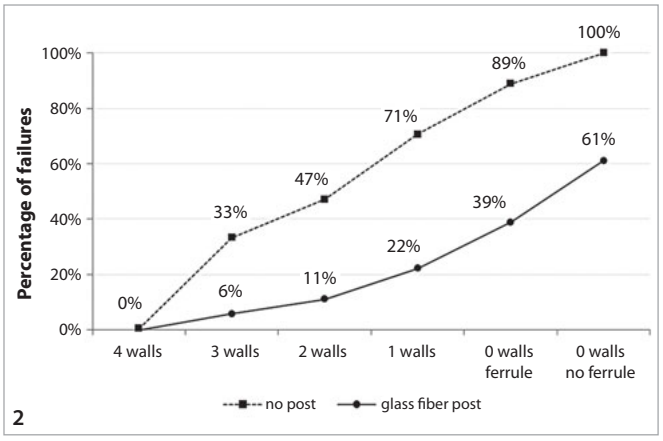



**Fig 2** Overall failures of ETT as a function of residual coronal walls, with and without glass fiber post. Modified from Ferrari et al.[15]

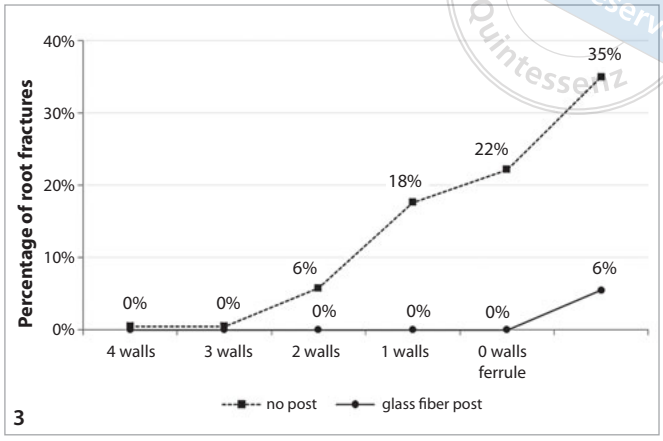



**Fig 3** Root fractures of ETT as a function of residual coronal walls, with and without glass fiber post. Modified from Ferrari et al.[15]

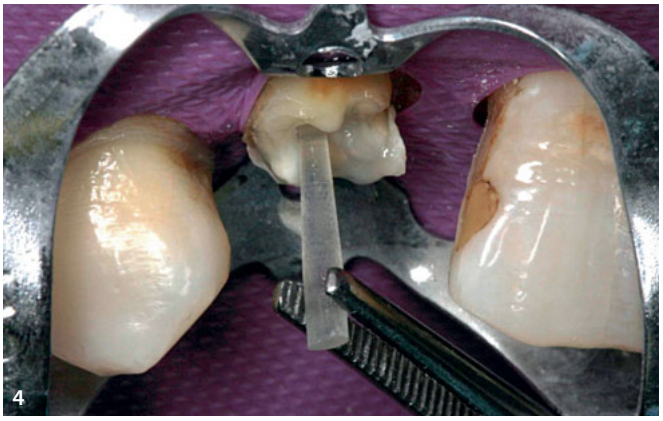



**Fig 4** For severely destroyed teeth, adhesive placement of a glass fiber post with subsequent core buildup and conventional crowning is recommended. Reprinted from Naumann[54] with permission.

- in premolars, the amount of residual coronal tooth structure generally influences survival, ie the more coronal walls, the fewer failures (Fig 2)[14,15]
- in premolars, glass fiber posts reduce failure risk (Fig 2)[14,15]
- in premolars, glass fiber posts protect against root fracture (Fig 3)[14,15]
- in premolars, the previous two effects are more pronounced the more coronal cavity walls remain[14,15]
- in decoronated teeth, quartz fiber posts significantly extend the time to restoration failure.[16]

Based on these findings it can be concluded that post placement is still a legitimate approach to restoration of ETT, especially for cases with extensive coronal structure loss (Fig 4). The more structure is lost, the more useful fiber post placement becomes. However, it needs to be taken into consideration that the above-mentioned clinical trials mostly focus on crowned premolars.

## *Molars and incisors*

There is only one RCT that matches the criteria and which also considers molars and incisors.[16] The trial followed a non-inferiority design with an assumed margin of equivalence of 15%. Its objective was to show that placement of quartz fiber posts makes no difference to clinical failure for any reason. Based on the results and in line with its non-inferiority design, the authors conclude that placement of a post provides no added clinical value except for the "no-wall" scenario, that is decoronated teeth. In this group, post retention exhibited a 7% failure rate compared to 31% for teeth without post retention. The authors conclude that quartz fiber post placement is efficacious in reducing failures of post-endodontic restoration of teeth exhibiting no coronal wall. The same study recommends that post insertion for teeth with minor structure loss should be critically reconsidered to avoid overuse. One circumstance limiting the validity of the trial is the lack of totally standardized conditions, as the authors themselves admit. Beyond pooling of various types of teeth, crowns of the teeth observed were, depending on the extent of the defect, restored using either metal, porce-

**Fig 5** In cases where placement of a conventional crown is planned, preparation of a ferrule is advised. Reprinted from Naumann[54] with permission.

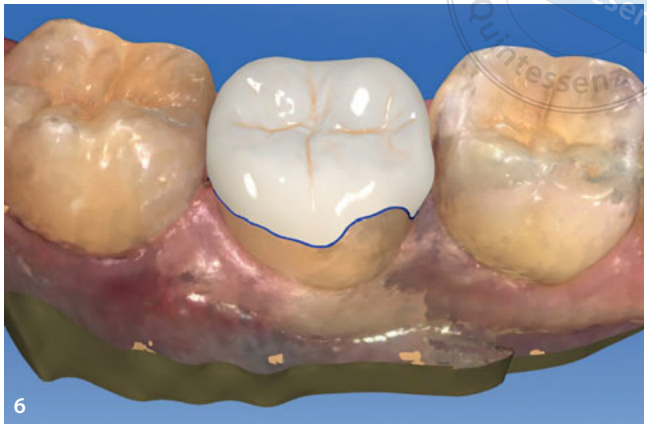


**Fig 6** CAD/CAM construction of an all-ceramic overlay. For posterior teeth presenting with few or undermined walls, cuspal coverage with a partial crown or an adhesively placed onlay is advised. (Courtesy of Dr Andreas Bindl, Switzerland.)

lain-fused-to-metal, or all-ceramic full crowns, metal or all-ceramic partial crowns, or composite restorations. Also, it should be taken into consideration that the cores were built up using a combination of conventional self-curing adhesive and core build-up composite – material classes characterized by moderate bond strengths and considerable shrinkage stress development.

In similar form, a comprehensive literature review recommends restoration of root filled molars (and premolars) exhibiting limited tissue loss, that is, with 50% or more of the coronal structure preserved, without post placement, especially when cusp protection is planned.[17] One of the rare in vitro investigations on the effects of post placement in molars also found fiber posts ineffective in increasing the fracture-resistance of teeth with cuspal coverage.[18]

In addition, data for anterior teeth are scant. Biomechanical considerations suggest that, due to different load directions, anterior teeth behave differently from premolars and molars. Which effect these load patterns ultimately have on restorative success and survival of ETT is the subject of scientific discussion. Some consider the maxillary anterior region a particularly high-risk area for mechanical failure after endodontic treatment owing to the oblique loading pattern,[8] while others argue that lateral, horizontal, or oblique forces generated at angles less than 90 degrees, as they occur in posterior teeth, are more destructive than vertical loads and can lead to greater failure of restorations.[19] Deep overbites, a horizontal envelope of function, and extreme parafunctional forces also may increase the possibility of fracture and loss of anterior teeth. It seems that in maxillary central incisors, tooth stability decreases starting with preparation of the endodontic access cavity, with further significant destabilization occurring after post space preparation.[19] In the mandible, the anatomy of incisors is generally daintier compared to other teeth. Some authors recommend coronal reconstruction of root-filled incisors with limited tissue loss using composite only.[17] Notwithstanding, a trend to achieve additional retention through post placement to compensate load patterns or anatomical limitations in anterior teeth, such as small pulp chambers and thin residual walls, is recognized.[20] Because it appears, however, that preservation of natural tooth structure is a decisive factor for successful restoration of ETT, post space preparation should be kept to a minimum in all cases.[21]

## Coronal restoration of ETT

### *Crowning and cuspal coverage*

Crowns are proven to function well as a long-term restorative measure for ETT. With an average annual failure rate of 1.9%, their longevity corresponds to those of various indirect restorations in vital teeth, which range between 1.4% and 1.9%.[22,23] The preparation of a ferrule (Fig 5) is deemed a decisive success factor in that context.[24]

With classic crowning, however, a significant amount of residual tooth structure is sacrificed in the preparation. Moreover, crowning often involves creating a subgingival preparation margin and therefore a significantly less hygienic margin region. For those reasons and in the light of recent research




**Figs 7a to 7c** Endodontically treated posterior teeth with four and three coronal walls, respectively. In such Class I and two-surface, Class II type (access) cavities with barely undermined residual tooth structure, the decision to treatment plan direct adhesive composite restorations is possible if risk factors discussed in the article and listed in Table 1 are favorable. (Courtesy of Dr Marcus Holzmeier, Germany, and Prof Simone Grandini, Italy.)

results, the almost habitual, reflex-like decision in favor of crowning single teeth regardless of the coronal cavity configuration must be considered questionable.

The epidemiologic investigation referred to earlier in this appraisal advises cuspal coverage for ETT lacking three or more coronal surfaces.[2] However, the call for cuspal coverage does not make crowning compulsory if coronal stabilization can be achieved by other means.

A recent retrospective clinical evaluation comparing 3-year survival of post-retained porcelain-fused-to-metal crowns and cast ceramic onlays without posts in mildly and severely destroyed premolars found no statistically significant differences in outcome across the various scenarios.[25] The authors concluded that onlays are a reliable method of restoring endodontically treated premolars.

On an ex vivo level, it has been demonstrated that in endodontically treated premolars with Class II MOD configuration, cuspal coverage can enhance fracture-resistance by a factor of 2.3 versus composite Class II MOD restorations without cusp replacement. In fact, for the former, fracture-resistance was increased to a level close to the value determined for the sound teeth in the control group.[26]

Cusp replacement is typically carried out in indirect procedures (Fig 6). However, this approach appears to be noncompulsory as direct resin-based cusp replacement was shown to be equally effective.[27]

## *Direct restoration*

With a two-surface Class II configuration, the increase in fracture-resistance through cusp replacement, though statistically significant, seems to be much less pronounced.[28] Here again the stabilizing effect of the remaining ridge becomes apparent. Access cavities with four intact walls are even more stable.[29]

A Cochrane review on the matter concluded that insufficient data are available for deciding whether preference should be given to direct restorations or crowns for restoring ETT.[30] The review identified one single acceptable study, in which survival of porcelain-fused-to-metal crowns and fiber-post-retained composite restorations in Class II cavities with preserved cusps were compared.[31] The reviewed investigation itself, however, established that clinical success rates of both restorative approaches are equivalent. Another recent RCT in largely destroyed ETT found a statistically significant and yet only slightly more frequent need for intervention for the composite group versus crowns. There was, however, no statistically significant difference between crowns and composites in terms of survival. The authors concluded that both composite restorations and porcelain-fused-to-metal crowns are acceptable approaches for achieving good survival and success rates.[32] In another retrospective clinical investigation, the authors concluded that ETT with coronal defects lacking up to three surfaces can be restored with adhesive composite fillings.[33] A similar view is supported by a systematic review which suggested that in teeth with limited coronal hard structure loss, composite resin restorations and crowns do not present significantly different longevity.[34] A recent retrospective study demonstrated that long-term (6 to 13 years) durability of Class II posterior composites with 2.5- to 3-mm cusp thickness in ETT was clinically comparable to that of vital teeth.[35] Placement of composite fillings in ETT should therefore be considered, depending on the amount and configuration of residual coronal tooth structure following endodontic treatment (Fig 7).

The use of a low-stress, flowable bulk-fill composite is a natural choice when restoring ETT directly. Such materials are deemed effective from both an in vitro[33-39] and clinical[40,41] point of view, and equally, or even more, reliable than conventional composites. Even in high C-factor cavities, such as in ETT with little coronal structure loss, flowable bulk-fill composites are proven to achieve high adhesion.[42,43] Likely reasons are their low shrinkage stresses as well as self-adaptational properties (Fig 8). However, at least in this particular indication, commercially available materials do not appear to be equally performant (Fig 9). Hence, careful consideration should be given to the choice of material. The choice of light-curing unit also influences the quality of clinical treatment. One important factor is the amount of light that arrives at the resin subject to curing.[44-46] This value is referred to as irradiance. Endodontic access cavities can easily exhibit depths of 10 mm or more, and the irradiance decreases according to the distance (Fig 10). The use of a curing device that delivers sufficient irradiance also across clinically relevant distances is advised.

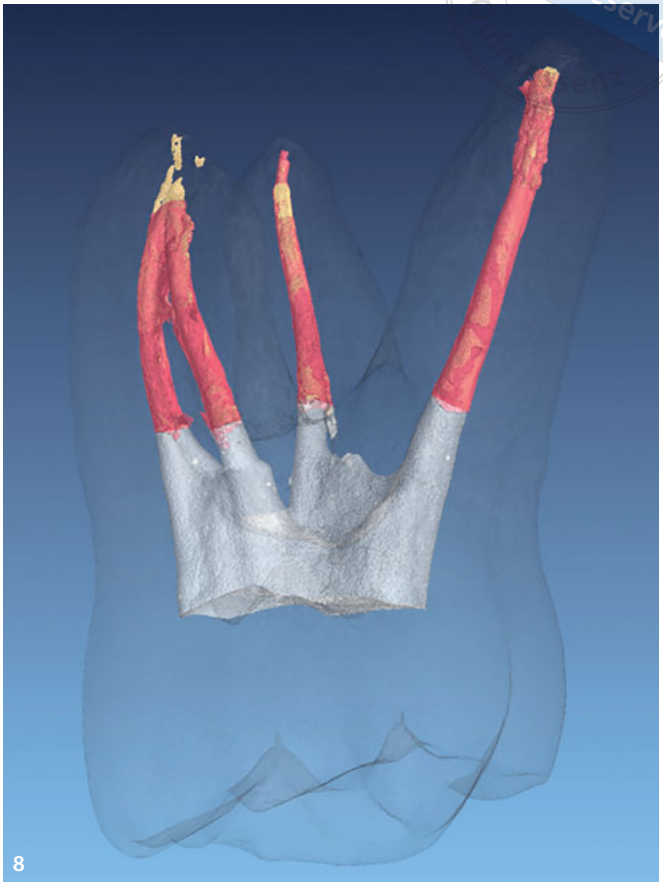



**Fig 8** Micro-computed tomography view of a flowable, bulk-fill composite (SDR, Dentsply Sirona, light blue portion) applied to an endodontic access cavity. Note the high degree of adaptation to the pulp cavity despite its complex geometry. (Courtesy of Dr Frank Paqué, Switzerland.)

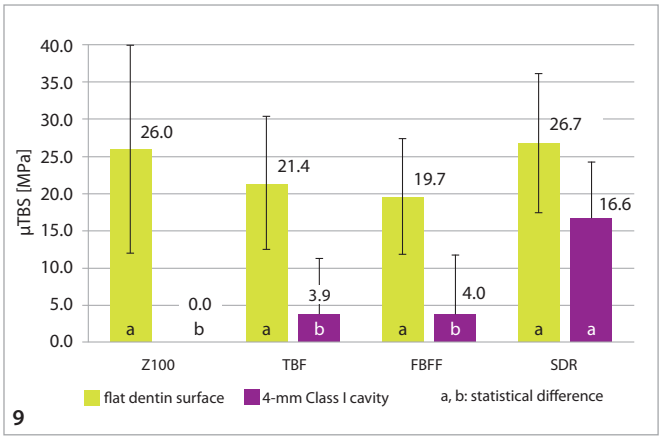
### *Risk factors*

An important prerequisite for direct restoration is that the individual tooth does not present with undermined and thus weakened residual coronal walls.[47] In posterior teeth, large cuspal heights and group function may generate greater lateral forces compared to canine-protected occlusions.[48] With respect to molars, factors such as occlusal patterns and parafunctional habits play a pivotal role. In the treatment planning sequence, periodontal status,[49-51] tooth location, number of adjacent teeth, requirement as a survey crown for a removable partial denture, parafunctional habits, gender, and the age of the patient are important diagnostic criteria for evaluating the requirement for a full coverage crown. Another important risk assessment during the treatment planning process is the patient's dietary habits. Harder type foods such as nuts and hard candies place enormous stress on teeth, especially those with restorations. Consumption of large quantities of these specific foods will cause a tooth with a large filling to flex, thus increasing the likelihood of fracture. Chewing gum and ice weaken the adhesive interface significantly and may cause the tooth to break even when eating something softer in consistency. Parafunctional habits such as nocturnal bruxism will significantly lower the lifespan of fillings and crowns.[35,52]

## Summary and clinical recommendations

### *Importance of coronal seal*

There is a strong link between endodontic treatment of the root and restoration of the crown. The quality of the coronal restoration is at least equal to or even more important for the endodontic treatment outcome than the quality of the actual root canal treatment. Hence, endodontic treatment cannot be considered completed unless the crown is adequately restored.



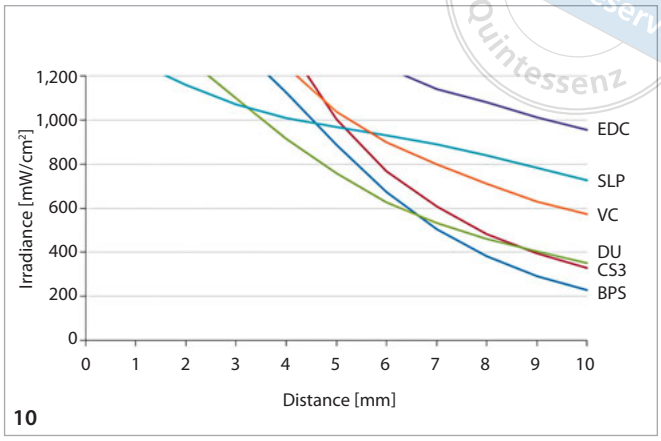




**Fig 9** Microtensile bond strength (µTBS [MPa]) of various (bulk-fill) composites achieved on flat dentin surfaces and in Class I, that is, the highest C-factor cavities. All composites were applied in 4-mm increments. It appears that commercially available materials are not equally performant. Z100, 3M; TBF, Tetric EvoCeram Bulk Fill, Ivoclar Vivadent; FBFF Filtek Bulk Fill Flowable, 3M; SDR, Dentsply Sirona. Modified from Van Ende et al.[42,43]

**Fig 10** Irradiance of LED curing units decreases over clinically relevant distances. BPS, Bluephase Style 20i, Ivoclar Vivadent; CS3, Coltene SPEC 3, Coltene; DU, Demi Ultra, Kerr; EDC, Elipar DeepCure, 3M; SLP, SmartLite Pro, Dentsply Sirona; VC, Valo Cordless, Ultradent. Data provided by Bluelight Analytics, Halifax, Canada.

## *Post versus no post*

Post placement remains a viable approach to restoration of ETT with extensive coronal structure loss. Owing to their mechanical and clinical properties, adhesively luted glass fiber posts can be considered the gold standard of care. For endodontically treated premolars with substantial coronal defects there is sound scientific evidence from prospective randomized controlled clinical trials that glass fiber post placement enhances clinical outcome. In the same trials, the use of fiber posts is shown to protect against root fractures. This correlation becomes clearer the more coronal tooth structure has been lost. Based on those trials, it is recommended to place a fiber post in premolars if three or more coronal surfaces, including the occlusal surface, have been lost.

There is a lack of clinical data regarding adequate treatment of root filled incisors and molars. For anterior teeth with limited tissue loss, reconstruction with composite without a post is recommended. There seems to be a trend, however, towards providing additional retention through fiber post placement due to the anatomical limitations and biomechanical load patterns. Therefore, the same approach to fiber post placement is advised for incisors and premolars.

Molars may be unaffected by the use of a post if they present with significant residual amounts of coronal hard tissue or if cuspal coverage is planned. Results from a RCT in which molars were also considered suggest that fiber post placement significantly prolongs the time to clinical failure of the restoration only in cases where no coronal walls remain at all. On those grounds, fiber post placement in molars is only recommended if the tooth is decoronated.

It should be noted that placement of fiber posts according to the present studies does not seem beneficial under certain circumstances, but is also not detrimental. If the preference is for placement of a fiber post, a conservative approach for preparing the post space is recommended to ensure long-term success of the residual tooth structure. In other words, preference should be given to posts with a small diameter as opposed to posts with a large diameter.

Posts are traditionally used to increase retention of the core. Self-adapting, low shrinkage stress, bulk-fill composite technology used in conjunction with modern light-curing adhesive agents for core buildup may become a viable alternative for post placement, even in largely destroyed posterior teeth. More research in this area would be desirable.

It is not clearly established to what extent fiber posts are beneficial in scenarios where no crown is placed. Some of the investigations dealing with such scenarios look into post retained restorations while others do not. Prospective investigations comparing onlays as well as direct composite restorations in Class II cavities, both with and without a post, do not exist at the moment.

**Table 1** Minimally invasive treatment recommendation for incisors, premolars, and molars

| | | Cavity configuration | | | | | |
|---|---|---|---|---|---|---|---|
| Teeth | Treatment | Access cavity | One ridge lost | Both ridges lost | One wall remaining | No walls remaining | Risk factors |
| Premolars and incisors | Glass fiber post | No | No | Yes | Yes | Yes | Parafunctional patterns, dietary habits, periodontal status, tooth location, number of adjacent teeth, gender, or patient age may necessitate crowning |
| | Coronal restoration: incisors | Composite filling | Composite filling | Ferrule and crown | Ferrule and crown | Ferrule and crown | |
| | Coronal restoration: premolars | Composite filling | Composite filling | Cusp coverage | Cusp coverage | Ferrule and crown | |
| Molars | Glass fiber post | No | No | No | No | Yes | |
| | Coronal restoration | Composite filling | Composite filling | Cusp coverage | Cusp coverage | Ferrule and crown | |

Cuspal coverage is typically carried out indirectly (adhesive composite or all-ceramic onlay, partial crown). In context with a crown preparation, creation of a ferrule is deemed beneficial. Use of the smallest post size available is advised.

### *Indirect versus direct restoration*

As to the question of whether the crown should be restored in direct or indirect fashion, the same approach is recommended for all types of teeth. In ETT with three or four coronal walls left, that is, at least one marginal ridge remaining, and no undermined cavity walls, direct adhesive restoration may be considered as an alternative to cuspal coverage. For posterior teeth with few or undermined coronal walls, cuspal coverage with an adhesively placed onlay, a partial crown, or a conventional crown is advised. Risk factors such as parafunctional patterns, dietary habits, periodontal status, tooth location, and more should be included in the evaluation as to whether a specific ETT can be restored with a direct composite filling, or requires full cuspal coverage or even a crown. In cases where crowning is intended, preparation of a ferrule is required.

An overview of the clinical treatment recommendation given above is provided in Table 1.

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