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Trends in Indirect Dentistry: 2. Post and Core Restorations

Abstract: Modern post preparation techniques reflect a change from what was once considered a prosthodontic procedure to one which marries endodontic principles with sound understanding of mechanical objectives. This article presents a rationale for techniques in materials selection and post-space preparation. A review of literature is presented and practical clinical guidelines are suggested when post placement is considered the treatment of choice.

Clinical Relevance: Modern techniques with a sound understanding of biological and mechanical principles will make the post-retained restoration a predictable treatment option.

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The original post-retained restoration was described by Pierre Fauchard in 1746.[1] Roots of anterior maxillary teeth were selected and gold or silver pivots (posts) were retained with an adhesive called mastic, softened by heat. Crown replacements made from bone, ivory, animal teeth and sound natural teeth were then cemented to the pivots. Today, the post is a universally accepted treatment modality when insufficient tooth substance exists to retain a coronal restoration.

Clinical studies have shown good success for post-retained restorations. Valderhaug *et al.*[2] reported a 25-year study which demonstrated that crowned, root-filled teeth with a high quality endodontic treatment and an optimal morphology of the dowel and core had a similar survival rate as crowned teeth with a vital pulp. It is evident therefore that careful clinical technique and appropriate case selection can make the post-retained crown a predictable treatment strategy. Other papers, however, show that posts do not provide optimal success rates[3] and there is therefore a need to re-assess contemporary materials and techniques.

The last decade has seen fundamental changes in the restoration of the root-filled tooth, including the development of the fibre-based post systems[4] and techniques of bonding to the prepared post-space.[5] Modern post and core techniques embrace a sound understanding of both biological and mechanical principles. No definitive guidelines are, however, available on best clinical practice. There is, in addition, a bewildering array of posts available and numerous techniques described for their placement. This article reviews some of the available evidence and suggests a protocol for predictable treatment using post-retained crowns.

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Case selection

Patient assessment

Careful case selection is important if treatment with an endodontic post is to be successful. This should take into account both patient-related factors and tooth-specific factors. Patient factors are common to all restorative procedures and have been considered earlier in this series.

Tooth assessment

A post should only be considered where there is insufficient tooth substance to retain a coronal restoration. Most root-filled anterior teeth for which crowns are planned will require a post. Posterior teeth, in contrast, very rarely require a post, as the pulp chamber and coronal root canal space can be used successfully to retain a core.[6] The tooth should be well obturated and free from signs and symptoms of periradicular disease.

Radiographic assessment

An up-to-date radiograph is mandatory and should be a good quality paralleling periapical view. Of particular importance is an assessment of root length, caries and quality of root canal treatment including both length, density and type

of the root canal filling, presence of peri-radicular disease and periodontal support. If a post is to be replaced, additional radiographic views should be considered to assess the length, width, angulation of the post and the potential for perforation or root fracture. A parallax technique should always be employed so that valuable information on the bucco-lingual anatomy of the tooth is not overlooked.

Clinical examination

The clinician should percuss the tooth and palpate soft tissues around the root for tenderness. This palpation also provides clues for the clinician on root angulation within the alveolus and may prevent inadvertent perforation during post preparation. The clinician should be mindful that if insufficient coronal tooth tissue exists to create a ferrule, the subsequent restoration may be predisposed to failure.[7] In these instances, crown lengthening or orthodontic extrusion should be considered as treatment options. Periodontal examination should be carried out and probing depths and mobility of the tooth should be carefully recorded. Poor periodontal support will compromise the success of the restoration.

Clinical techniques

Post selection

Post selection is complicated by a bewildering array of commercially available post systems and techniques. These can be classified in a number of different ways but, in general, will be either prefabricated or custom-made. Posts can also be classified as follows:

- Active or passive;
- Parallel or tapered;
- By their material composition.

Custom-made posts

Custom-cast posts have enjoyed widespread use and were regarded as the 'gold standard' for many years. These have, however, fallen from favour as they incur additional clinical and laboratory stages and require the provision of a temporary post restoration. Impression errors and faults in laboratory processing may render these posts ill-fitting. In addition, clinical data would suggest that custom-cast posts do not perform as well as pre-fabricated parallel-sided posts.[8] Nonetheless, such posts are of value in situations where direct post placement is impractical. These include cases where correction of unfavourable crown-root angulation is anticipated. Multiple post and core restorations may make direct placement and build-up inefficient. Where short clinical crown height will render a core build-up unretentive for a subsequent crown, a one-piece cast post, core and crown may represent the best treatment option.

Custom posts are most often constructed on a model poured from an impression of the teeth and the prepared root canal. These custom posts can be tapered to conform to the anatomic irregularities of the root canal and the core shaped by the technician for ideal retention and resistance form. Impression systems for constructing custom-made parallel posts are also widely available. These include matched reamers, impression posts and burn-out posts.

Prefabricated posts

Prefabricated posts offer a number of distinct advantages over custom-cast posts. Post preparation, cementation and core build-up can be completed at the same appointment. This obviates the need for a temporary post crown and the extra time and cost associated with a custom-cast post and core.

Active posts vs. passive posts

Active posts (screw-type posts) are threaded and are designed to engage the walls of the canal. These have been shown to be more retentive than passive posts which are designed to be retained solely by the luting agent.[9] Stress concentration with active posts may, however, predispose to root fracture.[10] Clinicians should only consider use of active posts in short roots where a passive post would be unretentive.

Parallel posts vs. tapered posts

Laboratory-based studies have shown better retention for parallel-sided posts when compared to tapered post designs.[11] Clinical trials have also shown the superiority of traditional metal-based, parallel-sided posts when compared to tapered posts.[8]

Root canal anatomy generally presents a tapered shape and, accordingly, preparation for a parallel-sided post may necessitate over preparation of the apical post-space to maintain good post adaptation coronally. Modern endodontic rotary preparation techniques create canals with a tapered shape from crown to apex and greater degrees of taper than traditional hand instrumentation techniques. This has been shown to have a significant effect on post retention in lab-based trials.[12] Root canal anatomy therefore plays an important role in selection of post shape and the operator should assess this carefully.

Fibre-based posts

In 1990, Duret *et al.*[4] reported a non-metallic material for the fabrication of posts based on the principle of carbon–fibre reinforcement**.** Laboratory-based studies have shown that these pre-formed posts have a high tensile strength[13] and a modulus of elasticity similar to that of dentine.[14] Rigid metal posts resisted lateral forces without distortion and hence this stress was transferred to the less rigid dentine, which could lead to root fracture. These posts are cemented with resin cements which are bonded to the root canal dentine and a core is built up directly with composite resin. Thus the root dentine, luting cement, post and core form a unified structure which is thought to allow even distribution of stresses between the post, core and the dentine.

Fibre-based posts are generally epoxy resin-based, with fibres running along

Figure 1. Different fibre-based post types. From left to right: *Parapost Fibre Lux #3, #6, Endo Light Posts #1, #2, #3, DT Light Post #2* and *#3*.

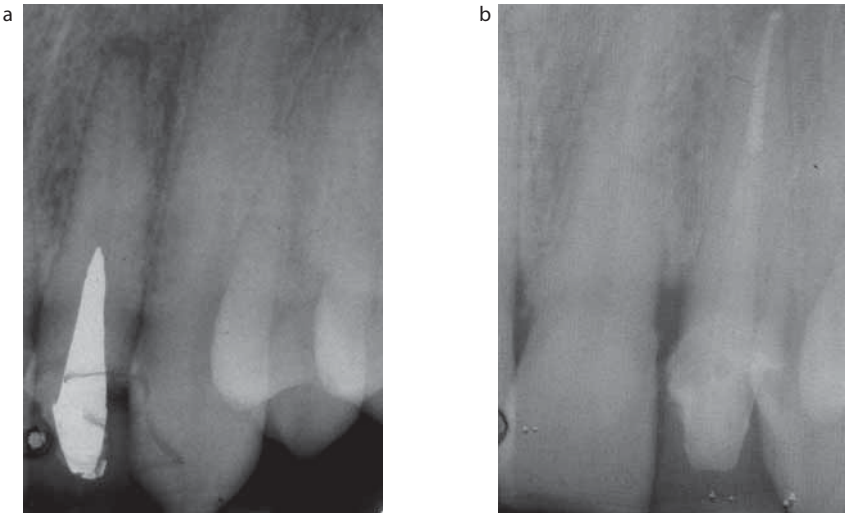

Figure 2. (a) Pre-operative radiograph. **(b)** Postoperative radiograph.

the long axis of the post. A wide variety of posts shapes are available and include parallel-sided, tapered, smooth and serrated forms (Figure 1). Carbon-fibre posts are black in colour and do not lend themselves to aesthetic restorations with all-ceramic units. This has led to the introduction of the quartz-fibre posts which are translucent and more tooth-coloured. These now dominate the market. These posts are also called glass-fibre and silica-fibre. Recent reviews of fibre-based post systems and their properties are available.[15,16]

Many laboratory studies have been carried out with fibre-based posts. A systematic review of fibre-based post research[15] would suggest that *in vitro* evidence is conflicting and may not reliably inform clinical practice.

Early clinical results are, however, very encouraging.[17-21] Fibre-based posts have been shown to have excellent success rates. Of particular note in retrospective clinical analyses is that failure owing to root fracture is very unusual. This type of failure generally necessitates extraction of the tooth and is a clear disadvantage of metal-based post systems. Duret *et al.*[4] postulate that the similar modulus of elasticity of the fibre post and dentine allows the posts to flex under stress. A rigid metal post will, however, transfer all stress directly to the root and therefore predispose to root fracture. Where fibre-based posts need to be removed, available literature would suggest that this is relatively straightforward.[22,23]

These posts are now widely used clinically in Europe and the United States.

Laboratory studies have suggested superior retention for parallel-sided posts,[24] however, clinical studies have shown no significant differences in failure between parallel and tapered fibre-based posts.[19]

Boudrias *et al.*[25] argue that remaining tooth structure and post adaptation to the canal walls represents an important element in the biomechanical performance of the prosthetic restoration. This has led to the development of a tapered post (*DT Post*, RTD, St Egreve, France) with a unique double taper which they report conforms more closely to root canal anatomy. This allows minimal removal of root canal dentine in post preparation and therefore minimizes the risk of perforation and weakening of root structure. Other tapered fibre-based posts are available, eg *Tenax* (Coltène/Whaledent, Cuyahoga Falls, OH, USA).

A technique has been described for the chair-side construction of custom-shaped composite/fibre-based posts,[26] which is useful for restoration of teeth with irregular and wide canals. These might include teeth with immature root anatomy, iatrogenically damaged from previous post treatment or with caries in root canal dentine. A fibre-based post is placed into a prepared canal along with a dual-curing resin cement without etching or bonding procedures. This is cured and the post subsequently removed. Further curing of the relined post takes place and the post is subsequently cemented with a dual-cure resin cement after etching and bonding to the canal dentine. However, caution is necessary with this technique where undercuts may preclude post removal.

Timing of post placement

The ideal time to place a post within the root canal of a tooth is as soon as the obturation of the tooth has been completed and verified radiographically.[27] This coronal seal will prevent potential bacterial contamination of the root canal system which may lead to endodontic failure.[28] Thus it should be possible to place the root canal filling and the definitive post without removing the rubber dam. The clinician who is endodontically treating the tooth will also be aware of the anatomic complexities of the root canal system and canal curvature. Figure 2 demonstrates a single-visit re-root canal treatment and post and core placement with dismantling of the existing restoration. It should be noted that the fibre-based post used to restore the tooth has a similar radio-density as gutta-percha.

Coronal tooth preparation

Before post placement and core build-up, the tooth should be prepared for the definitive coronal restoration, maintaining as much coronal dentine as possible. Straight line access will help prevent inadvertent root perforation and

Figure 3. Good access allows predictable gutta-percha removal.

ensure meticulous removal of gutta-percha and root canal sealer (Figure 3). Careful coronal preparation ensures a predictable dentine surface for subsequent core build-ups.

Isolation

Good isolation is mandatory in preparation and placement of a post. Rubber dam placement prevents ingress of saliva in the post-space and allows greater predictability when bonding to root dentine. In addition, rubber dam prevents aspiration or contamination of the post, allows improved vision and protects the patient from chemical agents used to prepare root dentine.

Post-space preparation

Magnification in the form of loupes or a microscope is invaluable in preparation of the post-space and allows visualization of root canal anatomy, coronal gutta-percha lingering on root canal walls and predictable control of dentine bonding inside the post-space. Length assessment should be made from a radiograph before canal preparation begins. Determining post length is often relatively subjective and much depends on root canal anatomy. The clinician should be guided by the need to leave at least 4–5 mm of apical gutta-percha. In this respect, in a recent study, Abramovitz *et al.*[29] have shown that 3 mm of apical root filling provides an unreliable apical seal. Another study has suggested a 97% success where post length is at least equal to crown height. The operator must also be mindful to avoid canal perforation in the thinner apical dentine. The post-space should be made no wider than is necessary to place a post of adequate diameter. In general, when size-matched post reamers are used and apical resistance is initially felt, there is no need to increase post diameter. Most prefabricated post systems include a radiographic guide which can be placed on periapical radiographs and are helpful in assessing width and length of potential posts.

Figure 4. Careless preparation technique can lead to perforation.

Figure 5. Cleaning the post-space with an interdental brush.

Figure 6. Etching post-space and coronal dentine.

Gutta-percha removal is most easily carried out with rotary instruments. If the root canal is being obturated at the same visit as post-space preparation, the use of an apical warm vertical condensation technique, eg *System B* (Sybron Endo, Orange, CA), greatly simplifies this process.

Post-space preparation for specific preformed posts should follow manufacturer's instructions. When using post preparation reamers, start with the smallest bur first and gradually increase the size in sequence. A careful technique at a slow speed or using reamers by hand means that there is less risk of perforation (Figure 4). Use of sodium hypochlorite is useful between each instrument to remove debris and is mandatory in cases where coronal canal contamination is suspected. After the final reamer has been used, a spiral interdental brush dipped in alcohol may be useful to remove any small particles of sealer and gutta-percha, thus leaving a clean dentinal surface (Figure 5). Any remaining gutta-percha or sealer on dentinal walls should be identified at this stage and carefully removed with an endodontic explorer. Such debris has been shown to occlude dentinal tubules and inhibit dentine bonding.[30] It is not normally necessary to prepare an anti-rotational notch as any irregularities in the root face will prevent rotation of the post and core. An anti-rotation notch may weaken the coronal dentine and predispose to root fracture.

Post adjustment

Posts should be adjusted carefully according to manufacturer's instructions. Parallel-sided posts are normally adjusted apically, leaving a retentive coronal portion ideally placed to support the core build-up. Tapered posts are adjusted coronally. Fibre-based posts should be cut with high speed diamond instruments. Wire cutters should not be used as these may weaken the post. Posts should normally be adjusted so that, after core build-up and preparation, the post material is surrounded by composite.[31] The post should be tried in the clean canal and confirmed as fitting at the appropriate working length. The post should be etched and bond applied if recommended by manufacturer's instructions.

Dentine preparation

Conventional cements

The post-space should be cleaned carefully with alcohol and an interdental brush. Drying with the triple air syringe is unpredictable at removing moisture in the canal and paper points should be used. The conventional cement selected should be mixed to a luting consistency and placed in the canal with a lentulo. This allows an even distribution of cement within the post-space. The surface of the post should be lightly coated with

Figure 7. Canal irrigation.

Figure 8. Gentle drying maximizes bond strengths.

cement and the post pumped firmly to length, taking care to prevent any trapped air bubbles. The post should be maintained at working length till the cement has set, at which stage any excess can be removed.

Resin-based cements

Resin-based cements have a number of physical advantages over conventional cements that have made them popular for cementing posts. These cements bond to dentine when a dentine bonding agent is applied and exhibit improved retention,[32] and less microleakage[33] than conventional cements. The fibre-based post restoration therefore appears to marry the strength of resin-based cements whilst permitting retreatment if necessary.

Bonding to root dentine is technique sensitive and more time consuming than conventional cementation techniques.[34] Phosphoric acid etch should be placed with a syringe to fill the deepest part of the post-space (Figure 6). It can be difficult clinically to wash etch from the post-space and the use of a syringe with an irrigating needle is recommended (Figure 7). Drying of the dentine with paper points is recommended as this will prevent desiccation, which may in turn compromise the bonding surface (Figure 8). Bonding agent should be placed with a brush. The use of tapered microbrushes (Figure 9), which conform well to root canal anatomy, have been recommended for this purpose.[35] Bonding resin should be blotted apically with paper points as pooling and subsequent cure of the resin may impede fit of post to length. Ferrari and Mannocci have shown that a one-step bonding agent does not perform as effectively as a traditional three-step bonding agent in preparing root dentine.[36] It is difficult to ensure that all of the bonding agent is cured within the canal, unless self-cure materials are used, eg *Excite DSC* (Ivoclar/Vivadent, Lichtenstein).

Self-cure or dual-cure resin cements should be used for luting because of limited light penetration into the root, even with translucent posts.[37] A newly introduced one-step, self-etching, resin-based luting cement has been introduced (*Rely-X Unicem*, 3M Dental Products, St Paul, MN, USA) which reduces the technique sensitivity of bonding posts. Laboratory results are already encouraging[38–40] and greater ease of clinical application may make luting posts with resin-based cements more predictable. It should be noted that some resin-based cements may set prematurely if a lentulo is used, so this is not advisable. Luting must be performed quickly and carefully to ensure that the post is completely seated prior to cement setting (Figure 10). The post should abut the apical gutta-percha; empty canal space may predispose to endodontic failure.[41]

Figure 9. *Composibrush*™ (RTD, St Egreve, France).

Figure 10. Definitive post placement.

Temporary post crowns

A direct post obviates the need for a temporary post-crown. Indirect techniques will normally make these a necessity in areas of aesthetic importance. These restorations are, however, prone to failure and are associated with significant microleakage.[42] Where possible, therefore, an apical barrier should be placed against gutta-percha after post-space preparation prior to cementation of the temporary post, and the definitive post and core cemented as soon as possible.

Core build-up

The purpose of the post is to retain the core, which in turn helps retain the crown. With cast post and cores, the core is formed on the post directly on the tooth or indirectly on a cast. The general shape and orientation of the core is developed during fabrication. Prefabricated posts are used in combination with a restorative build-up material which is formed after cementation of the post. The core should be designed to offer optimal retention and resistance form for the subsequent crown to be placed on the tooth. The choices are glass-ionomer materials, amalgam or composite resin.

Glass-ionomer materials, including resin-modified glass ionomer, do not possess sufficient strength as a build-up material[43] and should not be used in teeth with extensive loss of tooth structure.

Amalgam has been used as a build-up material, with well-recognized strengths and limitations. It has good physical and mechanical properties[44] and works well in high stress areas. In many

Figure 11. Composite core build-up.

cases, it may require the addition of pins or other methods to provide retention and resistance to rotation. Placement may be difficult where there is minimal coronal tooth structure. In addition, crown preparation must be delayed to allow time for the material to set. Aesthetic problems may occur with amalgam where ceramic crowns are planned. There is also a risk of tattooing the cervical gingiva with amalgam particles during the crown preparation. Amalgam does not have any intrinsic properties of adhesion and a bonding system should therefore be used for build-up.[45]

Core build-up for direct posts is most conveniently carried out with a direct placement of resin-bonded composite. Composite is aesthetic and will not adversely affect the shade of translucent all-ceramic restorations. It has high tensile strength and the tooth can be prepared for a crown immediately after polymerization. Composite can be bonded to many of the current posts and to the remaining tooth structure to increase retention.[46] One study[47] has shown composite cores to have fracture resistance comparable to amalgam and cast post and cores, with more favourable fracture patterns on failure. Again, effective isolation with rubber dam during post placement will make subsequent core build-up easier and more predictable (Figure 11). On the negative side, composite shrinks during polymerization, causing gap formation in the areas in which adhesion is weakest. It absorbs water after polymerization, causing it to swell,[48] and undergoes plastic deformation under repeated loads.[44] Adhesion to dentine on the pulpal floor is generally not as strong or reliable as to coronal dentine.[49] Strict isolation is an absolute requirement. If the dentine surface is contaminated with blood or saliva during bonding procedures, the adhesion is greatly reduced. Although composite resin is far from ideal, it is currently the most widely used build-up material. Composite is not a good choice, however, with minimal remaining coronal tooth structure, particularly if isolation is a problem.

Conclusions

Contemporary post placement technique embraces sound mechanical objectives and newer endodontic principles. Advances in preparation of the post-space, post materials and luting cements mean that greater predictability for restoration of the root-filled tooth can be achieved.

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References

1. Fauchard P. Le Chirurgien Dentiste ou traité des dents, etc. 2me édition, corrigée et augmentée. Ouvrage enrichi de ed: Paris, 1746.
2. Valderhaug J, Jokstad A, Ambjornsen E, Norheim PW. Assessment of the periapical and clinical status of crowned teeth over 25 years. *J Dent* 1997; **25**(2): 97–105.
3. Creugers NH, Mentink AG, Kayser AF. An analysis of durability data on post and core restorations. *J Dent* 1993; **21**(5): 281–284.
4. Duret B, Reynaud M, Duret F. [New concept of coronoradicular reconstruction: the Composipost]. *Chir Dent Fr* 1990; **60**(540): 131–141.
5. Ferrari M, Mannocci F, Vichi A, Cagidiaco MC, Mjor IA. Bonding to root canal: structural characteristics of the substrate. *Am J Dent* 2000; **13**(5): 255–60.
6. Nayyar A, Walton RE, Leonard LA. An amalgam coronal-radicular dowel and core technique for endodontically treated posterior teeth. *J Prosthet Dent* 1980; **43**(5): 511–515.
7. Stankiewicz NR, Wilson PR. The ferrule effect: a literature review. *Int Endod J* 2002; **35**(7): 575–581.
8. Torbjorner A, Karlsson S, Odman PA. Survival rate and failure characteristics for two post designs. *J Prosthet Dent* 1995; **73**(5): 439–444.
9. Cohen BI, Pagnillo MK, Newman I, Musikant BL, Deutsch AS. Retention of four endodontic posts cemented with composite resin. *Gen Dent* 2000; **48**(3): 320–324.
10. Mentink AG, Creugers NH, Meeuwissen R, Leempoel PJ, Kayser AF. Clinical performance of different post and core systems – results of a pilot study. *J Oral Rehabil* 1993; **20**(6): 577–584.
11. Standlee JP, Caputo AA, Hanson EC. Retention of endodontic dowels: effects of cement, dowel length, diameter, and design. *J Prosthet Dent* 1978; **39**(4): 400–405.
12. Pettiette MT, Phillips C, Trope M. Effect of endodontic instrument taper on post retention. *J Endod* 2003; **29**(1): 65–68.
13. King PA, Setchell DJ. An *in vitro* evaluation of a prototype CFRC prefabricated post developed for the restoration of pulpless teeth. *J Oral Rehabil* 1990; **17**(6): 599–609.
14. Asmussen E, Peutzfeldt A, Heitmann T. Stiffness, elastic limit, and strength of newer types of endodontic posts. *J Dent* 1999; **27**(4): 275–278.
15. Bateman G, Ricketts DN, Saunders WP. Fibre-based post systems: a review. *Br Dent J* 2003; **195**(1): 43–48: discussion 37.
16. Stewardson DA. Non-metal post systems. *Dent Update* 2001; **28**(7): 326–332, 334, 336.
17. Ferrari M, Vichi A, Garcia-Godoy F. Clinical evaluation of fiber-reinforced epoxy resin posts and cast post and cores. *Am J Dent* 2000; **13**(Spec. No.): 15B–18B.
18. Ferrari M, Vichi A, Mannocci F, Mason PN. Retrospective study of the clinical performance of fiber posts. *Am J Dent* 2000; **13**(Spec. No.): 9B–13B.
19. Monticelli F, Grandini S, Goracci C, Ferrari M. Clinical behavior of translucent-fiber posts: a 2-year

prospective study. *Int J Prosthodont* 2003; **16**(6): 593–596.
20. Malferrari S, Monaco C, Scotti R. Clinical evaluation of teeth restored with quartz fiber-reinforced epoxy resin posts. *Int J Prosthodont* 2003; **16**(1): 39–44.
21. Mannocci F, Bertelli E, Sherriff M, Watson TF, Ford TR. Three-year clinical comparison of survival of endodontically treated teeth restored with either full cast coverage or with direct composite restoration. *J Prosthet Dent* 2002; **88**(3): 297–301.
22. Gesi A, Magnolfi S, Goracci C, Ferrari M. Comparison of two techniques for removing fiber posts. *J Endod* 2003; **29**(9): 580–582.
23. de Rijk WG. Removal of fiber posts from endodontically treated teeth. *Am J Dent* 2000; **13**(Spec. No.): 19B–21B.
24. Qualtrough AJ, Chandler NP, Purton DG. A comparison of the retention of tooth-colored posts. *Quintessence Int* 2003; **34**(3): 199–201.
25. Boudrias P, Sakkal S, Petrova Y. Anatomical post design meets quartz fiber technology: rationale and case report. *Compend Contin Educ Dent* 2001; **22**(4): 337–340, 342, 344 *passim*: quiz 350.
26. Grandini S, Sapio S, Simonetti M. Use of anatomic post and core for reconstructing an endodontically treated tooth: a case report. *J Adhes Dent* 2003; **5**(3): 243–247.
27. Heling I, Gorfil C, Slutzky H, Kopolovic K, Zalkind M, Slutzky-Goldberg I. Endodontic failure caused by inadequate restorative procedures: review and treatment recommendations. *J Prosthet Dent* 2002; **87**(6): 674–678.
28. Saunders WP, Saunders EM. Coronal leakage as a cause of failure in root-canal therapy: a review. *Endod Dent Traumatol* 1994; **10**(3): 105–108.
29. Abramovitz L, Lev R, Fuss Z, Metzger Z. The unpredictability of seal after post space preparation: a fluid transport study. *J Endod* 2001; **27**(4): 292–295.
30. Serafino C, Gallina G, Cumbo E, Ferrari M. Surface debris of canal walls after post space preparation in endodontically treated teeth: a scanning electron microscopic study. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2004; **97**(3): 381–387.
31. Mannocci F, Sherriff M, Watson TF. Three-point bending test of fiber posts. *J Endod* 2001; **27**(12): 758–761.
32. Hedlund SO, Johansson NG, Sjögren G. Retention of prefabricated and individually cast root canal posts *in vitro*. *Br Dent J* 2003; **195**(3): 155–158: discussion 147.
33. Ravanshad S, Ghoreeshi N. An *in vitro* study of coronal microleakage in endodontically-treated teeth restored with posts. *Aust Endod J* 2003; **29**(3): 128–133.
34. Mannocci F, Bertelli E, Watson TF, Ford TP. Resin-dentin interfaces of endodontically-treated restored teeth. *Am J Dent* 2003; **16**(1): 28–32.
35. Ferrari M, Grandini S, Simonetti M, Monticelli F, Goracci C. Influence of a microbrush on bonding fiber post into root canals under clinical conditions. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2002; **94**(5): 627–631.
36. Ferrari M, Mannocci F. A 'one-bottle' adhesive system for bonding a fibre post into a root canal: an SEM evaluation of the post-resin interface. *Int Endod J* 2000; **33**(4): 397–400.
37. Ferrari M, Vichi A, Grandini S, Goracci C. Efficacy of a self-curing adhesive-resin cement system on luting glass-fiber posts into root canals: an SEM investigation. *Int J Prosthodont* 2001; **14**(6): 543–549.
38. Behr M, Rosentritt M, Regnet T, Lang R, Handel G. Marginal adaptation in dentin of a self-adhesive universal resin cement compared with well-tried systems. *Dent Mater* 2004; **20**(2): 191–197.
39. Kumbuloglu O, Lassila LV, User A, Vallittu PK. A study of the physical and chemical properties of four resin composite luting cements. *Int J Prosthodont* 2004; **17**(3): 357–363.
40. Piwowarczyk A, Lauer HC. Mechanical properties of luting cements after water storage. *Oper Dent* 2003; **28**(5): 535–542.
41. Fishelberg G. Clinical response to a vacant post space. *Int Endod J* 2004; **37**(3): 199–204.
42. Demarchi MG, Sato EF. Leakage of interim post and cores used during laboratory fabrication of custom posts. *J Endod* 2002; **28**(4): 328–329.
43. Mollersten L, Lockowandt P, Linden LA. A comparison of strengths of five core and post-and-core systems. *Quintessence Int* 2002; **33**(2): 140–149.
44. Gateau P, Sabek M, Dailey B. Fatigue testing and microscopic evaluation of post and core restorations under artificial crowns. *J Prosthet Dent* 1999; **82**(3): 341–347.
45. Howdle MD, Fox K, Youngson CC. An *in vitro* study of coronal microleakage around bonded amalgam coronal-radicular cores in endodontically treated molar teeth. *Quintessence Int* 2002; **33**(1): 22–29.
46. Hsu YB, Nicholls JI, Phillips KM, Libman WJ. Effect of core bonding on fatigue failure of compromised teeth. *Int J Prosthodont* 2002; **15**(2): 175–178.
47. Pilo R, Cardash HS, Levin E, Assif D. Effect of core stiffness on the *in vitro* fracture of crowned, endodontically treated teeth. *J Prosthet Dent* 2002; **88**(3): 302–306.
48. Oliva RA, Lowe JA. Dimensional stability of composite used as a core material. *J Prosthet Dent* 1986; **56**(5): 554–561.
49. Kijsamanmith K, Timpawat S, Harnirattisai C, Messer HH. Micro-tensile bond strengths of bonding agents to pulpal floor dentine. *Int Endod J* 2002; **35**(10): 833–839.

April

CPD Answers

1. A, C, D	6. B, C
2. A, B, C, D	7. A, B, D
3. A, B, D	8. B, C
4. A, B, C	9. A
5. B	10. A, D