

PRATIQUE
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Predictably Restoring Endodontically Treated Teeth

(Comment restaurer avec des résultats prévisibles les dents traitées par endodontie)

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SOMMAIRE

Les dents traitées par endodontie peuvent être restaurées à l'aide de nombreuses techniques plus ou moins complexes. Dans cet article, on en présente une qui est simple pour restaurer les dents dont le traitement par endodontie répond à certaines normes. On indique, à cet effet, les critères d'utilisation des couronnes, des résines composites, des tenons radiculaires coulés en or, des reconstructions de pile à l'amalgame ou à la résine composite, ainsi que des tenons en acier inoxydable passif, cylindriques ou de petit diamètre. Enfin, on se penche sur la conception du cerçage.

Mots clés MeSH : dental restoration, permanent/methods; patient care planning; post and core technique; tooth, non-vital/therapy

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Le présent article a fait l'objet d'une révision par des pairs.

A preceding paper¹ provided criteria to help identify a predictably restorable endodontically treated tooth. The criteria for an endodontically treated tooth requiring a post is that the minimum length of remaining solid tooth equal the sum of the biologic width (2.5 mm), the ferrule length (2 mm), the apical seal (4 mm) and the post length, or 8.5 mm + post length (**Fig. 1**). For teeth not requiring a post, the requirements are for biologic width + ferrule length, or 4.5 mm of supra-bony solid tooth. Solid tooth refers to dentin that is a minimum of 1 mm thick after preparation. In addition, consideration of the functional loads on a tooth is essential. Single abutments supporting precision attachment removable partial dentures (RPDs), distal extension RPDs or cantilever fixed partial dentures (FPDs) that are endodontically treated or likely to become so in the future should be avoided. Careful assessment of

the occlusal demands and other loads such as FPDs or RPDs must be made prior to restoration.

Choices in Build-up Materials

Any endodontically treated tooth will require a build-up, which may be as simple as closing the access and pulp chamber on an intact anterior. The optimal build-up material will have adequate strength, be biocompatible, exhibit a high level of resistance to bacterial leakage, and be insoluble and dimensionally stable in the presence of oral fluids. Bullard and others² showed that a coefficient of thermal expansion close to that of the tooth reduces leakage, which is important. This paper considers the four materials commonly utilized today for build-ups: cast gold, amalgam, composite, and glass ionomer.

Cast Gold

Cast gold offers strength. Its resistance to leakage is derived

from the luting agent. It doesn't absorb water and has a coefficient of thermal expansion (CTE) very close to that of dentin. Typical CTE for gold³ is 14×10^{-6} ; the CTE of dentin⁴ is 10.6×10^{-6} . Cast gold build-ups require a post for retention and a substantial degree of coronal destruction to be used. Where applicable, this is the build-up material of choice.

Amalgam

Amalgam offers strength. Its coefficient of thermal expansion is almost double that of dentin (about 22×10^{-6} , versus 10.6×10^{-6}), and it is relatively stable in the presence of water. It offers a high-level resistance to leakage once it has been in place for a period of time due to the sealing effects of its corrosion products. Initial leakage has been shown to be significantly lower with dispersed phase alloys than with spherical⁵ alloys. Bonding of amalgams is an option, and has the potential to strengthen



Table I

	Tensile Strength MPa	Young's Modulus GPa	Coefficient of Thermal Expansion $\times 10^{-6} \text{ }^\circ\text{C}$
Cast Gold Type IV³	701 to 786	69 to 110	14
Amalgam	65.7 ¹⁷	38 to 60 ¹⁸	22 ²
Composite Biscore¹²/Ticore¹¹	55/35	13/18.5	25/35
Glass Ionomer	12.4 ¹⁹	9.4 ¹⁹	14 ²
Dentin	59.6 ²⁰	10.2 ²¹	10.6 ⁴

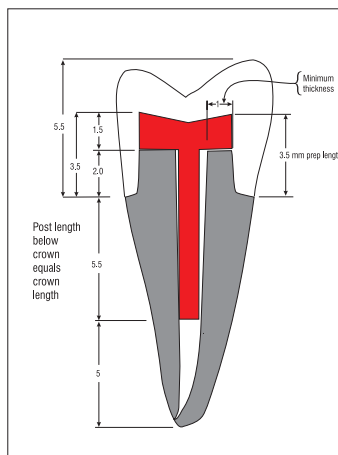


Fig. 1: Minimum dimensions for a predictably restorable tooth.

the tooth and reduce leakage. Christensen⁶ recommends that bonding of amalgam restorations be routine; however, with root-treated teeth, sensitivity is not an issue and the additional strength obtained is apparently transient. Santos and Meiers⁷ found no significant strengthening of teeth with amalgam bond after thermocycling, and Bonilla and White⁸ found short-term increases in strength that disappeared after 500-day storage or load cycling. As apparently the bond of amalgam to dentin will ultimately degrade, there is concern about increased leakage after bond failure. The bonded surface of the amalgam may be more corrosion resistant than an unbonded amalgam, leading to the risk of increased leakage on a long-term basis.⁹ Given the short-term nature of the bond, the additional

time and cost to bond, and unanswered questions as to the effects on long-term leakage, amalgam bonding is contraindicated for build-ups. On posterior teeth with enough pulp chamber depth to obviate the need for a post (2 to 4 mm), amalgam is the material of choice. Where a post is required to retain the build-up, amalgam is cheaper and faster than a cast gold core and often less destructive of tooth structure.

Composite

Composite apparently offers adequate strength clinically, its ultimate strength being somewhat lower than that of amalgam. Its resistance to leakage is almost totally dependent on the luting agent, and the ability of dentin bonding agents to prevent leakage over the long term is unproven. Burrow and others¹⁰ showed a degradation of dentin bond strength in vitro over three years almost to the level of an unbonded restoration. If this is typical clinically, then the long-term ability of dentin adhesives to reduce leakage cannot be relied on, which means composite build-ups must rely on mechanical retention as do amalgam build-ups. The coefficient of thermal expansion for most modern self-polymerising composite build-up materials is significantly higher than that of tooth; examples include Ticore¹¹ by EDS at 34×10^{-6} , and BisCore¹² by Bisco at 25×10^{-6} . In addition, composites show significant setting shrinkage. Sakaguchi and others¹³ showed 0.2% post gel contraction. This

shrinkage results in stresses on the bonding systems that may contribute to long-term bond failure. On anterior teeth where a crown is not required and enamel margins offer the promise of long-term resistance to leakage, composite is an excellent choice. With the poor long-term prognosis for dentin bonding agents and the corresponding risk of leakage, relying on composite build-up materials for leakage control seems risky and unpredictable. On posterior teeth where composite is used as a build-up material, maintaining at least 2 mm between crown margins and the build-up should reduce leakage. The absorption of water with composites is a potential concern due to the generation of internal stresses, but it is difficult to assess the clinical significance of this concern. In addition, it has been shown that the mechanical properties of composites degrade with thermocycling and exposure to water.¹⁴ Kovarik and others¹⁵ showed significantly shorter fatigue life for composite build-up supported crowns than for those with amalgam build-ups. While composites are fast and convenient to use, in most instances they are inferior to amalgam and gold.

Glass Ionomer

Glass ionomer filling materials offer a low level of leakage,^{16,2} a relatively weak dentin bond and a low level of mechanical strength (Table I). They offer the appeal of fluoride release to reduce decay potential, but there is minimal evidence that this has any clinical significance. Kovarik and others¹⁵ fatigue-tested crowns with amalgam, composite and glass ionomer cores, and found that amalgam was significantly stronger than composite and that glass ionomer had inadequate strength as a core build-up. Because of its weak mechanical properties, glass ionomer has little to offer as a build-up material and should be reserved for limited applications such as blocking out minor undercuts.

Ranking of Build-up Materials

When a post is required and there is sufficient coronal destruction to allow cast gold without sig-



nificant additional loss of tooth structure, cast gold is best. In situations where a build-up can be retained without a post, or where a post is needed but the placement of a cast gold core build-up would require significant removal of additional tooth structure, amalgam would be the material of choice. In teeth where simple closure of the access preparation is all that is required and enamel margins offer the potential for long-term resistance to leakage, composite resin is the material of choice. Glass ionomer is not suitable for build-ups.

How to Retain the Build-up

With the use of cast gold, a post is mandatory for retention. With amalgam or composite, the retentive options are pins, posts and mechanical undercuts such as offered by a pulp chamber. The use of pins to retain build-ups carries the risk of microfracture and introduces stress into the adjacent dentin. Teeth that require pins or posts to retain build-ups have already suffered significant coronal destruction. Caputo²¹ recommends a minimum of 1 mm of solid dentin to surround a pin, yet this thickness is rarely available to retain build-ups on root-treated teeth. The undercuts in pulp chambers can be used to retain build-ups; Nayyar and others²² and Kane and others²³ have shown that pulp chamber depths of 2 to 4 mm offer adequate retention for an amalgam build-up without pins or posts. The use of slots or dovetails cut into dentin to retain the amalgam has appeal but requires the destruction of more tooth structure. There is also a risk that these retentive devices will be removed or weakened during crown preparation.

Posts offer the ability to retain the build-up and, if carefully placed, remove little tooth structure. They are also removable for orthograde endodontic retreatment.

The Choice of Final Restoration

Crowns placed on anterior teeth do not make teeth inherently stronger.^{24,25} In the absence of significant coronal destruction, a

tooth is better restored simply by closing the access with a composite resin. Once distal to the cuspid, placement of a cast restoration that shoes the cusps improves the odds of success.²⁴ Placement of a crown on an anterior tooth is indicated when there is extensive coronal destruction or the need for occlusal change, or for esthetic reasons. In such situations, the mechanical and esthetic properties of porcelain, porcelain on gold, or modified resin crowns such as Vectris-reinforced Targis crowns offer advantages over large composites.

Considerable focus has been placed on the potential for coronal leakage to cause the failure of otherwise acceptable endodontic treatment. Torabinejad and others,²⁶ Swanson and Madison,^{27,28} and Khayat and others²⁹ showed that leakage will occur coronally along the obturated canal if the coronal access is not effectively sealed. In a retrospective study, Ray and Trope³⁰ have shown that the long-term success of a restoration depends more on the quality of the final restoration than on the quality of the endodontics. The importance of the quality of the final restoration and its ability to minimize leakage cannot be overstated.

Ferrule Design

The importance of ferrule, its design and execution cannot be ignored. A recent *in vitro* study by Freeman and others³¹ compared leakage under post-retained composite cores and cast gold post cores and the number of cycles until a strain gage detected movement between the artificial crown and the root. Movement between crown and root was measured very early in the experiment, on average after only a few hundred cycles. In the experimental design, tooth preparation "extended 1 mm apical to the core-tooth interface, thereby providing a 1 mm ferrule on tooth structure."³¹ In reality, when the teeth were sectioned and the margins examined, there was little or no ferrule present. The cross-sections effectively showed a chamfered or bevelled margin that was far from parallel. Both Barkhordar³²

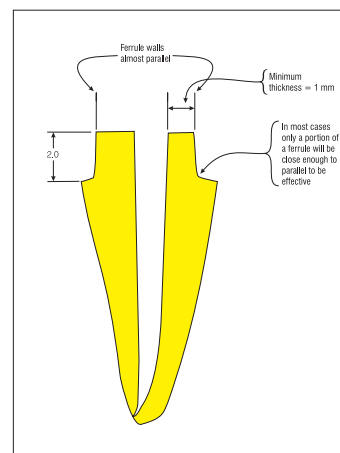


Fig. 2: Ferrule criteria and dimensions.

and Sorensen³³ have shown the importance of at least 1 mm of almost parallel wall preparation. The study by Freeman and others highlights the misconceptions as to what constitutes a ferrule. Given the realities of intraoral tooth preparation, a minimum of 2 mm of preparation length on solid tooth is recommended to ensure an adequate length of parallel wall to achieve an effective ferrule (Fig. 2).

When to Place a Post

Posts have one purpose, to retain a build-up on a tooth. There is compelling evidence that they do not strengthen teeth.³⁴⁻³⁶ The use of certain post designs can predispose them to catastrophic failure, as shown by Sorensen and Engelman.³³ Based on this premise, posts function primarily in tension. A relatively small diameter post has ample strength in tension to retain any crown. The rather loose adaptation of a small diameter post in a canal does not reduce retention, as shown by Chan and others.³⁷ Standlee and others³⁸ showed that post diameter was not a major factor in retention and the parallel-sided para post was more retentive than a smooth-tapered dowel design. In situations where an artificial crown breaks off and either shears off the post or dislodges it, there is at least the potential for retreatment. Utilization of larger posts requires the removal of additional tooth structure and weakens the tooth,³⁹⁻⁴¹ increasing the risk of

catastrophic failure and of having a tooth that is unrestorable.

Passive Metal Posts

Passive metal posts include parallel, tapered, and custom posts. Weine⁴² showed a 94% success rate with smooth-tapered posts over 10 years. In a study of 1,273 teeth restored a minimum of one year, Sorensen and Martinoff⁴³ showed a 97% success rate for any post crown restoration in which the post length equalled or exceeded the crown length. Torbjorner and others⁴⁴ reviewed almost 800 posts after four years, and parallel posts showed half the failure rate of custom-cast tapered posts. Post length is key and ideally should extend into the root past the crown margin by an amount equal to the length of the crown. Conservation of dentin is critical in post placement and dictates a post diameter that requires minimal canal instrumentation. Parallel post designs offer increased retention over tapered designs.^{37,38}

Active Posts

Active post designs rely on some form of mechanical engagement of cutting flutes into dentin to gain increased retention. One active post design, the Flexi-Post by EDS, purports to provide the retention of an active post while avoiding the potential stress on the root of a conventional solid active post design. As pointed out by Manning and others,⁴⁵ for the Flexi-Post design, the change in diameter provided by the slot in the post is minimal. The post compresses to an ellipse whose greatest width is almost equal to the original diameter. Standlee and Caputo⁴⁶ showed Flexi-Posts generated significant stress levels comparable with other active post designs. While the additional retention of an active post has appeal, any active post design induces more stress into a root than a passive design.

Carbon Fibre Posts

There has been a lot of interest in carbon fibre post systems, specifically the composipost. These claims include ease of

removal for retreatment (apparently valid), a modulus of elasticity (Young's) close to natural tooth, which decreases the risk of stress concentrations, and a high level of retention because the post bonds to the resin system used to retain it in the root. Sidoli and others²⁵ showed in vivo crowns retained with composiposts failed under 63% of the load required to break para-post retained crowns. Purton and Love⁴⁷ showed bonded para-posts to have 168% of the retention of carbon fibre posts. The suggestion that a Young's modulus close to tooth is an advantage is questionable when the coronal restoration will be a rigid cast metal or ceramic crown. The increased flexibility in the coronal and radicular tooth structure resulting from these posts should cause increased, not decreased, stress concentrations at the crown margins. Despite the preceding, Fredriksson⁴⁸ and others showed an almost 100% success rate in a retrospective study of 236 teeth restored with carbon fibre posts for over two years. Carbon fibre posts may offer promise, but with conflicting evidence and limited clinical trials, they cannot be recommended for routine use. The clinical evidence is clear in both in vivo and in vitro studies that adequately designed passive posts deliver highly predictable results. Passive, small diameter, parallel post designs are predictable and simple to use and are the design of choice.

Cast or Preformed Post

With a passive round post design as a starting point, the question is whether to use a cast post core or a preformed post-retained amalgam or composite build-up.

A cast post design is indicated where alignment of the proposed crown is significantly different from the inclination of the canal, which is often the case with anterior teeth. With most anterior, and some bicuspid teeth, there is also inadequate room for sufficient bulk of build-up material around the post to provide a solid unit. Thus for most anterior teeth and

small bicuspid teeth requiring a post, the choice is a cast post core design. When used, a cast post core should utilize a high-strength type IV gold alloy or a similar high-strength non-precious alloy. Preformed posts with a direct build-up work very well in posterior teeth where there is room for sufficient bulk of build-up material. Canal angulation is infrequently a problem. Preformed posts with an amalgam build-up are often more conservative of tooth structure than cast gold in posterior teeth. They are generally less expensive and quicker to fabricate.

With preformed posts, stainless steel (SS) posts are stronger for any given size than titanium posts and they are more radiopaque. This radiopacity is an advantage, making a post easier to identify clinically. The Parapost system by Whaledent is currently the only passive, parallel, SS preformed post series on the market available in small diameters. The system provides 0.9, 1, 1.14 and 1.25 mm diameter posts in addition to larger diameters.

Post Head Design

Where a preformed post is used to retain a composite or amalgam build-up, the ability of the build-up material to attach itself to the post is important. Chang and Millstein⁴⁹ tested the retention of Paraposts and Unity posts by Whaledent, and the Flexi-post by EDS with two types of composite build-up as well as amalgam. They found that the amalgam core was significantly more retentive than either composite core. Their results show the importance of the retentive features built into a post head. When trimming preformed posts, it is essential that this feature be retained. Use of preformed posts without such features should be avoided.

Post Cements

From the perspective of the ability to retrieve the post in the case of fracture or for orthograde endodontic retreatment, the use of a resin cement is contraindicated. In addition, the ability of resin cements to provide long-term resistance to coronal leakage is dependent not

only on the longevity of the dentin bond but also on the bond to the post. Both are unproven. There is little or no evidence that the increased retention offered by these cements is a factor in clinical success where adequate post length can be obtained. In fact, Standlee and Caputo⁵⁰ warn that too much retention may predispose a tooth to fracture. ZnPO₄, and resin modified glass ionomer cements such as vitremer luting, offer adequate retention and resistance to leakage and simplify post removal. Pure glass ionomer cements should work as well but are sensitive to moisture or the lack of it in a canal when setting. The use of resin cements should be reserved for cases outside of these criteria where adequate post length and retention are not available.

Post Hole Preparation

It is possible to disturb the apical seal during post-hole preparation. A 4 to 5 mm apical seal of gutta-percha is recommended based on research by several authors.⁵¹⁻⁵³ Mattison,⁵¹ Camp,⁵² Suchina and Ludington,⁵⁴ and Haddix and others⁵⁵ reviewed a range of techniques for post hole preparation and the removal of gutta-percha. Mattison and others, Camp and Todd, and Suchina and Ludington found little difference between mechanical removal with Gates-Glidden burs and removal with a hot plugger, while Haddix and others found that removal with a warm plugger produced the least leakage. Gates-Glidden burs offer a simple and predictable method for the removal of gutta-percha.

Discussion

The restoration of anterior teeth needs better criteria on which to base restorative decisions. Even knowing when to place a crown on an anterior tooth is very hard to determine. The issue of leakage with endodontically treated teeth is of concern: how much leakage is too much? Does the degradation of dentin bonding agents over time present a concern for clinically significant leakage under build-ups or along posts? This paper does not provide guidelines for the restora-

tion of compromised endodontically treated teeth nor indicate how to restore structural integrity to existing crowns that have had an endodontic access placed through them. Both areas need research and guidelines to aid the clinician in restoring these teeth.

Summary

When restoring an endodontically treated tooth, the first step is to assess the level of predictability involved in the restoration. If the tooth meets the previously outlined criteria, then the following approach is recommended.

On anterior teeth with intact crowns, simply closing the access with composite is as successful as placing a crown. Where significant coronal destruction has occurred, use a crown with a cast post core.

A crown is indicated on all endodontically treated posterior teeth. In preparing the tooth, parallel ferrule walls are essential and should be a minimum of 2 mm long apico-coronally. In addition, the thickness of the remaining dentin should be no less than 1 mm on the buccal and lingual wall areas, and optimally interproximally as well.

For the build-up use amalgam, and where inadequate pulp chamber depth remains to retain the build-up, a preformed post should be placed. On some posterior teeth such as small upper first bicusps, cast gold post cores will be preferable to amalgam where tooth size prevents adequate bulk of build-up around the post.

Where a post is needed, use a small diameter, passive round post requiring a minimum of dentin removal and use a post length that extends into the root past the crown margin by the length of the crown. Cement the post with ZnPO₄ or a hybrid resin/glass ionomer cement, leaving an apical seal of 4 mm of gutta-percha. ■

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