REVIEW

Temporization for endodontics

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Abstract

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Teeth undergoing root-canal therapy are susceptible to microbial contamination from oral fluids both during and after treatment. With the exception of single-visit treatment, the use of a temporary restoration is mandatory. This review aims to provide an overview of the materials and techniques used for short- and long-term restorations during and immediately after endodontic treatment, and to make clinical recommendations. Further research is necessary to determine the effectiveness of temporary restorations in the conditions of the oral environment, especially with respect to leakage and functional demands.

Keywords: endodontic materials, microleakage, temporary cements, temporary fillings, temporization.

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Introduction

Bacterial infection is the most common cause of pulpal and periradicular disease (Kakehashi *et al.* 1965, Möller *et al.* 1981). Successful root-canal treatment requires effective mechanical and chemical debridement, elimination of bacteria and pulp tissue remnants and proper canal shaping to facilitate effective obturation. Root-canal treatment can be carried out in a single visit in vital, non-infected teeth, eliminating the need for dressing and temporization (Ørstavik 1997). Many clinical cases with infected canals require dressing with antibacterial medicaments in a multivisit treatment in which effective temporization for different periods of time becomes mandatory (Sjögren *et al.* 1997). Lack of satisfactory temporary restorations during endodontic therapy ranked second amongst the contributing factors in continuing pain after commencement of treatment (Abbott 1994). Accordingly, temporary filling materials must provide an adequate seal against ingress of bacteria, fluids and organic materials from the oral cavity to the root-canal system, and at the same time prevent seepage of intracanal medicaments. Furthermore, these materials are required to allow ease of placement and removal, provide acceptable aesthetics, and protect tooth structure during treatment. Many materials can be used to achieve some of these goals. For effective inter-appointment temporization, it is essential to have adequate knowledge of temporization techniques and material properties in order to satisfy a wide variety of clinical requirements such as time, occlusal load and wear, complexity of access and absence of tooth structure.

In the past, the sealing ability of temporary filling materials was tested commercially either to improve products or for marketing purposes. One of the earliest studies was conducted by Fraser (1929) to test the sealing ability and antibacterial effect of nine materials. Fraser used small glass ampoules, 5 cm long and 6 mm in diameter with a 5-mm constriction from the open end. The lower compartments of the ampoules were filled with sterile broth, whilst the test materials were mixed and used to fill the open end to the level of constriction. The ampoules were then immersed in a flask filled with sufficient broth seeded with bacteria to cover them completely. The lower compartments of the ampoules were regularly checked to confirm bacterial penetration. To determine the antibacterial effect of the test materials, agar plates cultured with bacteria were used. Fraser

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concluded that all freshly mixed cements and copper amalgam had an antibacterial effect, and both were more efficient than gutta-percha stopping in preventing bacterial penetration (Fraser 1929). Grossman (1939) emphasized the importance of achieving a bacteria-tight seal between visits. He tested many materials (or combinations) for leakage using 3-mm-diameter glass tubes. Methylene blue dye alone, methylene blue dye mixed with saliva or bacteriological tests using *Bacillus prodigiosus* were used to test 2–3 mm thickness of the materials. Grossman concluded that zinc oxide and eugenol (ZOE) cements provided the best seal when compared to gutta-percha and oxyphosphate cements (Grossman 1939). Despite the relative simplicity of these studies, they represent the earliest attempts to investigate the seal of temporary restorative materials.

The aim of this review is to examine the variety of materials and techniques used for short- and long-term restorations for endodontics. Contemporary endodontic, operative dentistry and fixed prosthodontic texts were consulted, and a database search performed using Medline. Because of the extensive lineage of some of the materials and techniques, a range of older texts were also examined, and data provided by manufacturers studied.

Temporization of access cavity in tooth structure

A state of sterility must be maintained until a definitive coronal restoration is placed following root-canal obturation. The following studies have assessed the sealing ability of temporary restorative materials in intact teeth where the interim restorations were entirely in direct contact with the tooth structure. A variety of materials and methods were used to evaluate microleakage, which makes data from studies difficult to compare (Tables 1 and 2).

Gutta-percha

Base plate gutta-percha and temporary stopping gutta-percha were amongst the first materials tested, with less than ideal characteristics. Using dye and bacterial penetration tests in extracted teeth, Parris *et al.* (1964) found that gutta-percha temporary fillings leaked when subjected to two temperature extremes, 4–60 °C. In an *in vivo* study, Krakow *et al.* (1977) re-made access cavities in successfully root-filled teeth. The cavities were chemically disinfected with 15 mL sodium hypochlorite irrigation (concentration not stated) followed by 15 mL of 0.067 M phosphate buffer (pH 7.2). Cotton pellets were left in the cavities under the temporary fillings for at least 1 week, after which the pellets were retrieved and cultured anaerobically. Six out of eight samples temporized with gutta-percha demonstrated gross leakage. Findings from these studies are consistent with findings reported by Kakar & Subramanian (1963) in which gutta-percha was inferior to ZOE with and without thermocycling. Gutta-percha is not a commonly used temporary restorative material, and is not recommended for this purpose in endodontics.

Zinc phosphate cement

Studies have shown controversial results concerning the sealing ability of zinc phosphate cement. Access cavities temporized with this material showed no leakage in more than two-thirds of cases in an *in vivo* study (Krakow *et al.* 1977). In another study using the fluid filtration method to test microleakage, zinc phosphate cement did not show significant microleakage when compared to the intact crown, but visible leakage was observed in some of the samples temporized with this material (Bobotis *et al.* 1989). In a study by Marosky *et al.* (1977), radioactive calcium was used as a tracer to test microleakage of commercially available products for temporary restorations. The root surfaces of extracted teeth were covered with tin foil and nail polish leaving the temporarily restored crowns exposed. The teeth were then immersed in an aqueous solution of calcium chloride after which the test teeth were removed, cleaned and sectioned through the test materials. The teeth were placed with the cut surfaces on dental X-ray films to produce autoradiographs. It was found that zinc phosphate cement was inferior to a zinc oxide/calcium sulphate-based material, Temp-Seal (Union Broach Co. Inc., Bethpage, NY, USA), Cavit (3M ESPE Dental AG, Seefeld/Oberbay, Germany) and ZOE. Kakar & Subramanian (1963) also found that this cement provided an inferior seal when compared to properly condensed amalgam and ZOE. Zinc phosphate cement is not widely used for endodontic temporization, probably owing to the emergence of newer temporary filling materials with more predictable sealing characteristics.

Polycarboxylate cement

This material has been tested as a temporary restoration in *in vitro* studies with conflicting results. Marosky *et al.* (1977) found polycarboxylate cement to provide the least desirable seal when compared to Temp-Seal, Cavit, ZOE, zinc phosphate cement and Intermediate Restorative Material (IRM; L. D. Caulk Co., Milford, DE, USA). On the other hand, Pashley *et al.* (1988) using a fluid filtration method found that polycarboxylate cement at a powder to liquid ratio of 2 : 4 was not significantly

Table 1 Summary of *in vitro* studies on leakage of temporary endodontic materials in access cavities in tooth structure

Author(s)	Year	Marker	Thickness (mm)	Thermal cycling	Best materials (in listed order)*
Dye					
Parris *et al.*	1964	2% aniline blue	–	+, –	Cavit = Kwikseal > No-Mix > ZOE > 'Dentin' > Temp-Pac = Kalsogen = zinc phosphate = gutta-percha
Oppenheimer & Rosenberg	1979	Methylene blue	2	+, –	Cavit = Cavit-G
Tamse *et al.*	1982	1% methylene blue 0.5% eosin Y dye	5	+	Cavidentin > Cavit-G > Cavit > IRM > Kalzinol
Chohayeb & Bassiouny	1985	Methylene blue	2.5	+	Cavit > Adaptic > Aurafil > ZOE > zinc phosphate
Teplitsky & Meimaris	1988	10% methylene blue	4	+	Cavit > TERM
Barkhordar & Stark	1990	50% silver nitrate	-	+	Cavit > TERM > IRM
Noguera & McDonald	1990	50% silver nitrate	5	+	TERM > Cavit > Cavit-G > Cavit-W Dentemp > IRM
Lee *et al.*	1993	Basic fuchsin	4	+	Caviton > Cavit > IRM (6 : 1 and 2 : 1)
Kazemi *et al.*	1994	2% methylene blue	5	+	Cavit > Tempit > IRM
Mayer & Eickholz	1997	1% methylene blue 1% fuchsin	3.5	+	Cavit > TERM > Kalsogen > IRM
Cruz *et al.*	2002	2% methylene blue	4	+	Fermin > Caviton > Cavit > Canseal
Radioactive isotopes					
Marosky *et al.*	1977	Ca45	–	+, –	Temp-Seal > Cavit > ZOE > zinc phosphate > IRM > polycarboxylate
Friedman *et al.*	1986	Na	3	–	IRM > ZOE > Cavit-G > Cavidentin
Fluid filtration technique					
Anderson *et al.*	1988	0.2% fluorescein	4	+, –	Cavit > TERM > IRM
Pashley *et al.*	1988	Evans blue	–	+, –	Cavit-G > polycarboxylate (4 : 1 and 2 : 1) > ZOE (2 : 1) > IRM (6 : 1) > ZOE (4 : 1) > IRM (4 : 1) > ZOE (6 : 1) > IRM (2 : 1) > IRM (7 : 1) > gutta-percha
Bobotis *et al.*	1989	0.2% fluorescein	4	+, –	Cavit > GIC = TERM > Cavit-G > zinc phosphate > IRM > polycarboxylate
Bacteria					
Parris *et al.*	1964	*Sarcina lutea* *Serratia marcescens*	–	+, –	Cavit = Kwikseal = ZOE = Kalsogen> No-Mix = 'Dentin' > zinc phosphate > gutta-percha
Blaney *et al.*	1981	*P. vulgaris*	3	–	IRM > Cavit
Deveaux *et al.*	1992	*S. sanguis* (Cavit)	3.7	–	Cavit > TERM > IRM
		(TERM)	5.4	+	TERM > Cavit > IRM
Barthel *et al.*	1999	*S. mutans*	4	–	GIC > IRM/GIC > IRM > Cavit > Cavit/GIC
Electrochemical technique					
Lim	1990	10 V potential difference	3.5	–	GIC (conditioned) > GIC (unconditioned) > Kalzinol > Cavit-W
Jacquot *et al.*	1996	5 mV potential difference	4	–	IRM > Cavit > Cavit-W > Cavit-G

*Rank order does not necessarily imply statistical significance in the publication.

Table 2 Summary of *in vivo* studies on leakage of temporary endodontic restorative materials

Author(s)	Year	Thickness (mm)	Best material (in listed order)*
Krakow *et al.*	1977	–	(no leakage) ZOE > zinc phosphate (3 brands collectively) Cavit > Caviton > gutta-percha
Lamers *et al.*	1980	2	–
Beach *et al.*	1996	4	Cavit > IRM > TERM

*Rank order does not necessarily imply statistical significance in the publication.

different from Cavit-G, even after thermocycling. Polycarboxylate cement is not commonly used in endodontics and cannot be recommended, as its clinical effectiveness for endodontic temporization does not appear to have been well established.

Zinc oxide/calcium sulphate preparations

Cavit is a premixed temporary filling material that contains zinc oxide, calcium sulphate, zinc sulphate, glycol acetate, polyvinyl acetate resins, polyvinyl chloride acetate, triethanolamine and pigments. As a hygroscopic material, Cavit possesses a high coefficient of linear expansion resulting from water sorption. Its linear expansion is almost double that of ZOE, which explains its excellent marginal sealing ability (Webber *et al.* 1978). Body discoloration of this material was observed in fresh samples allowed to set in vegetable dye indicating sorption of the dye rather than body leakage (Widerman *et al.* 1971). However, it was proved later that this material showed body leakage even when allowed to set in water before immersion in dye (Todd & Harrison 1979, Tamse *et al.* 1982, Kazemi *et al.* 1994). It was also suggested that the marked body discoloration resulting from sorption or body leakage could influence the marginal leakage observed (Teplitsky & Meimaris 1988, Kazemi *et al.* 1994, Jacquot *et al.* 1996, Uranga *et al.* 1999). Assessment of immediate and early sealability of Cavit revealed that after placement, marginal penetration can be considered as a potential pathway for oral contaminants (Todd & Harrison 1979). Cavit's compressive strength is approximately half that of ZOE, so there is a need for sufficient bulk to overcome poor strength qualities and provide an adequate seal (Widerman *et al.* 1971, Webber *et al.* 1978). Temperature fluctuations did not influence the sealability of Cavit products, indicating good dimensional stability (Gilles *et al.* 1975, Oppenheimer & Rosenberg 1979). When left in contact with metacresylacetate, camphorated mono-chlorophenol (CMCP) and formocresol intracanal medicaments for 1 and 7 days, the surface hardness of Cavit did not differ significantly to the material left in contact with saline (Olmsted *et al.* 1977).

The sealing ability of Cavit has been tested in many studies, both *in vitro* and *in vivo*, with generally favourable results. In *in vitro* studies, Webber *et al.* (1978) tested the thickness of Cavit required to prevent methylene blue dye leakage. It was found that at least 3.5 mm of the material was required to prevent dye leakage. Comparing sealing ability in parallel or divergent class I cavity preparations, Cavit proved more effective than Temporary Endodontic Restorative Material (TERM, L. D. Caulk Co., Milford, DE, USA) and IRM in that order. However, the difference between Cavit and TERM and the effect of the two cavity designs did not reach significance (Barkhordar & Stark 1990). In *in vivo* studies, no leakage or minor leakage was found in 27 out of 32 cases when Cavit was used to temporize access cavities in anterior teeth and only 15% of cases tested showed gross leakage (Krakow *et al.* 1977). In another study, Cavit in a 4-mm thickness provided the best seal over a 3-week temporization period when compared to IRM and TERM (Beach *et al.* 1996). A 2-mm thickness of Cavit was tested in anterior teeth of monkeys over 2, 7 and 42 days. This thickness was not effective in preventing bacterial microleakage over the experimental period, and the longer the restoration stayed in the mouth the more bacterial contamination was detected (Lamers *et al.* 1980). These findings further confirm the need for sufficient bulk of this material and are in agreement with the previous findings (Webber *et al.* 1978). Other studies have also shown that Cavit can provide an acceptable seal when compared to other materials (Chohayeb & Bassiouny 1985, Pashley *et al.* 1988, Kazemi *et al.* 1994).

Cavit-G and Cavit-W are varieties of Cavit that differ in the content of resin and their resulting hardness and setting. The hardness and dimensional stability of Cavit, Cavit-W and Cavit-G decrease, respectively. It was found that Cavit and Cavit-W provided almost equal watertight seals, which was significantly superior to the seal provided by Cavit-G (Jacquot *et al.* 1996). Cavidentin (Laslo Laboratories, Natanya, Israel) is another calcium sulphate-based material, which has a similar formula to Cavit but with the addition of potassium aluminium sulphide as catalysts and thymol as an antiseptic. In an *in vitro* study, a 5-mm thickness of Cavidentin provided superior sealing ability compared with IRM, Kalzinol (a reinforced ZOE preparation, De Trey, Weybridge, UK) and Cavit. Cavidentin and Cavit-G were almost equally effective (Tamse *et al.* 1982). Coltosol is a zinc oxide, zinc sulphate and calcium sulphate hemihydrate-based material (Coltene Whaledent, Mahwah, NJ, USA). The surface of Coltosol hardens within 20–30 min when in contact with moisture and according to the manufacturers the filling can be subjected to mastication pressure after 2–3 h. This material is designed for short-term temporization not exceeding 2 weeks; it does not appear to have been tested as a temporary restoration for endodontics.

A recent paper compared Cavit and Caviton (zinc oxide, Plaster of Paris and vinyl acetate, GC Corporation, Tokyo, Japan) with Fermin (a zinc sulphate cement, Detax GmbH & Co. KG, Weisendorf, Germany) and Canseal (a noneugenol cement requiring mixing, Showa

Yakuhin Kako Co. Ltd., Tokyo, Japan) in a leakage study using methylene blue (Cruz *et al.* 2002). The best seal was provided by Fermin, followed by Caviton, Cavit and Canseal. The study indicated that thermal cycling procedures influenced seal more than load cycling.

Clinically, Cavit and its relatives have the advantages of ease of manipulation, availability in premixed paste and of being easily removed from access cavities after setting. Additionally, it is clear that Cavit can provide adequate seal of an access cavity between appointments. However, its hardness, wear resistance, slow-setting reaction, and deterioration with time are key disadvantages (Widerman *et al.* 1971, Todd & Harrison 1979, Lim 1990). For these reasons, Cavit can be recommended for short-term temporization in small cavities. A double seal using Cavit as an inner layer and IRM as an outer layer has been recommended to compensate for the undesirable physical properties of Cavit. Furthermore, this combination showed better dentine adaptation when compared to IRM alone (Pai *et al.* 1999).

Zinc oxide and eugenol preparations

Many temporary restoration products are ZOE based, with or without reinforcement. Plain ZOE with a powder to liquid ratio of 4 : 1 (g mL^{-1}) as commonly used results in a poor initial seal, which shows some improvement after 1 week. A lower powder to liquid ratio of 2 : 1 gives better initial sealability but this seal may slightly deteriorate with time (Pashley *et al.* 1988). Simple ZOE temporary cement was found less effective in precluding radioactive tracer leakage when compared to Cavit and Temp-Seal, but superior to zinc phosphate cement, IRM and polycarboxylate cement (Marosky *et al.* 1977). Commercial products based on ZOE such as Dentemp (a ZOE-based material that lacks reinforcement; Majestic Drug Co., Bronx, NY, USA) and Kalsogen Plus (a ZOE-based material that lacks reinforcement; De Trey, Dentsply, York, PA, USA) have been tested and compared with other materials. After thermocycling, Dentemp proved less effective in preventing silver nitrate penetration when compared to TERM and three different Cavit preparations, but almost equally effective when compared to IRM (Noguera & McDonald 1990). Kalsogen was also found less effective in preventing dye penetration when compared to Cavit and TERM after thermocycling and mechanical loading (Mayer & Eickholz 1997).

Kalzinol is a ZOE-based cement reinforced with 2% by weight polystyrene polymer to double its compressive strength. Using an electrochemical technique to test microleakage, it was reported that this cement provided better sealing properties when compared to Cavit-W and was almost equal to glass-ionomer cement used in unconditioned cavities (Lim 1990). IRM is a ZOE cement reinforced with polymethyl methacrylate. This reinforcement provides the restoration with improved compressive strength, abrasion resistance and hardness (Blaney *et al.* 1981, Anderson *et al.* 1990). The manufacturers recommend the use of IRM as a temporary restoration for cavities for up to 1 year using a powder to liquid ratio of 6 : 1 (g mL^{-1}). Following these recommendations usually results in a less than ideal seal but provides more optimum physical properties. The use of less powder provides a better seal at the expense of minimally compromising the physical properties (Pashley *et al.* 1988, Anderson *et al.* 1990). In addition, a softer mix exhibits greater antibacterial activity due to hydrolysis and the subsequent increase in the release of eugenol, an antibacterial agent which may prevent bacterial colonization if leakage takes place (Chandler & Heling 1995). In this regard, IRM is also supplied in pre-measured capsules for mixing in an amalgamator. Leakage of IRM increased when subjected to thermal stress, which was attributed to its dimensional instability (Gilles *et al.* 1975, Anderson *et al.* 1988, 1990, Bobotis *et al.* 1989,). IRM was assessed and compared to other temporary restorative materials in a number of studies both *in vivo* and *in vitro* with conflicting findings. In an *in vivo* study, IRM performed almost equally to Cavit for temporizing class I access cavities in human teeth using a 4-mm thickness over a 3-week period (Beach *et al.* 1996). In an *in vitro* study, IRM allowed to set next to CMCP prevented *Proteus vulgaris* penetration significantly better than Cavit set next to both CMCP and saline solution (Blaney *et al.* 1981). These findings are of special interest knowing that CMCP significantly reduced the surface hardness of IRM whilst it did not influence the hardness of Cavit (Olmsted *et al.* 1977). Using the fluid filtration method, IRM microleakage was not significantly different from intact crowns except at 7 days and after thermocycling (Anderson *et al.* 1988, Bobotis *et al.* 1989). Other *in vitro* studies using radioisotope and electrochemical methods showed more favourable results with IRM compared to Cavit (Friedman *et al.* 1986, Jacquot *et al.* 1996). On the other hand, several *in vitro* studies using silver nitrate as an indicator (Barkhordar & Stark 1990, Noguera & McDonald 1990), calcium chloride radioisotope (Marosky *et al.* 1977), dye penetration (Lee *et al.* 1993, Kazemi *et al.* 1994, Mayer & Eickholz 1997), fluid filtration method (Anderson *et al.* 1988, Pashley *et al.* 1988, Bobotis *et al.* 1989) and bacterial penetration (Deveaux *et al.* 1992) all demonstrated that IRM provides sealing properties inferior to those of Cavit.

Some of these studies provided semi-quantitative results where dye penetration was assessed in one longitudinal section, which limits three-dimensional penetration to a two-dimensional section (Lee *et al.* 1993, Mayer & Eickholz 1997). Others did not take into consideration dye penetration into the body of the material, which may effect the overall microleakage values (Barkhordar & Stark 1990). Furthermore, data obtained from semi-quantitative methods depends on the subjective interpretation of the evaluator rather than providing numerical data for statistical analysis. Radioisotope penetration studies also provide semi-quantitative results where the measurements were done at the filling-tooth interface only, without assessing the body penetration (Marosky *et al.* 1977). Studies using the fluid filtration technique showed better results with Cavit when compared to IRM (Anderson *et al.* 1988, Pashley *et al.* 1988, Bobotis *et al.* 1989). The fluid filtration method is an accurate quantitative method to test microleakage of temporary restorative materials. The measurements can be repeated at different intervals and before and after thermocycling without destroying the sample. However, this method may be accurate in measuring the marginal microleakage but probably not the body leakage of the material because the time of measurement was often too short.

The majority of *in vivo* and *in vitro* studies employing bacteria demonstrated almost equal or better seal with IRM (or ZOE) than with Cavit (Parris *et al.* 1964, Krakow *et al.* 1977, Blaney *et al.* 1981, Beach *et al.* 1996, Barthel *et al.* 1999). Only Deveaux *et al.* (1992) showed that Cavit was superior to IRM in preventing *Streptococcus sanguis* penetration. The authors related this finding to the presence of a growth-inhibiting factor (probably zinc ion) present in Cavit. However, in a pilot study with unpublished data, the authors found that IRM also demonstrated antibacterial effects as tested by agar diffusion tests. Therefore, it is possible to speculate that either the antibacterial effect of IRM could not prevent *S. sanguis* penetration, or that Cavit provided a better seal. When comparing *P. vulgaris* penetration, IRM set on a cotton pellet saturated with CMCP was more effective than IRM set next to saline and Cavit next to CMCP or saline in this order (Blaney *et al.* 1981). The bacterial penetration method *in vitro* is considered an acceptable approach for microleakage studies. It however, omits some clinical factors and does not directly reflect the sealability of the tested materials rather, a combination of leakage resistance and antibacterial effect. From the clinical point of view, microleakage studies of temporary filling materials should account for their antibacterial effect. In addition, the effect of intracanal medicaments on the setting and the subsequent leakage and the combined antibacterial effect of the temporary filling and intracanal medicament should be considered.

Based on the previous discussion and the results of *in vivo* studies, it can be stated that ZOE temporary restorative materials, including IRM, can provide adequate resistance to bacterial penetration during the course of endodontic treatment especially when used with a low powder to liquid ratio.

Glass-ionomer cement

Glass-ionomer cements have a variety of applications in endodontics (Friedman 1999). Use of these materials as a temporary restoration during endodontic therapy has been investigated in a number of studies with favourable results. In one study using the fluid filtration method, glass-ionomer cement microleakage values did not differ significantly from the intact crown values after 8 weeks (Bobotis *et al.* 1989). In another *in vitro* study using an electrochemical technique, glass-ionomer cement placed in unconditioned cavities was almost equally effective compared to Kalzinol and superior to Cavit-W after a 1-month experiment period (Lim 1990). In a more recent study, glass-ionomer cement alone or on top of an IRM base provided a significantly superior seal against penetration of *S. mutans* when compared to Cavit, IRM and glass-ionomer cement on a Cavit base, over a 1-month period (Barthel *et al.* 1999).

The adhesion mechanisms of glass-ionomer cements explains their acceptable sealing ability (Watson 1999). Additionally, glass-ionomer cements possess antibacterial properties against many bacterial strains (Tobias *et al.* 1985, Chong *et al.* 1994, Heling & Chandler 1996, Herrera *et al.* 1999). The antibacterial activity of the material is attributed to the release of fluoride, low pH and/or the presence of certain cations, such as strontium and zinc in some cements. For these reasons, glass-ionomer cements can be considered as a satisfactory temporary endodontic restorative material and may also be used in cases requiring longer term temporization. The cost, speed of setting and the difficulty in differentiating glass iomomers from the surrounding tooth structure during removal have presented problems. A new material, Fuji VII Command Set (GC Asia Dental, Singapore) addresses some concerns. It autocures in 4 min or cures with a halogen light in 20–40 s, and has a pink chroma for easy identification of margins. It also claims a higher fluoride release than other glass-ionomer cements. Metal-reinforced glass-ionomer cements (cermets) are only available with silver particles (Chelon-Silver, Ketac-Silver, 3M ESPE, Seefeld/Oberbay, Germany) and are recommended by manufacturers as temporary posterior materials. They do not appear to be in common use in endodontics, and whilst exhibiting increased wear resistance and higher flexural strength they have less fluoride release and lower bond strengths than other glass-ionomers.

Composite resin

TERM is a relatively recently introduced temporary restorative for endodontics. This material is a single-component light-curable resin that contains urethane dimethacrylate polymers, inorganic radiopaque filler, organic prepolymerized filler, pigments and initiators. Like other composite resins, this material undergoes polymerization shrinkage representing 2.5% of its volume. This contraction is usually followed by expansion owing to secondary water sorption (Deveaux *et al.* 1992). The minimum thickness for effective cavity sealing was investigated *in vitro* using thermocycling and the fluid filtration technique. It was found that 1–3-mm-thick TERM were as effective as a 4-mm thick one in providing a cavity seal after a 5-week interval and thermocycling. This does not represent an indication to use 1- or 2-mm-thick TERM clinically, as other factors not accounted for in the study may operate *in vivo* (Hansen & Montgomery 1993). It is generally accepted that TERM has higher hardness, tensile and compressive strengths than Cavit. Also, TERM's sealability was not affected by certain intracanal medicaments (Rutledge & Montgomery 1990).

Following its introduction, the material was investigated in several *in vivo* and *in vitro* studies with controversial findings. In an *in vitro* study, Teplitsky & Meimaris (1988) found that TERM provided an effective marginal seal in only 33.3% of cases compared with 91.7% for Cavit. Thermocycling did not adversely effect the sealability of Cavit, but led to an increased incidence of microleakage with TERM. In another study, Melton *et al.* (1990) found that TERM provided 67% sealability compared to 100% for Cavit when used to seal-etched and nonetched cavities without thermocycling. *In vivo*, it was found that TERM is inferior to IRM and Cavit in class I cavities when used in 4-mm thickness and for a 3-week temporization period (Beach *et al.* 1996). Many other studies have demonstrated similar effectiveness of TERM and Cavit. TERM was found to be as effective as Cavit for marginal seal and superior to IRM, but the authors stated that the physical properties of IRM were considered superior to those of TERM and Cavit (Barkhordar & Stark 1990). These findings are in accordance with other reports (Deveaux *et al.* 1992) where both TERM and Cavit were almost equally effective in preventing *S. sanguis* penetration before and after thermocycling. Findings from another *in vitro* study showed that after thermocycling, TERM provided better sealing ability when compared to Cavit, Cavit-G and Cavit-W (Noguera & McDonald 1990).

TERM does not possess antibacterial activity when tested with *S. sanguis* on agar plates. The good sealing properties of TERM demonstrated in some studies can be attributed to the mode of insertion of this material. The material can be injected using a syringe with a fine compule end-piece, eliminating the possible inclusion of gaps within the body of the material or at the margins (Deveaux *et al.* 1992). In addition, dye leakage studies failed to show significant body penetration for this material (Teplitsky & Meimaris 1988, Noguera & McDonald 1990). Although TERM did not consistently provide better sealing ability than Cavit and IRM, it can be stated that TERM may have the potential to provide an adequate seal for temporization of an endodontic access cavity when used in sufficient bulk. Further clinical studies are required with standardized methodologies to confirm the effectiveness of this material. The use of composite resin materials designed for permanent restorations to temporize access cavities has also been investigated. Uranga *et al.* (1999) found that composite resin and resin-modified glass-ionomer cement provided a better seal against methylene blue dye penetration after thermocycling when compared to Cavit and Fermit (Vivadent, Schaan, Liechtenstein), two temporary restorative materials.

Temporization of an access cavity within a restoration

The literature is replete with both *in vitro* and *in vivo* studies evaluating the sealing ability of endodontic temporary restorative materials in intact teeth. However, many teeth requiring endodontic therapy have large permanent coronal restorations of acceptable quality. Few studies have tested the sealing ability of temporary restorative materials in such situations. Pai *et al.* (1999) found that dye leakage at the interface between an amalgam restoration and IRM, Caviton and a double seal of Caviton and IRM temporary restorations was less than the leakage between the temporary materials and tooth cavity walls. In another *in vitro* study, access cavities were prepared entirely in amalgam restorations and temporized with Cavit, Cavit-G, TERM, zinc phosphate cement, polycarboxylate cement, glass-ionomer cement and IRM. Apart from zinc phosphate and polycarboxylate cements, all the tested materials provided a seal that was as leak-proof as the control teeth which had class I preparations restored with amalgam alone (Turner *et al.* 1990). Also, it has been demonstrated that access cavities prepared through composite resin restorations and temporized with ZOE or Cavit showed less leakage when compared to access cavities prepared in amalgam restorations and temporized with these two materials (Orahood *et al.* 1986). *In vivo*, Beach *et al.* (1996) showed that both Cavit and IRM could effectively seal access cavities in an IRM temporary restoration, amalgam fillings and gold or porcelain fused to metal crowns.

From these studies, its is reasonable to conclude that access cavities prepared in coronal restorations and temporized with an appropriate temporary filling material can provide as good a seal as that provided by the primary restoration. Nevertheless, these studies were conducted *in vitro* and may not reflect the actual clinical situation of an aged primary restoration which has been in function for many years. That is why when the temporary restoration is in contact with the tooth structure apical to the primary restoration-tooth interface a more predictable seal can be expected. When doubts arise about the quality and seal provided by the primary restoration, removal of the entire restoration and its replacement with a temporary restorative material is justified (Melton *et al.* 1990) (Table 3).

Clinical recommendations

During material placement, the chamber and cavity walls should be dry. The use of a thin layer of cotton wool over canal orifices is a controversial step during temporization. The advantage is the ease of removal of the temporary restoration without running the risk of unnecessary removal of intact tooth structure or even worse, perforating the floor of the pulp chamber. Placement of a cotton layer can also preclude the accidental blockage of the canal by small fragments of the temporary filling displaced into the canal. The technique was recommended in occlusal cavities by Messer & Wilson (1996) and used in *in vivo* studies (Krakow *et al.* 1977, Lamers *et al.* 1980). In another *in vivo* study, Sjögren *et al.* (1991) used a sterile foam pellet under the temporary filling without compromising the seal for an extended period of time of up to 5 weeks. However, the use of a cotton layer can introduce complications which may seriously compromise the intended seal. First, it may significantly reduce the thickness of the temporary restoration to increase leakage. Second, it may compromise the stability of the restoration by acting as a cushion allowing displacement during masticatory loading. Third, it could compromise the adaptation of the temporary cement during placement. Fourth, fibres of the cotton pellet may inadvertently adhere to the cavity walls and serve as a wick. Finally, there is an increased risk of leakage through exposed lateral canals (Webber *et al.* 1978, Orahood *et al.* 1986, Bishop & Briggs 1995). Based on the above, the following empiric recommendations can be made. A small-sized pellet that covers the canal orifice but avoids the floor of the pulp chamber, or a thin and well-adapted cotton layer to cover the floor of the chamber may be used. A small sterile and well-adapted piece of polytetrafluoroethylene tape can also be used as a mechanical barrier under the temporary restoration (Stean 1993). The importance of having as much bulk and thickness as possible of the temporary restoration cannot be overstated. The material can be inserted in increments with good condensation into the access

Table 3 Summary of *in vitro* and *in vivo* studies on leakage of temporary endodontic materials in access cavities within coronal restorations

Author(s)	Year	Marker	Thickness (mm)	Thermal cycling	Best material (in listed order)*
Dye					
Melton *et al.*	1990	India ink	3.5	–, +	Cavit > TERM
Pai *et al.*	1999	Basic fuchsin	6	+	Caviton > Caviton/IRM > IRM
Radioactive isotopes					
Orahood *et al.*	1986	Ca45	3.5	+	ZOE > Cavit
Fluid filtration technique					
Turner *et al.*	1990	0.2% fluorescein dye	4	–	GIC > TERM > Cavit > Cavit-G > IRM > zinc phosphate > polycarboxylate
Bacteria					
Beach *et al.*	1996	*In vivo*	4		Cavit > IRM > TERM

*Rank order does not necessarily imply statistical significance in the publication.

cavity to obtain adequate adaptation to cavity walls. The margins should be carefully finished and the occlusion adjusted. Careful removal of the temporary restoration with rotary instruments or the use of ultrasonically energised tips may preclude possible complications (Bishop & Briggs 1995).

After completion of endodontic treatment gutta-percha should be cut back to within the canal orifices and an intermediary restoration (coronal barrier) placed to protect it. For a variety of reasons, the placement of a permanent coronal restoration may be delayed. It is generally accepted that the sealing quality of the available endodontic temporary restorative materials deteriorates with time (Lamers *et al.* 1980). Few studies have investigated microleakage of temporary restorations placed after root-canal preparation and obturation. Imura *et al.* in an *in vitro* study showed that gutta-percha stopping, IRM and Cavit all permitted bacterial penetration of obturated canals. The average times for broth contamination in access cavities closed with gutta-percha, IRM and Cavit were 7.8, 12.9 and 9.8 days, respectively (Imura *et al.* 1997). Safavi *et al.* in an *in vivo* study observed greater endodontic treatment success in teeth restored with permanent restorations within 2 months of completion of root-canal therapy than teeth with temporary restorations. However, the difference did not reach significance (Safavi *et al.* 1987). Due to the possible disintegration of the temporary restorations with time and the potential for canal contamination, it is recommended to restore teeth after endodontic treatment with an immediate definitive coronal restoration after canal obturation.

Influence on final restoration

Materials used for provisional restorations in endodontics can affect the polymerization and adhesion obtained with composite resins and other materials used to permanently restore endodontically treated teeth. Many studies have proved that residual eugenol may have a deleterious effect on the physical properties of composite resin restorations such as surface roughness, microhardness and colour stability. Other studies demonstrated that residual eugenol reduced the bond strength or even precluded bonding of the composite resin (Macchi *et al.* 1992). Hansen & Asmussen (1987) showed that the incidence and the extent of marginal gaps were markedly increased in cavities previously temporized with ZOE temporary fillings. This is, in fact, more closely related to possible marginal microleakage. In a similar more recent study using two newer dentine bonding systems, it was demonstrated that neither IRM nor Cavit interfered with the dentine or enamel bond strength or increased the mean value of wall-to-wall contraction (Peutzfeldt & Asmussen 1999). These findings were explained by the differences in the technique required for each particular bonding system, namely the total-etch procedure. A study using migration of streptococci *in vitro* indicated that a eugenol containing root-canal sealer had no significant effect on the sealing ability of a light- and dual-curing bonding system (Wolanek *et al.* 2001). The use of 30–35% phosphoric acid for 15 s may result in demineralization of dentine to a depth of approximately 10 μm, and removes any residual cement or contaminated enamel. From the clinical point of view, the influence of the temporary restorative materials on the physical properties and bond strength of permanent restorations are not the only factors that should be accounted for. More important in endodontics is the marginal seal at the permanent filling-tooth interface. Woody & Davis (1992) showed that both eugenol-containing or eugenol-free temporary cements increased microleakage at the dentine–restoration interface but not at enamel margins. Thus, it seems that the negative effect was mainly because of the residual cement rather than the eugenol itself. This can be further consolidated by the fact that Cavit also adversely influences the composite resin bond strength (Macchi *et al.* 1992). Removal of eugenol-free or eugenol-containing temporary restorations such as IRM may not be complete and remnants may be left behind in microscopic surface irregularities. Accordingly, and owing to the conflicting findings in the literature and the availability of many different bonding systems, it is preferable to avoid the use of ZOE temporary restorations in cavities to be restored permanently with composites. It is also recommended to use bonding systems that rely on the total-etch procedure. Glass-ionomer cement bond strength is not effected by either IRM or Cavit temporary restorations (Capurro *et al.* 1993); however, this does not imply that glass-ionomer cement would provide a good marginal seal following the use of a eugenol-containing temporary cement. The insertion of a coronal barrier of sufficient thickness may provide an additional, more predictable coronal seal for endodontically treated teeth than can be achieved with just one of the available restorative materials (Wilcox & Diaz-Arnold 1989, Diaz-Arnold & Wilcox 1990).

Temporization of broken down teeth

Many teeth requiring endodontic therapy have lost considerable coronal tooth structure. During the course of multivisit endodontic treatment the pulp-canal system must be sealed to preclude the ingress of oral fluids and the subsequent contamination of the root-canal system and leakage of intracanal medicaments into the mouth. Proper endodontic temporization may also serve some other purposes.

Root-canal treatment requires adequate isolation of the area of operation. Proper placement of the rubber dam on a mutilated tooth is often impossible because of extensive loss of tooth structure. In the past, temporary cements, copper bands, orthodontic bands and temporary crowns have been used. These methods cannot provide an adequate seal and a pleasing aesthetic result (Walton 2002). In addition, the methods are time consuming, and gaining an access into cements can run the risk of introducing and blocking a canal with cement particles. It is also quite difficult, if not impossible, to obtain acceptable restoration contours, marginal adaptation and occlusion (Abdullah Samani & Harris 1979, Kahn 1982, Brady 1983). Pin-retained amalgam or composite resin as interim restorations to aid isolation have been suggested (Messing 1976, Kahn 1982). However, this practice may influence future restorative options, and introduces the risks involved in pin placement and their possible removal. Other retentive means for the interim restoration have been advised. Brady recommended the use of retention grooves or locks with composite resin materials for build-ups for isolation and cavity sealing between appointments (Brady 1983). The use of retention grooves may provide more flexibility in the future restoration, but at the expense of sacrificing valuable tooth structure. Crown-lengthening surgery may be indicated.

Following the introduction of glass-ionomer cements, this material has found a wide and increasing use in dentistry (Wilson & Kent 1972). The material has the ability to bond to prepared and unprepared tooth surfaces with significant increase in bond strength after preparation with polyacrylic acid (Powis *et al.* 1982). More recent research has demonstrated that polyacrylic acid pretreatment does not significantly enhance the dentine–glass-ionomer restorative bond strength, but produces more consistent results (Hewlett *et al.* 1991). Furthermore, glass-ionomer sealability of the unconditioned access cavity is almost equal to the sealability of reinforced ZOE cement (Lim 1990). Nevertheless, it is preferable to condition the exposed surfaces with polyacrylic acid and to protect the filling material after insertion with varnish or unfilled resin as these steps improve the long-term sealing ability (Lim 1987, 1990). The use of glass-ionomer cement as a provisional build-up to aid in endodontic isolation and coronally seal the root canal was suggested recently (Bass & Kafalias 1987, Morgan & Marshall 1990, Rice & Jackson 1992). The advantages are: providing adequate seal with the tooth structure and sufficient strength and retention to withstand the forces of the application of the rubber-dam clamp. The material is also radiopaque and can be rapidly and easily inserted with the possibility to commence endodontic treatment at the initial appointment (Bass & Kafalias 1987, Morgan & Marshall 1990, Rice & Jackson 1992). The disadvantages of the material are its cost and the aesthetic result that makes it less than ideal for use on anterior teeth. After the material sets, formal endodontic access can be created and root-canal instrumentation and obturation can proceed in the usual manner. Another technique to provide long-term provisionalization was described using resin-modified glass-ionomer cement, reinforced with a rounded wire tailored to allow direct entry to the pulp chamber. The disadvantage of this method is the need to involve the occlusal surfaces of the adjacent teeth to which the reinforcing wire will be cemented (Liebenberg 1994).

Composite resins have also been used for temporization of badly broken down teeth. The material enjoys wide acceptance because of its superior aesthetic results and micromechanical bonding to the prepared tooth structure (Abdullah Samani & Harris 1979, 1980). Composite resin does not always offer an acceptable material tooth interface seal, especially with poor moisture and contamination control (Derkson *et al.* 1986). Composite resins cannot be recommended as the ideal option for interim build-up and temporization of severely damaged teeth (Rice & Jackson 1992). Fracture of crown or root is a risk for teeth of this type, and the use of a stainless steel band has been shown to reduce cusp flexure and to double fracture strength (Pane *et al.* 2002). This, together with the use of a command-set resin-modified glass-ionomer cement and taking the tooth 'out of occlusion' may be appropriate management for badly broken down posterior teeth.

Provisional crowns

A high percentage of endodontically treated teeth receive a coronal coverage cast restoration, as the rate of clinical success is significantly improved for posterior teeth treated in this manner (Sorensen & Martinoff 1984). It has also been reported that approximately 19% of vital teeth restored with full-coverage cast restorations demonstrate radiographic evidence of periradicular disease (Saunders & Saunders 1998). Consequently, many teeth restored with coronal-coverage cast restorations may present for either endodontic treatment or re-treatment. Endodontic treatment can be completed through an access cavity gained in a well-fitted good quality cast restoration (Beach *et al.* 1996). However, when the existing restoration is of an unacceptable quality, secondary caries is present around its margins or doubts arise about the remaining tooth structure under the restoration, removal of the permanent crown and its replacement with a provisional restoration is mandatory. According to Shillingburg *et al.* (1997), a temporary restoration must provide pulp protection, positional stability, occlusal function, ease of cleaning, biologically acceptable margins, strength, retention and aesthetics. Little is mentioned in the literature about the importance of microleakage of provisional restorations and their relation to endodontic treatment. Marginal accuracy of the provisional restoration is an important factor in determining its sealing ability. The amount of cement exposed to oral fluids, which depends on the marginal gap, may be related to cement dissolution. A provisional crown made by the indirect technique with a properly selected material provides superior marginal accuracy compared to a crown made by the direct technique (Crispin *et al.* 1980). Temporary cement sealability is another factor which should be accounted for. In one comparative study of the marginal leakage of six temporary cements, it was found that all the materials tested demonstrated different degrees of microleakage. Zinc phosphate cement and cavity base compound had the best sealing properties (Baldissara *et al.* 1998). For these reasons, it is essential to remove caries from the remaining tooth structure after the removal of the defective crown and an appropriate sealing material can be used to replace this loss. The access cavity through the core must be temporized between the appointments. The provisional crown should be used for as a short a period as possible and if left for longer period must be checked frequently to replace the temporary cement.

Temporary post crowns

A temporary post crown may be necessary for temporizing broken down teeth, especially when a custom-made cast post and core is planned. Temporary post crowns can be constructed using an aluminium temporary Parapost® (Whaledent, Mahwah, NJ, USA) combined with polycarbonate temporary crowns and a self-curing acrylic polymer. Alternatively a methacrylate resin crown can be made directly in the mouth using an impression or external surface form. Both techniques are widely used and can provide a good aesthetic result and acceptable margins (Gegauff & Holloway 2001). When microleakage of a temporary post crown cemented with a ZOE temporary cement was compared to microleakage of a cast post and core and a prefabricated post and composite core, it was found that the temporary post crowns leaked significantly more than the permanent types (Fox & Gutteridge 1997). A recent *in vitro* study compared prefabricated posts cemented permanently with zinc oxyphosphate and temporarily with Temp Bond (Sybron Kerr Corp., Orange, CA, USA), and found the temporary posts leaked to a similar degree to the positive controls: there was significantly less leakage amongst the permanently cemented posts (Demarchi & Sato 2002). Clearly, temporary luting cements such as Temp Bond cannot be expected to provide a perfect marginal seal, and the material sealing ability deteriorates with time (Mash *et al.* 1991). In addition, unlike other temporary crowns, temporary post crowns are often used in teeth with minimal remaining coronal tooth structure, which in turn does not provide adequate contact of the temporary restoration with the axial walls of the remaining core. For these reasons, it is recommended to restore the tooth immediately after obturation with a prefabricated post and core system to minimize microleakage and resultant canal re-contamination (Fox & Gutteridge 1997). If a custom-made cast post and core is selected, the temporary post crown should be left in place for as short time as possible (Fox & Gutteridge 1997). A provisional removable partial denture may also be used as an alternative. With this method, it is unlikely that the coronal seal will be disturbed between appointments (Messer & Wilson 1996).

Temporization for internal bleaching (walking bleach)

Sodium perborate mixed with water or 35% hydrogen peroxide (Superoxol) is commonly used in the walking bleach technique (Freccia *et al.* 1982, Rotstein *et al.* 1991, 1993). A protective cement barrier is placed over the obturation material, especially if Superoxol is used. Polycarboxylate, zinc phosphate, glass-ionomer, IRM or Cavit at least 2 mm thick are recommended (Rotstein & Walton 2002). Sodium perborate as an oxidiser decomposes into sodium metaborate and hydrogen peroxide, releasing nascent oxygen (Naoum 2000). The gas release may increase the pressure inside the pulp chamber resulting in loosening or displacement of the temporary restoration. After insertion, the bleaching paste should be removed from the cavity walls and the access is temporized with a suitable material. Cavit and Coltosol used with sufficient bulk can provide a better seal when compared to composite resin materials, ZOE and zinc phosphate cement (Rutledge & Montgomery 1990, Waite *et al*. 1998, Hosoya *et al*. 2000).

Long-term temporization

Some clinical situations such as apexification or root resorption may require long-term temporization. A permanent-type restoration can be used in these instances. Glass-ionomer cement can be considered an appropriate material as its sealability for longer periods of time is well documented (Bobotis *et al*. 1989, Lim 1990, Barthel *et al*. 1999). Composite resins are another alternative, but it is preferable to seal the canal opening with another temporary material before placement of composite, to allow relative ease of access and to prevent accidental loss of composite material into the root canal. For severely broken down posterior teeth, pin-retained amalgam restorations can be used for long-term temporization.

Conclusion

A review of the relevant literature shows that many *in vitro* studies using different methodologies provide conflicting results about the effectiveness of endodontic temporary restorative materials. The studies lack standardization and cannot claim clinical significance as they did not reproduce the clinical environment and the functional demands to which a temporary filling is exposed. Proper clinical assessments can only be obtained from well-designed *in vivo* studies that reflect the superiority of some of the available materials more accurately in the actual clinical environment and in more complex cavities. Because of the nature of these materials, they should be used for as short a period as possible during the course of endodontic treatment.

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