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Adhesive Restoration of Endodontically Treated Teeth – Current Research

Abstract: Restoring endodontically-treated teeth using adhesively cemented fibre posts is becoming popular in general practice. Clinical studies have been promising, however failures can occur, usually because of de-bonding of the post. Current research, aimed at identifying factors that could improve the adhesion of fibre posts, is described.

Clinical Relevance: Adhesively-retained fibre posts are becoming a popular choice for the restoration of endodontically treated teeth. Dental practitioners should be knowledgeable on the rationale behind these restorations, factors that can lead to failure, and ongoing developments.

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The clinician is now faced with a variety of choices when restoring an endodontically-treated tooth with a substantial loss of enamel and coronal dentine. Does one go for a traditional cast post and core or an adhesively retained fibre post? This article focuses on current research being undertaken to improve the clinical performance of fibre posts.

Rationale behind the development of fibre posts

Laboratory studies have shown that removing the root filling and preparing a post space weakens the root of a tooth.[1] Traditionally, cast precious metal alloy posts and cores and prefabricated metallic posts have been used to replace coronal and root dentine lost because of trauma, caries, iatrogenic damage and root canal treatment. However, clinical retrospective studies have shown that posts cannot strengthen teeth and that post-core restorations may result in root fractures or perforations, post fractures and post dislodgement.[2] The ideal post should transfer minimal stress to the tooth, provide retention and support for the core in such a manner that a cemented crown does not lose its attachment and yet be relatively easy to remove to permit endodontic re-treatment.[3]

In order to fulfil these requirements, carbon fibre posts were developed.[4,5] These consist of unidirectional carbon fibres embedded in an epoxy resin matrix and have an elastic modulus close to that of root dentine.[6] A post with an elastic modulus close to that of root dentine is less likely to induce a root fracture. However, a carbon fibre post is black and could be visible through an all-ceramic crown on an anterior tooth.[7] Therefore, white fibre posts composed of 'quartz and silica fibres' in an epoxy resin matrix were developed. More recently, translucent fibre posts have been developed.[8] Fibre posts are placed into the prepared post space using a frictionless bonded post technique to reduce the risk of root fracture.[8]

However, laboratory and clinical research has shown that failures of fibre post and core restorations often occur through decementation between the fibre post-resin and/or resin root dentine interfaces as a result of inadequate bond strength between these interfaces.[9,10] Current research has been directed towards looking at ways in which adhesion at these interfaces can be improved.

Adhesion to root dentine

Bond strength testing is selected as an *in vitro* test on the basis that the higher the actual bonding capacity of the adhesive, the better it will withstand mechanical stresses such as chewing forces and the longer the restoration will survive in the oral environment.[11] The bond strength test now commonly employed to measure resin-dentine bond strengths is the microtensile bond strength, which was introduced by Sano and others in 1994.[12]

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Previous tests, such as the shear test, had the inherent disadvantage that, at bond strengths higher than 20MPa, cohesive failures of the substrate were more likely to occur leaving the bonded interface still intact.[11] The microtensile test can measure much higher bond strengths, with the majority of failures occurring at the interface. The tested specimens have a very small cross-sectional area, typically 1 mm^2 or less.[12] However, this test is labour intensive and technically demanding. The data obtained from bond strength tests may vary among laboratories throughout the world because of different experimental conditions and, therefore, caution should be applied when looking at the results of similar materials from different centres.[11]

Dentine from the crown, cervical margin and root canal possess different morphological characteristics, which could influence the bond strength of adhesive systems.[13-15] Previous studies have demonstrated that the bond strength of adhesive systems to dentine is dependent on the microstructure of the substrate at the site of bonding, however, this is more evident with acetone- or ethanol-based adhesive systems than with self-etching systems.[15-19]

Adhesion at the cervical margin is established with the dentinal tubules orientated parallel to the surface and studies have shown that the direction of the dentinal tubules appears to be an important variable in hybrid layer formation and high bond strength values [20-22] Cervical regions and inside the root canal exhibit a high tubule density.[14] Studies have shown that resin-dentine bond strengths are lower when the bonding site has a high tubule density.[15,17-19] A recent study examined the bonding efficacy of two adhesives (*Single Bond*, 3M ESPE, St Paul, USA , *Clearfil SE Bond*, Kuraray Medical Inc., Tokyo, Japan) to coronal, cervical and root dentine (unpublished). It was concluded that, when restorations are placed at different bonding sites, consideration should be given to the fact that bond strengths in root canal dentine will be lower; adhesion to crown dentine will be good and adhesion at the cervical margins will depend on the selected adhesive system (unpublished).

It has recently been discovered that, even when a tooth has been endodontically treated, water droplets can be found on the surface of an adhesive placed in a prepared post space.[23] Water droplets were found on the surface of two-step total etch, two-step self-etching adhesives and one-step self-etching adhesives after polymerization in the post space. It was postulated that the water could have come from tubular retention of water following acid etching, residual water in the adhesive, or unbound water present in pulpless teeth. These findings imply that certain adhesives, used in conjunction with chemical or dual-cured resin cements, could be incompatible if the adhesive is permeable.[23]

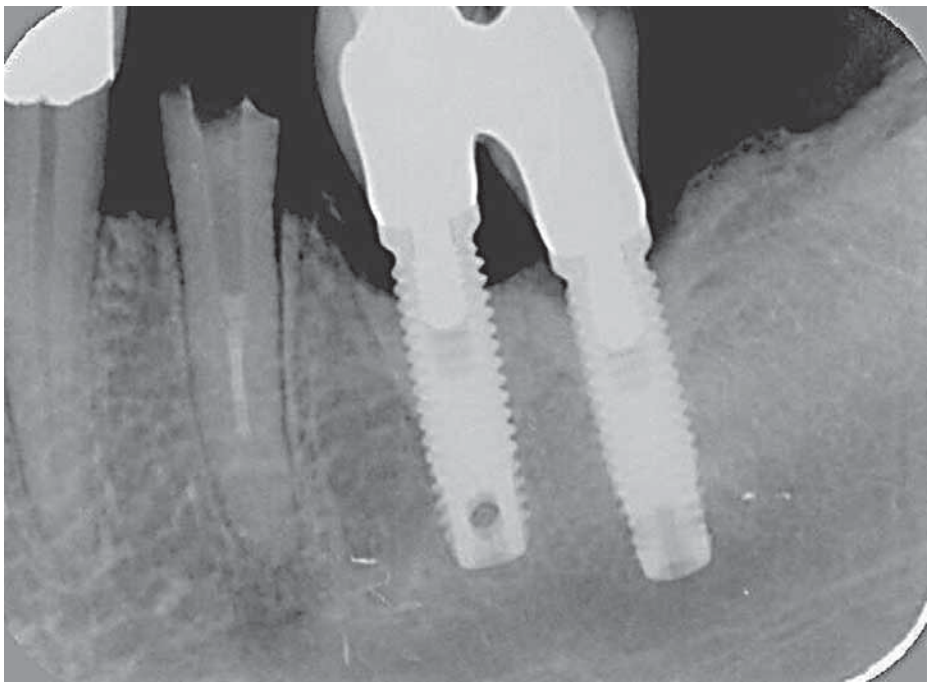

Figure 1. The patient complained about the decementation of a cast post and core from the lower left mandibular second premolar. The periapical radiograph shows the presence of a periapical radiolucency associated with a deficient root canal treatment.

Adhesion to fibre posts

The other important interface is the resin-fibre post interface. Research carried out *in vitro* has recently been published on the adhesion of dual-cured composite resin to two different types of fibre post, zirconium glass fibre posts (*Snowpost*, Carbotech, Ganges, France) and quartz-fibre posts (*Aestheti-Plus*, Bisco Inc, Schaumburg, USA) using different bonding agents.[24] It was shown that bond strengths depended upon the type of post and surface treatment. Coating the fibre posts with a silane coupling agent significantly improved bond strengths.[24] This was true even when the posts (*Snowpost*, Carbotech, France) were silanized during fabrication. It was considered that handling and trimming the posts during the luting procedure may have damaged the surface.[24] This finding has recently been confirmed by another study, which looked at the adhesion of composite resin to *FRC Postec* (Ivoclar-Vivadent, Schaan, Liechtenstein) and *DT Light-posts* (RTD, St Egève, France).[25] Again, bond strengths were improved when the posts were coated with a silane agent. The authors attributed this to coupling of the silane agent to the resin of the core material and exposed fibres of the post.[25]

Other fibre resin core materials, such as *everStick* (StickTech, Turku, Finland), utilize a semi-interpenetrating polymer network structure. The fibres are pre-impregnated with a polmethylmethacrylate, which can be partially dissolved with the application of a light-curing resin. Partial dissolution creates grooves and undercuts on the surface of the fibre frame, enabling micromechanical bonding as well as chemical adhesion.[26] Longitudinal clinical

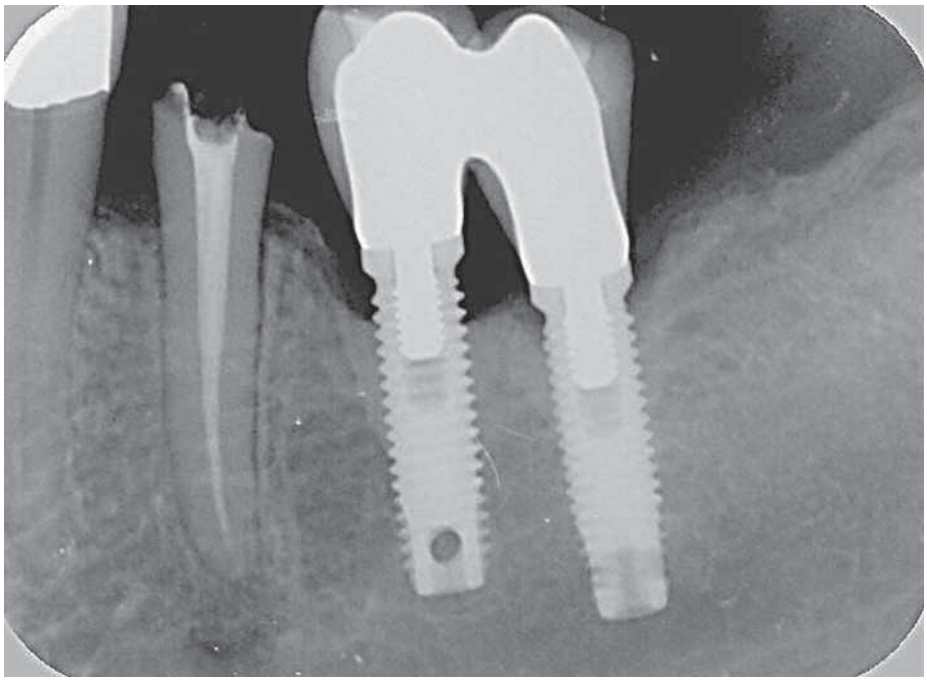

Figure 2. The completed retreatment of the lower left mandibular second premolar. Care was taken not to produce further enlargement of the coronal third of the root canal in order to prevent further cervical loss of tooth structure.

Figure 3. A customized post is constructed by bonding self-curing composite (*Bis-core*, Bisco, Schaumburg, USA) to a prefabricated glass-fibre post (*Snowpost*, Carbotech, Ganges, France). This was necessary to prevent the formation of voids in the cement layer within the coronal third of the root canal owing to a mismatch between the morphology of the root canal and the morphology of the prefabricated fibre post.

Figure 4. The customized post has been cemented using a dual-curing self-etching primer cement (*RelyX*, 3M, St Paul, USA) and prepared for a metal ceramic crown.

studies are required to evaluate these laboratory findings.

Luting fibre posts

As mentioned earlier, fibre posts need to be luted in the prepared post space with adhesive resin cement in order to be adhesively retained. Currently, the practitioner has a choice of chemically-cured, photo-cured or dual-cured resin cements. As with currently available bonding agents, luting cements were developed to adhere primarily to coronal dentine, and it is only post-development that their adherence to root dentine has been investigated. Chemical-cured resin cements will polymerize in the absence of light, which is beneficial if the post does not transmit light. Both chemical and dual-cured resin cements have exhibited good performance in clinical use.[10]

A study comparing the effectiveness of three different resin cements in bonding translucent glass-fibre posts (*FRC Postec*, Ivoclar-Vivadent, Schaan, Liechtenstein) to root-treated teeth has recently been published.[27] The tested cements were a total etch dual-cured resin cement (*Excite DSC/Variolink II*, Ivoclar-Vivadent, Schaan, Liechtenstein), a self-etch chemically-cured resin cement (*ED Primer/Panavia 21*, Kuraray Medical Inc, Tokyo, Japan) and a self-adhesive dual-cure resin cement (*RelyX Unicem* (3M ESPE, St Paul, USA). The total-etch dual-cured resin cement exhibited significantly higher bond strengths than the self-etch chemically–cured resin cement and self-adhesive dual-cure resin cement.[27] The authors attributed this finding to the greater effectiveness of the total-etch adhesive in etching through the thick smear layer, which is created on the root dentine during post space preparation.[27]

The illustrated case shows how currently available materials can be adapted to an unfavourable clinical situation (Figures 1–5).

Recently, new dual-cure composite core materials have been developed.[15,28] These can be injected into the post space to cement the fibre post and to build the core. They could be especially useful in the case of a post space widened through caries. If the post space has become excessively widened in the coronal region, it may be difficult to find a well-fitting fibre post. A resin-based cement would not possess the necessary mechanical properties to withstand repetitive occlusal loading. These new dual-cure composite materials have been shown to bond well to root canal dentine and fibre posts.[3,15,27]

Composite resin core

When placing the composite resin core around the fibre post, the clinician needs to be wary of several things:

- The choice of dentine bonding agent is important. While all-in-one, single bottle adhesives are gaining in popularity through virtue of their simplicity, laboratory studies in two key areas are limited. One area is the type or region of dentine being bonded to, which has been discussed previously, and the other is the durability of the resin-

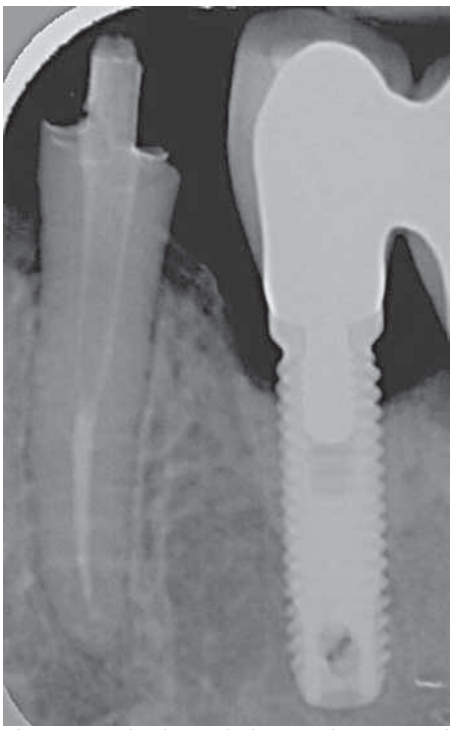

Figure 5. Final radiograph showing the cemented post following the crown preparation.

dentine bond.

■ The resin-dentine bond is subject to hydrolytic degradation over time.[29] The same is true for the silane bond between the glass filler particles and the resin matrix of composite resin. It is important that a good marginal seal is obtained when a crown is placed over a composite core. A poor marginal seal could allow saliva to degrade the luting cement and the underlying composite core through microleakage and nanoleakage.[30] Microleakage is the clinically undetectable passage of oral bacteria, liquids or molecules between a cavity wall and the restorative material.[11] Any composite resin will shrink to some extent and induce stresses between the adhesive and tooth structure, thus creating a gap.[30] Nanoleakage, on the other hand, is a term coined by Sano and others, who discovered that, following acid etching, the adhesive may not infiltrate all the demineralized dentine.[31] Tiny sub-micro spaces are left which could allow the penetration of water, acids and enzymes, leading to degradation of the resin-dentine bond.[30] Clinical studies on this phenomenon are difficult to set up and, as such, it is difficult to predict how much degradation of the resin-bond is necessary before the restoration fails.

■ It is widely accepted that as much supragingival tooth tissue should be preserved as possible in order to improve the fracture resistance of the tooth. This enables any subsequent crown to encircle tooth tissue rather than restorative material, creating a ferrule effect.[32,33] While 1–2 mm of supragingival tissue has been shown to improve the fracture resistance of teeth restored with cast posts and cores, there is, at present, very little published data available on the fracture resistance of teeth restored with fibre posts and composite cores.[32,33]

Clinical studies

Initial published studies on the clinical performance of fibre posts were regarding carbon fibre posts. The performance of carbon fibre posts has been compared to that of cast post and cores.[34] A retrospective study evaluated 100 carbon fibre *Composiposts* and 100 cast post and cores cemented in 200 endodontically treated teeth over a period of four years. Of the *Composiposts* 95%, and of the cast post and cores 84%, were found to be successful. Reports on the clinical performance of glass and quartz fibre posts are beginning to be published. A randomized controlled clinical trial on the behaviour of three types of translucent fibre posts (*Aesthetic Plus*, *DF light-post*, *FRC Postec*) in 225 patients has recently been published.[10] A failure rate of 3.5% was reported, which was because of de-bonding of the post.[10] A similar failure rate, 3.2%, was reported by Ferrari and others, who evaluated the performance of 1304 fibre posts (*Composipost*, *Aestheti Posts* and *Aestheti Plus*) over a period of 1–6 years.[8]

Conclusion

However, failures have been reported to occur through de-bonding at both the resin-dentine and resin-post interfaces. *In vitro* research has attempted to identify factors that could affect the strength of the bond at these interfaces and ways that this could be improved. These include silanization of the fibre post prior to cementation. Further laboratory research is needed on the durability of the bond at the resin-dentine and resin-post interfaces. Initial clinical studies on the long-term performance of fibre post-retained restorations are promising. However, further studies on the performance of fibre posts in a general practice setting are necessary. The continual development of dental adhesives, resin cements and composite core materials makes it difficult to recommend particular materials, and practitioners should be aware of their continuing improvement.

References

1. Bolhuis P, De Gee AJ, Feilzer AJ, Davidson CL. Fracture strength of different core build-up designs. *Am J Dent* 2001; **14**: 286–290.
2. Tamse A. Iatrogenic vertical root fractures in endodontically treated teeth. *Endod Dent Traumatol* 1988; **4**: 190–196.
3. Mannocci F, Ferrari M, Watson TF. Intermittent loading of teeth restored using quartz fiber, carbon-quartz fibre, and zirconium dioxide ceramic root canal posts. *J Adhesive Dent* 1999; **2**: 153–158.
4. Duret B, Reynaud M, Duret F. Un noveau concept de reconstitution cororadiculaire: le Composipost (1). *Le Chir Dent de France* 1990; **540**: 131–141.
5. Bateman G, Ricketts DNJ, Saunders WP. Fibre-based post systems: a review. *Br Dent J* 2003; **195**: 43–48.
6. Duret B, Reynaud M, Duret F. Un noveau concept de reconstitution cororadiculaire: le Composipost (2). *Le Chir Dent de France* 1990; **542**: 69–77.
7. Asmussen E, Peutzfeldt A, Heitmann T. Stiffness, elastic limit, and strength of newer types of endodontic posts. *J Dent* 1999; **27**: 275–278.
8. Ferrari M, Vichi A, Mannocci F, Mason PN. Retrospective study of the clinical performance of fiber posts. *Am J Dent* 2000; **13**: 9B–13B.
9. Martinez-Insua A, da Silva L, Rilo B, Santana U. Comparison of the fracture resistances of pulpless teeth restored with a cast post and core or carbon-fiber post with a composite core. *J Prosthet Dent* 1998; **80**: 527–532.
10. Monticelli F, Grandini S, Goracci C, Ferrari M. Clinical behavior of translucent-fiber posts: a 2-year prospective study. *Int J Prosthodont*

2003; **16**: 593–596.
11. Van Meerbeek B, De Munck J, Yoshida Y, Inoue S, Vargas M, Vijay P *et al*. Adhesion to enamel and dentine: current status and future challenges. *Oper Dent* 2003; **28**(3): 215–235.
12. Sano H, Shono T, Sonoda H, Takatsu T, Ciucchi B, Carvalho R, Pashley DH. Relationship between surface area for adhesion and tensile bond strength – evaluation of a microtensile bond test. *Dent Mater* 1994; **10**: 236–240.
13. Mjör IA. Human coronal dentine: structure and reactions. *Oral Surg* 1972; **33**: 810–823.
14. Ferrari M, Mannocci F, Vichi A, Cagidiaco MC, Mjör IA. Bonding to root canal: structural characteristics of the substrate. *Am J Dent* 2000; **13**: 255–260.
15. Foxton RM, Nakajima M, Tagami J, Miura H. Bonding of photo and dual-cure adhesives to root canal dentin. *Oper Dent* 2003; **28**: 543–551.
16. Akagawa H, Nikaido T, Takada T, Burrow MF, Tagami J. Shear bond strength to coronal and pulp chamber floor dentin. *Am J Dent* 2002; **15**: 383–388.
17. Pereira PNR, Okuda M, Sano H, Yoshikawa T, Burrow MF, Tagami J. Effect of intrinsic wetness and regional difference on dentin bond strength. *Dent Mater* 1999; **15**: 46–53.
18. Yoshikawa T, Sano H, Burrow MF, Tagami J, Pashley DH. Effect of dentin depth and cavity configuration on bond strength. *J Dent Res* 1999; **78**: 898–905.
19. Giannini M, Carvalho RM, Martins LRM, Dias CTS, Pashley DH. The influence of tubule density and area of solid dentin on bond strength of two adhesive systems to dentin *J Adhesive Dent* 2001; **3**: 315–324.
20. Schüpbach P, Krejci I, Felix L. Dentin bonding: effect of tubule orientation on hybrid-layer formation. *Eur J Oral Sci* 1997; **105**: 344–352.
21. Phrukkanon S, Burrow MF, Tyas MJ. The effect of dentine location and tubule orientation on the bond strengths between resin and dentine. *J Dent* 1999; **27**: 265–274.
22. Ogata M, Okuda M, Nakajima M, Pereira PNR, Sano H, Tagami J. Influence of the direction of tubules on bond strength to dentin. *Oper Dent* 2001; **26**: 27–35.
23. Chersoni S, Acquaviva GL, Prati C, Ferrari M, Grandini S, Pashley DH, Tay FR. *In vivo* fluid movement through dentin adhesives in endodontically treated teeth. *J Dent Res* 2005; **84**: 223–227.
24. Aksornmuang J, Foxton RM, Nakajima M, Tagami J. Microtensile bond strength of a dual-cure resin core material to glass and quartz fibre posts. *J Dent* 2004; **32**: 443–450.
25. Goracci C, Raffaelli O, Monticelli F, Balleri B, Bertelli E, Ferrari M. The adhesion between prefabricated FRC posts and composite resin cores: microtensile bond strength with and without post-silanization. *Dent Mater* 2005; **21**: 437–444.
26. Kallio TT, Lastumäki TM, Vallittu PK. Bonding of a restorative and veneering composite resin to some polymeric composites. *Dent Mater* 2001; **17**: 80–86.
27. Goracci C, Sadek FT, Fabianelli A, Tay FR, Ferrari M. Evaluation of the adhesion of fiber posts to intraradicular dentin. *Oper Dent* 2005; **30**(5): 627–635.
28. Foxton RM, Nakajima M, Tagami J, Miura H. Adhesion to root canal dentine using one and two-step adhesives with dual-cure composite core materials. *J Oral Rehab* 2005; **32**: 97–104.
29. De Munck J, Van Meerbeek B, Yoshida Y, Inoue S, Vargas M, Suzuki K *et al*. Four-year water degradation of total-etch adhesives bonded to dentin. *J Dent Res* 2003; **82**: 136–140.
30. White SN, Ingles S, Kipnis V. Influence of marginal opening on microleakage of cemented artificial crowns. *J Prosthet Dent* 1994; **71**: 257–264.
31. Sano H, Takatsu T, Ciucchi B, Horner JA, Matthews WG, Pashley DH. Nanoleakage: leakage within the hybrid layer. *Oper Dent* 1995; **20**: 18–25.
32. Stankiewicz NR, Wilson PR. The ferrule effect: a literature review. *Int End J* 2002; **35**: 575–581.
33. Ricketts DNJ, Tait CME, Higgins AJ. Tooth preparation for post-retained restorations. *Br Dent J* 2005; **198**: 463–471.
34. 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**: 15B–18B.

Abstract

SCIENCE SUPPORTS ART

Survival of ART and amalgam restorations in permanent teeth of children after 6.3 years. JE Frencken, D Taifour, MA van't Hof. *Journal of Dental Research* 2006; **85**(7): 622–626.

The atraumatic restorative technique (ART) was originally developed for use in situations where lack of resources, supporting infrastructure etc. meant 'conventional' treatment was impossible. Interestingly recent evidence has suggested that this approach may be effective when compared to conventional methodologies.

This study compared the restoration of predominantly single surface cavities, either by removal of caries with a drill followed by placement of amalgam, or by removal of caries with an excavator and restoration with a high viscosity glass ionomer (including covering surrounding pits and fissures). Local anaesthesia was available but rarely used. Participants were randomly selected and aged between 6 and 9 years of age (681 in total with 1117 restorations placed). Restorations were evaluated over 6.3 years by independent observers.

Researchers found that a statistically significant higher percentage of ART restorations (approximately 10%) survived at each assessment interval over the full 6.3 years. It is difficult to assess from this report the size and depth of the cavities and, unfortunately, the dropout rate was high (less than a third of subjects were available at the end of the 6.3 year period). Nevertheless, the differences between the two groups were significant and further investigation of this approach for single surfaces may well be warranted.

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