Figure 11: An endodontically treated lower bicuspid that has been subjected to clearing and stained methylene blue for 40 days and following the removal of the cervical layer of cementum, exposed to human saliva (Berutti, 1996)

dead space of composite resin and the uncured resin that has been exposed to eugenol are also a source of formaldehyde residue (Oysaed et al, 1986). Formaldehyde is an antigen and may also cause destruction of the cementum and the periodontium or attachment apparatus, which may also contribute to endodontic failure (Langeland et al, 1971). This could explain the chronic inflammation that often occurs in the gingival sulcus opposite deeply placed composite cores.

Posts

When there is inadequate tooth structure remaining to support the final restoration a post may be required. The materials that are chosen should meet the same requirements as those for core materials, i.e. they should have physical properties that are similar to tooth structure, they should be adaptable and inert.

Posts must have adequate stiffness or modulus of elasticity and compressive strength. Insufficient stiffness and strength may lead to deformation of the post and localization of force, which could cause radicular fracture. Perversely excessive stiffness can also create radicular fracture (Standlee and Caouto, 1978; Hunter et al, 1989; Trope and Maltz, 1985). A custom fit cast gold post has a modulus of elasticity and a compressive strength that is ideal (Tables 1 and 2), it can be cast to fit the endodontic cavity space precisely and it is inert.

Preformed posts have also been demonstrated to provide satisfactory results and may be more time and cost effective (Torbjorner et al, 1985). Preformed posts combined with amalgam have also been demonstrated to be superior to posts with glass ionomer or posts with composite resin cores. In simulated chewing experiments, Kavorich et al (1992) demonstrated that posts combined with amalgam required more than one million chewing cycles prior to notable failure, whereas restorations with posts and composite failed 83% of the time during the same period. All post-endodontic restorations with posts and reinforced glass ionomer cement cores failed.

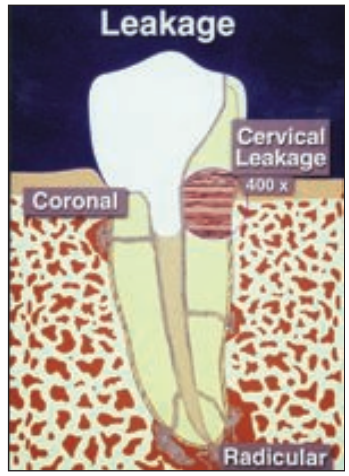


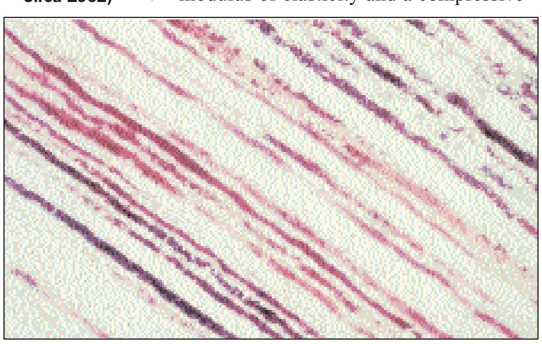
Figure 13: Illustration of radicular (primary), coronal (secondary) and cervical (tertiary) leakage

Cements

The most popular cements in use today are zinc phosphate cement, polycarboxylate cement, glass ionomer cement, composite resin cements and composite hybrid cements. Composite resin and glass ionomer cements are predisposed to leakage in endodontically treated teeth

Figure 14: A photomacrograph of an endodontically treated upper lateral incisor. The glass ionomer cement core surrounding the post has failed. Radial fractures in the cement can be seen extending laterally from the center of the post

Figure 12: Bacterial penetration of patent dentinal tubules exposed to saliva (Stanley H, Circa 1962)



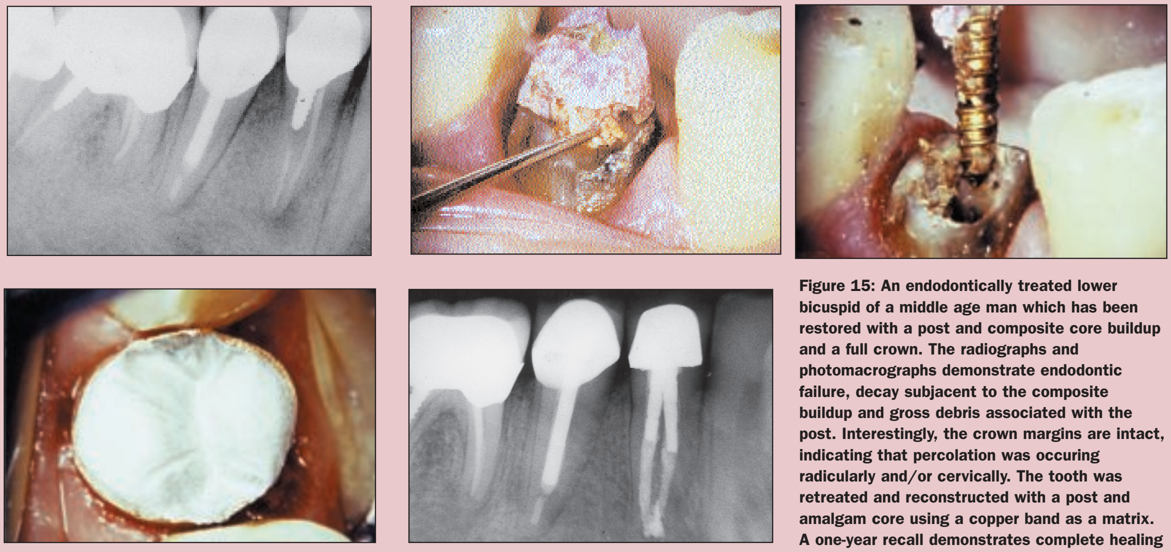


Figure 15: An endodontically treated lower bicuspid of a middle age man which has been restored with a post and composite core buildup and a full crown. The radiographs and photomacrographs demonstrate endodontic failure, decay subjacent to the composite buildup and gross debris associated with the post. Interestingly, the crown margins are intact, indicating that percolation was occuring radicularly and/or cervically. The tooth was retreated and reconstructed with a post and amalgam core using a copper band as a matrix. A one-year recall demonstrates complete healing

and are incompatible with endodontic filling materials. Furthermore, endodontics is not universally successful and endodontic retreatment is often required. Although these materials leak they become interlocked with the post and intaglio of the canal and cannot be easily removed without predisposing the tooth to fracture (Mendoza et al, 1997).

Zinc phosphate cement remains one of the most widely used dental adhesives because of its ease in manipulation and because of its long history of success (Schwartz, 1996). It is also compatible with zinc oxide and eugenol. In addition, the mechanical bond that is created using zinc phosphate cement can be broken without predisposing the tooth to radicular fracture (Mendoza et al, 1997).

Table 2: Compressive strengths of dental materials

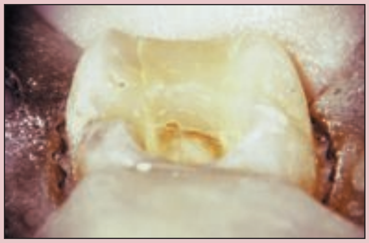
Materials	Elastic Modulus lbs/in^2
Scotch Bond	500-600
Gluma	1,500-1,800
Tenure	1,500-1,800
Glass ionomer	8,000-9,000
Amalgam	60,000-70,000
Cast gold	32,000-89,000

Standlee and Caputo, 1988 and Leinfelder, 1993

Rationale, treatment, strategy and design

The ideal post-endodontic restoration would be completely compatible with tooth structure, dimensionally stable, truly adhesive and biologically inert. Clinical and scientific review of the materials indicate that glass ionomer cement is soluble and has low compressive strength. Composite bonding materials also have low compressive strengths, are hydroscopic and incompatible with zinc oxide and eugenol. These materials must then be eliminated for post-endodontic restorations.

Conversely, amalgam has a modulus of elasticity that approximates human enamel and dentin with a compressive strength in excess of 60,000psi and a coefficient of thermal expansion and contraction, which is also comparable (Table 3). It is completely adaptable to the access cavity and may often be used as a complete post-endodontic restoration eliminating the need for long posts that may themselves predispose teeth to radicular fracture (Nayyar, 1980). The material is non-porous and insoluble and it is one of the few materials that is impenetrable, forming a corrosive seal that improves with time. The amalgam post-core can be adapted with a matrix band or copper



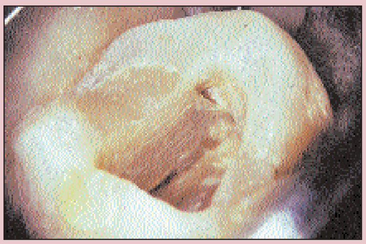


Figure 16: An endodontically involved lower molar demonstrating a class II composite restoration with a material void in the gingival and axial line angles

band and placed immediately after treatment to ensure the complete and final seal of the endodontic cavity space. The depth of the amalgam in the orifice area should be below the level of the attachment to eliminate cervical leakage, but not placed deeply in the canal, again, guarding against radicular fracture. The cavity space should be cleansed with solvent to remove any remaining sealer of debris. Copalite (Roghanizad, Jones, 1986) may also be used to help cleanse the chamber and to enhance the coronal seal until a corrosion barrier has developed (Figure 17).

As previously mentioned posts can not be demonstrated to strengthen teeth and may predispose them to fracture thus they should be avoided. When 2mm of sound coronal tooth structure remains a post is not required (Assif and Gorfil, 1994). Several studies demonstrate that the amount of remaining tooth structure was more important to retention or prevention of radicular fracture than the post design itself (Sorensen and Engelman,1990; Assif and Gorlif, 1994; Hunter et al, 1989) and that a 1mm ferrule design in coronal tooth structure significantly reduced the likelihood of failure. Crown lengthening procedures, then should be considered in all teeth with a minimum of remaining tooth structure and procedures which eliminate further tooth structure to create post spaces for specilized posts should be abandoned.

Standlee et al (1978) demonstrated that the more deeply the post is placed the more retentive it became. Hunter et al (1989) however, demonstrated that the post did not gain increased retention beyond two-thirds of the length of the root. In addition posts that were longer than two thirds of the length of the root jeopardized the apical seal. Further, increasing the diameter of the post does not provide a significant increase in retention, however, it can increase the stiffness and predispose the tooth to fracture (Standlee, Caputo, 1978; Hunter et al, 1989; Trope, Maltz, 1985).

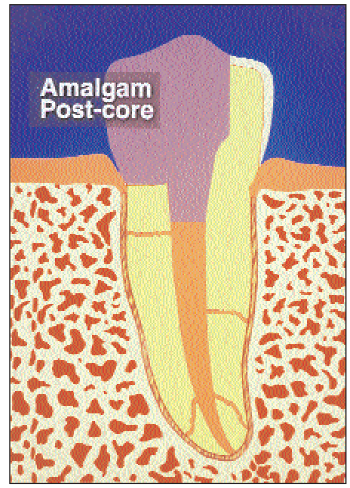


Figure 17: An illustration of a well placed amalgam post-core restoration. Placement below the level of the sulcus and the periodontal attachment is noted

When these concepts are combined post design is more forthcoming (Table 4). Modern endodontic cavity preparations by nature, undermine existing tooth structure. Removal of additional tooth structure after endodontics to accommodate a post is counterproductive or destructive. The post then should be custom made using Type II or Type IV cast gold or a preformed post should be trimmed or tapered to fit the existing endodontic cavity space that remains. This can usually be done using prosthetic pliers to hold the post of adequate length and size and a tapered diamond burr to trim the post (Figure 18). Finally the post should be cemented with zinc phosphate cement which is compatible with endodontic sealer and reversible, if endodontic treatment is required. Following post placement the core portion can be constructed using amalgam similar to the above.

There are several situations when there

Table 3: Coefficients of thermal expansion

Material	Coefficients of therma expansion (x10-6/ºC)
Enamel	10
Dentin	12
Gold	11
Acrylic resin	50-75
Amalgam	25

Craig, 1997

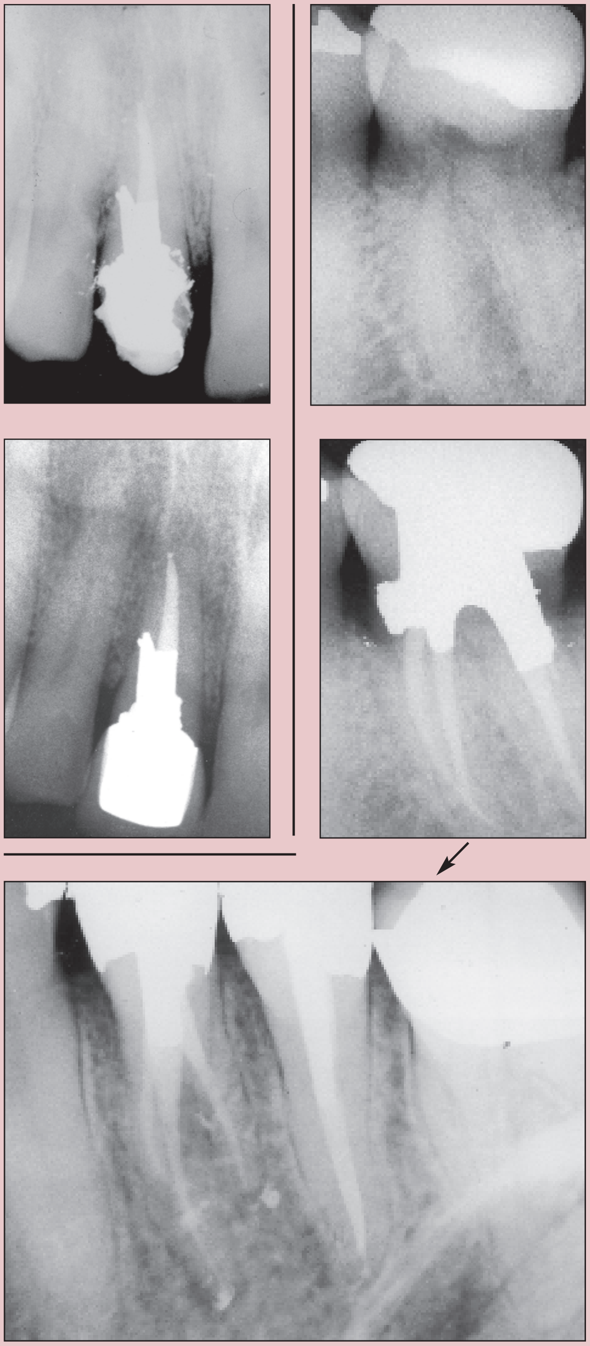


Figure 19: Radiographs of an upper anterior tooth with a perforation defect in the upper portion of the chamber. Post placement with cast metal would be predisposed to failure whereas amalgam serves as a seal for the perforation and as a post-endoodntic restoration.
A lower molar with a significant resorptive defect at the level of the CEJ. The amalgam post core provides adequate coronal restoration and seals the area of restoration simultaneously.
An upper first bicuspid with three roots which are severely dilacerated unamenable to cast metal post placement. The well adapted amalgam post core restoration seals the chambers three-dimensionally eliminating the possibility of coronal and cervical leakage and providing adequate resistance to coronal fracture

is a minimum of coronal tooth structure but cast metal or preformed metal restorations are impractical or undesirable and a dimensionally stable, homogenous material such as amalgam is irreplaceable. These would include teeth that are compromised restoratively and predisposed to secondary decay e.g. teeth that are deeply decayed, perforated, resorbed, or roots that are severely curved or divergent.

There remains a small constituency which questions the safety of amalgam. Hundreds of well designed studies substantiate the safety and effectiveness of this material. A review of the physical and biochemical literature indicates that silver amalgamate is a non-dissociable material after 24 hours of setting time. Further, the amount of measurable free mercury during setting is one third the level of residual mercury consumed in the daily diet (Craig, 1997). One of the best studies demonstrating the safety of this material was conducted by Ahlquist et al (1993). It studied a large female population in Western Europe over a 20-year period. They concluded that women with the least number of amalgam restorations experienced the lowest incidence of cardiovascular disease, diabetes, cancer and early death. Although nothing can be touted to be completely safe, amalgam has been and remains a safe, effective and durable material for human tooth restoration. If any further doubt remains, these restorations are encapsulated by the cast metal restorations that are placed following the post-endodontic restoration.

Lastly the requirements for aesthetic dentistry can still be reconciled with these strategies. For anterior teeth requiring a post and core, cast gold remains the material of choice. Unlike non-precious metal posts the hue of Type III or IV gold mimics the dental pulp and provides a more natural color background for anterior crowns. In addition, gold is an inert material which is not predisposed to oxidation and corrosion (Kerschbaum, 1984). For those teeth that do not require posts or crowns, composite resin restoratives could still be considered. The force generated in cusp to fossa rela-

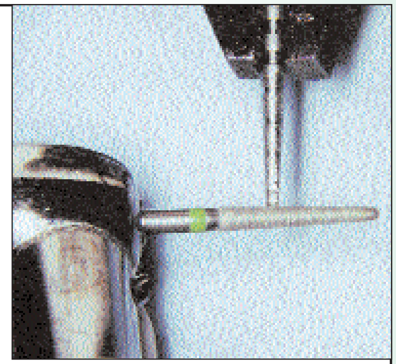


Figure 18: Customization of a preformed post with a tapered diamond bur

tionships in the posterior region is substantially reduced or absent in the anterior region. And although the hygroscopic nature of composite resin may precipitate percolation and endodontic failure the incidence is lower. Placing the material at or above the level of the sulcus can also mitigate tertiary or cervical leakage.

Conclusions

The use of hydroscopic materials such as composite resin in post-endodontic restorations, particularly in posterior teeth, may be contraindicated due to the increased porosity of endodontically treated teeth and the concomitant absorption of bacteria and bacterial endotoxin. Further, the physical and chemical properties of composite resins appear to be incompatible with an ideal material for the restoration of endodontically treated teeth. The usefulness of amalgam and cast gold in post-endodontic restorations is already well established. New materials that are dimensionally stable, truly adhesive and biologically compatible should continue to be evaluated.

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