The use of glass ionomer cements in both conventional and surgical endodontics

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Abstract

The capacity to bond to dental tissues, especially to dentine, their long-term fluoride release and their biocompatibility make glass ionomer cements (GICs) advantageous for use in endodontics, as well as in restorative dentistry. This review provides information on the basic properties of GICs, such as adhesion, antimicrobial effects and biocompatibility, particularly as they relate to use in endodontics. Indications for the use of GICs in endodontics are orthograde root canal sealing, root-end filling, repair of perforations and root resorption defects, treatment of vertical fractures and maintenance of the coronal seal. The paper includes a review on each of these indications. It is concluded that in spite of the critical handling characteristics and the inconclusive findings regarding sealing ability and antimicrobial activity, there is substantial evidence to confirm their satisfactory clinical performance. Both soft tissue and bone compatibility make them suitable for use during endodontic surgery.

Keywords: glass ionomer cement, root canal sealer, root-end filling, surgical endodontics.

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Introduction
Glass ionomer cements (GICs) were developed in the late 1960s and were a product of an acid–base reaction between a basic fluoro-alumino-silicate glass powder and polycarboxylic acid in the presence of water (Wilson & Kent 1971, 1972). Since then, many modifications and improvements to the original formulation have been made. Present-day conventionally setting GICs (conventional GICs) are hybrid materials with both organic and inorganic constituents. These materials are composed of calcium fluoro-alumino-silicate glass powder and aqueous solutions of homopolymer and copolymers of acrylic acid-containing tartaric acid (Smith 1990). As stated by McLean et al. (1994), a more accurate term for this type of material is glass polyalkenoate cement, because these cements are not true ionomers in the chemical sense. However, this term has not been used as widely as the name GIC.


In order to reinforce conventional GICs, the addition of metals to the filler component has been proposed (Simmons 1983, McLean & Gasser 1985). The powder then
contains fluoro-alumino-silicate glass and a silver alloy (Miracle Mix; GC-Corporation, Tokyo, Japan; Simmons 1983), or the glass is sintered with silver (Ketac-Silver: Espe, Seefeld, Germany; McLean & Gasser 1985). The latter product is called a cermet cement (ceramics and metal). Metal-reinforced GICs have been proposed for restorations and core build-up (McLean 1990).

Another modification of conventional GICs, suggested as an alternative to amalgam for posterior preventive restorations, is the highly viscous GIC (Wilson & McLean 1988); examples of present-day formulations are Fuji IX (GC-Corporation, Tokyo, Japan) and Ketac-Molar (Espe, Seefeld, Germany).

Resin-modified GICs (RMGICs) were introduced in the late 1980s in order to widen the range of clinical applications (Antonucci et al. 1988, Sidhu & Watson 1995). Resin modification of GIC was designed to produce favourable physical properties similar to those of resin composites and resin cements while retaining the basic features of the conventional GIC (Yoshii et al. 1992). The RMGIC is defined as a material that undergoes both a polymerization reaction and an acid–base reaction.

The interest in the clinical use of GICs arises mainly from their behaviour as adhesive – bioactive materials with therapeutic action (Wilson & McLean 1988, Davidson & Mjör 1999). As the capacity to bond to dentine (Wilson & McLean 1988), the fluoride release without loss of strength of the material (Cattani-Loretti et al. 1994, Mitra & Kedrowki 1994) and the biocompatibility (Sidhu & Schmalz 2001) make GICs advantageous for use in restorative dentistry, these characteristics also contribute to their indicated use in endodontics. Moreover GICs possess antibacterial properties against many bacterial strains (Tobias et al. 1985, Chong et al. 1994b, Heling & Chandler 1996, Herrera et al. 1999).

Use of GICs in endodontics

The use of GIC in root canals was first introduced by Pitt Ford (1979) in a laboratory study. Using a single cone technique (gutta-percha or silver cones in combination with a GIC), he found that the working time was too short to be used in conjunction with the lateral compaction technique. Stewart (1990) proposed two other formulations in order to prolong the working time, and added barium sulphate to increase radiopacity. Ray & Seltzer (1991) developed a usable experimental formulation with adequate working time, radiopacity and adhesion to the root canal wall. These modifications led to the commercialization of Ketac-Endo (Espe, Seefeld, Germany) in 1991.

Apart from the conventionally hardening cements, RMGICs were also tested. Saunders et al. (1992) tested Vitrebond (3M, St Paul, MN, USA) in combination with gutta-percha and showed that there was good adaptation of the sealer to the root canal.

Good adhesion and a strong material contribute to the strength of the tooth. In an in vitro study, Trope & Ray (1992) found an increased resistance to vertical fracture when obturating canals in conjunction with a glass ionomer sealer.

More recent developments are two experimental GIC sealer formulations: KT-308 (GC-Corporation, Tokyo, Japan; Lahl et al. 1999a), which is a conventional GIC with an increased radiopacity and an extended working time, and ZUT (University of Toronto, Canada; Lahl et al. 1999a), consisting of KT-308 combined with an antimicrobial agent, a silver-containing zeolite (0.2–20% weight). ZUT demonstrated an effective suppression of adherent Enterococcus faecalis over a 12-week period (Patel et al. 2000), which may promote its efficacy as a root canal sealer.


General properties – endodontic perspective

Adhesion and bonding to dental tissue

The adhesion of GIC to dental tissue relies primarily on chemical interaction and, to a lesser extent, on micromechanical interlocking (Wilson et al. 1983, Akinmade & Nicholson 1993, Shen 1996). Lahl et al. (1999a) investigated the bond strength of two experimental GIC sealers (’KT-308’ and ‘ZUT’) and Ketac-Endo to bovine dentine conditioned with the most common irrigants. Bond strength appeared to be lowest after treatment of dentine by 17% ethylene diamine tetra-acetic acid (EDTA) and 2.6% sodium hypochlorite (NaOCl). Irrigation with NaOCl or even with distilled water resulted in a higher bond strength (Lahl et al. 1999a) and the formation of a hybrid layer between the GIC and the dentine (Lahl et al. 1999b). This research suggested that the smear layer should be preserved. In a more recent study (Timpawat
et al. 2001), contradictory results were obtained. Conditioning with phosphoric acid or citric acid, which was also more effective in removing the smear layer, resulted in higher bond strengths than conditioning with EDTA and NaOCl or conditioning with polyacrylic acid. Bonding to dentine without smear layer removal (5.25% NaOCl) was too low to be measured in the testing apparatus (Timpawat et al. 2001). According to this study, the smear layer should be removed. Apart from this, Ketac-Endo demonstrated a lower shear bond strength than 'KT-308' or 'ZUT' (Lalh et al. 1999a, Chung et al. 2001).

Anti-microbial effects

Conventionally setting glass ionomer cements

Several studies have demonstrated that conventionally setting GICs are able to reduce bacterial growth (Tobias et al. 1985, Meryon & Johnson 1989, Scherer et al. 1989, Palenik et al. 1992, Prati et al. 1993). Although bacterial inhibition associated with GICs is measurable (Tobias et al. 1985), variations in techniques make it difficult to make comparisons among studies. It is important to note that the extent of bacterial inhibition differs between and among materials (Forss et al. 1991, Seppä et al. 1993), as well as between the different strains of bacteria and the methods used (Meryon & Johnson 1989). The mechanism of the antibacterial activity of GICs is not clear, and several theories have been put forward. The most documented one suggests that fluoride ions released from GICs are responsible for bacterial inhibition. The fluoride release alone, however, may not be the only antimicrobial mechanism (Seppä et al. 1993). There may be an added antimicrobial effect because of acidity (Palenik et al. 1992), related to the polyalkenoic acid (Seppä et al. 1993). Yet another theory points to the zinc component; it is known that zinc exhibits a stronger antibacterial activity than fluoride (de Rosas & Chan 1996). In this respect, it has been shown that GICs without zinc did not have effective antibacterial properties (Tobias et al. 1985). It has been hypothesized that the combined release of zinc and fluoride may be responsible for the antimicrobial activity (Sidhu & Schmalz 2001).

Studies on the antibacterial activity of GICs related to their use in endodontics are few, although the bacterial inhibition of Ketac-Endo endodontic sealer has been reported. Abdulkader et al. (1996) found that Ketac-Endo inhibited all the bacteria used in their study. The antimicrobial action, according to the authors, was related to the low pH, when freshly prepared (Mount 1994), and the potential to release fluoride ions (Tobias et al. 1985, Meryon & Johnson 1989). The possibility that other components were involved was not excluded. Heling & Chandler (1996) found antibacterial activity only after 7 days for Ketac-Endo and none at 24 h, whereas all other sealers compared in the study showed antibacterial activity at 24 h. In another study, Shalhav et al. (1997) concluded that Ketac-Endo possessed a very potent but short-acting antibacterial activity.

Two experimental GIC root canal sealers (‘KT-308’ and ‘ZUT’) were tested in different studies for antibacterial activity against E. faecalis. Depending on the experimental design, different results were obtained. ‘ZUT’ demonstrated a significant reduction in bacterial growth in contrast to ‘KT-308’ (Patel et al. 2000), whereas it could not provide more resistance to bacterial ingress compared to ‘KT-308’ or AH 26 (DeTrey, Zürich, Switzerland; Padachey et al. 2000). In another in vitro study, ‘KT-308’ effectively prevented penetration of E. faecalis into root canals, whereas ‘ZUT’ did not (McDougall et al. 1999).

Resin-modified glass ionomer cements

The most investigated RMGIC is Vitrebond (3M, St Paul, MN, USA). Freshly mixed Vitrebond revealed a significantly greater antimicrobial activity than the conventional cement Aquacem (DeTrey, Zürich, Switzerland). The inhibitory properties were similar when the material was light-cured or chemically cured. This suggests that antibacterial agents dissolved rapidly (Coogan & Creaven 1993). On one hand, it was suggested that the antibacterial activity was associated with low pH of the freshly mixed RMGIC combined with the release of fluoride ions above a threshold value (De Schepper et al. 1989). Furthermore, HEMA (2-hydroxyethyl methacrylate) was also considered to contribute to the antimicrobial action (Coogan & Creaven 1993). In case of Vitrebond, the marked antibacterial activity may be because of high levels of toxic agents released during curing, such as benzine bromine and benzine iodine (Geurtsen et al. 1998).

Biocompatibility

Conventionally setting glass ionomer cements

Research on the biocompatibility of GICs in conventional and surgical endodontics has focused mainly on conventionally setting GICs. The latter exhibit good biocompatibility for three main reasons (Nicholson et al. 1991): (i) they set with minimal exotherm; (ii) neutralization is generally sufficiently rapid that any potential irritation because of the presence of free acid is minimal; and (iii)
the substances leached from the set cement are generally either benign or beneficial to the tissue in which the cement is placed.

Crisp et al. (1978) measured setting exotherms and found that GICs gave the smallest setting exotherm of any other dental cements examined, making them unlikely to cause any thermal damage or necrosis. This is in marked contrast with other biomedical cements and is a feature that contributes to the biocompatibility of GICs.

The aqueous polymeric acids used for the preparation of GICs are relatively weak acids. Polyacrylic acid has a $pK_a$ of 4.5–5.0, depending on the concentration. This value rises to between 6 and 7.5 as full neutralization is approached (Mandel 1983). After the initial step of neutralization, which is reasonably rapid, the process slows down, and 1000 min after the start of mixing, it is still incomplete (Cook 1982). This implies that the material remains slightly acidic for some time. However, the pH rises sufficiently quickly in a way that there is no attack on the tooth surface as such, neither does the initial mismatch of the pH of the cement and the bone structure lead to problems either of cement failure or of loss of biocompatibility (Jonck et al. 1989a).

The species leached from a GIC are dependent on the initial constituents of the cement. Little or no organic species have been found to be leached out of GICs (Kuhn et al. 1983), the components described so far being all inorganic, as follows:

- Silica: The precise role of silica in the human metabolism is unclear, although it appears to lower the cholesterol levels in blood (Iler 1979). This, in combination with its low toxicity, suggests that the leaching of silica either in the teeth or in the bone is likely to be benign to the body (Nicholson et al. 1991).
- Aluminium: In some respects, aluminium is the least biologically acceptable of all the leached elements. However, in endodontic applications, the release of aluminium would not be expected to cause problems. First, the amount released has been shown to be very small (Crisp et al. 1980, Brookman et al. 1986); secondly, any release that does occur, takes place in close proximity to mineralized tissues, either teeth or bone. The main constituent of this mineralized tissue is hydroxyapatite, and because of its size, the $\text{Al}^{3+}$ ion would be expected to occupy suitable vacancies in the surface of this material (Atkinson & Witt 1985).
- Calcium: Is released in very small amounts (Crisp et al. 1980, Brookman et al. 1986) and is beneficial to mineralized tissues. As the main inorganic constituent of teeth and bone is calcium phosphate mineral hydroxyapatite, calcium can be incorporated in the hydroxy-apatite during remodelling of the bone (Atkinson & Witt 1985).
- Phosphate: Ionomer glasses do not necessarily contain phosphate, although most of the commercially available ones do. Its most important physiological use is the formation of the mineral hydroxy-apatite (Nicholson et al. 1991).
- Fluoride: The fluoride ions fit better than the hydroxyl ions into the hydroxy-apatite lattice of the teeth, which, afterwards, is more resistant to the attack of acids produced in the mouth (Atkinson & Witt 1985). The fluoride ions can be incorporated into bone, which is less easily resorbed and does not undergo ion exchange as readily as nonfluoridated bone (Atkinson & Witt 1985).

Root canal sealer

One of the requirements of an ideal root canal sealer is that it should be non-irritating to the periapical tissues and should be compatible with living connective tissues (Grossman 1982). Although specific research on GIC root canal sealers is limited, GICs in general are believed to be biocompatible. Subcutaneous implantation in rats caused a mild inflammatory reaction on the fifth day, which diminished progressively, compared with a zinc oxide–eugenol-based sealer, Tubli-Seal (Kerr Manufacturing Co., Romulus, MI, USA), which caused a severe reaction and remaining irritating (Kokkuris et al. 1996). Jonck et al. (1989a,b) and Jonck & Grobbelaar (1990) conducted a series of experiments on baboons and then on humans: GICs were nontoxic in bulk, and allowed, as well as promoted, normal haemopoetic and osteoblastic activities on the cement surface. The cement had no inhibitory effect on bone tissue development and there was a total absence of fibrous tissue envelopment with the cement being effectively incorporated into the bone. Osteoblastic activity has also been demonstrated in cell cultures in the presence of Ketac-Endo (Snyder et al. 1997).

Sealing material (perforation, root-end filling) in surgical endodontics

The use of GICs in the periradicular region implies that the material will have direct contact with the healing bone. Direct contact will take place between the mineralized bone and root dentine, as well as the cementum (Craig & Harrison 1993, Torabinejad et al. 1995). Bone implantation studies confirmed good tolerance to different kinds of GICs (Zmener & Dominguez 1983, Lehtinen 1986, Blackman et al. 1989, Jonck et al. 1989a,b, DeGrood et al. 1995). Unfortunately, the interpretation of these bone implantation studies is difficult (Mjör 1980).
However, more relevant clinical studies confirm the biocompatibility (Callis & Santini 1987, Zetterqvist et al. 1987). This intimate bond between GIC and living bone seems to be enhanced by fluoride leaching from the GIC (Brook et al. 1991).

Resin-modified glass ionomer cements
Resin-modified glass ionomer cements contain unsaturated groups and hence may lack the biocompatibility of conventionally setting GICs (Wilson 1990), and concerns have been raised about their use. Moreover, differences in the amounts and patterns of fluoride released (Verbeek et al. 1998) and cytotoxicity amongst RMGICs have been reported (Kan et al. 1997). Aluminium is also released from RMGICs in the short term, as well as in the long term (Forss 1993). According to Geurtsen et al. (1998), the eluates in RMGICs were the prime causes for cytotoxic reactions. The cytotoxicity of Vitremer (3M, St Paul, MN, USA) has been studied (Yoshikawa et al. 1994, Kan et al. 1997, Geurtsen et al. 1998), and the release ofHEMA has been shown to be one of the prime causes. Vitrebond used for pulp capping was more irritating to the pulp tissue than calcium hydroxide (do Nascimento et al. 2000). On the other hand, direct pulp capping with Vitremer did not seem to cause pulpal inflammation, and Vitremer implants only caused slight reactions in rabbits (Bazzucchi et al. 1995, Tassery et al. 1997).

Compared to conventionally setting GICs, RMGICs have easier handling properties; this, in association with their adhesion potential, makes them attractive as root-end filling materials. The low cytotoxicity (Chong et al. 1994a) and the pronounced antibacterial activity (Chong et al. 1994b), as well as a favourable tissue response when used as a root-end filling material in infected teeth (Chong et al. 1997a, b), demonstrate that this material might be used in endodontic surgery.

Root canal sealing
Orthograde root canal sealing
The objectives of root canal treatment are total debridement of the pulpal space, development of a fluid-tight seal at the apical foramen and total obliteration of the root canal (Ingle et al. 2002). Complete elimination of microorganisms is impossible (Sjögren et al. 1997, Sundqvist et al. 1998). The ideal root canal filling would thus be the one which possesses bactericidal properties against remaining microorganisms and which creates a barrier against newly invading microorganisms.

Thanks to their properties of chemical adhesion (Wilson et al. 1983, Akinmade & Nicholson 1993, Shen 1996) and long-term fluoride release (De Moor et al. 1996, Verbeek et al. 1998), GICs appear to have the desirable properties.

Sealing ability
Incomplete obturation of the root canal system is one of the causes of endodontic failure when microorganisms remain in the canal (Pettersson et al. 1986, Ingle et al. 2002). Endodontic filling materials with ability to seal the root canal hermetically are therefore important for successful root canal treatment.


Short working time and fast set are both factors that contribute to the fact that GICs are often used in combination with a single cone technique. This is in contradiction to the concept of gutta-percha condensation, of which it is expected that proper condensation and reduced thickness of the sealer enhance the seal (De Gee et al. 1994, Wu et al. 1994, 1997, Georgopoulou et al. 1995, Kontakiotis et al. 1997). The single cone technique in combination with GIC might therefore be the reason for the more extensive leakage (Lee et al. 1997).

Hence, also for GICs, sealer thickness appears to be a crucial factor in sealing efficacy. As with other sealers, the seal appears to be inversely related to the thickness of the sealer layer (De Gee et al. 1994, Wu et al. 1994, 1997, Georgopoulou et al. 1995, Kontakiotis et al. 1997). A thick layer implies more shrinkage and consequently more leakage (Wu et al. 1994).

Leakage mainly appears between the root canal wall and the sealer, where the presence of a smear layer influences the seal (Saunders & Saunders 1994a, Tidswell et al. 1994, Goldberg et al. 1995, Holland et al. 1995, Raiden et al. 1997, Taylor et al. 1997). This interface is affected by irrigants and medicaments used during root canal
layer allowed GIC-based sealers to enter some of the
dentinal tubules (Saunders et al. 1992), although not as
deply as other sealers (Sen et al. 1996). Nevertheless,
the literature remains contradictory. Thus, again
because of the limitations of the in vitro methodology,
removal of the smear layer has been reported to reduce
leakage significantly (Holland et al. 1995, Raiden et al.
1997, Taylor et al. 1997) or to make no difference
(Saunders & Saunders 1994a, Tidswell et al. 1994,
Goldberg et al. 1995).

In vivo evaluation To overcome the limitations of
in vitro investigations, Friedman et al. (1997) developed
a model to assess the functional efficacy of endodontic
filling materials and techniques in vivo, in which they
evaluated bacterial ingress in mandibular premolars in
beagle dogs. According to this model, an experimental
GIC sealer (KT-308), used in combination with cold
lateral gutta-percha condensation, scored better than Roth
801 cement (zinc oxide–eugenol sealer; Roth Interna-
tional Ltd., Chicago, IL, USA), when the canals of root-
filled teeth were inoculated with plaque (Friedman et al.
2000).

Retreatment
One of the requirements for an ideal root canal filling
material is that it should be removed easily from the root
Canal if necessary (Grossman 1982). Experience indi-
cates that removing a root filling that consists only of
hardened cement is difficult (Lovedahl & Gutmann
1997). Therefore, GIC sealer should be used in combi-
nation with gutta-percha: gutta-percha can be dissolved
and then the cement can be removed ultrasonically from
the canal without leaving excessive amounts of residue
on the canal walls (Friedman et al. 1992, Friedman et al.
1993a, Moshonov et al. 1994). Nevertheless, it has been
shown that it takes more time to remove a GIC sealer than
a conventional sealer during retreatment procedures
(Friedman et al. 1992, Friedman et al. 1993a, Moshonov
et al. 1994) and for partial removal during dowel space
preparation (Raiden et al. 1998).

Long-term clinical follow-up
Data on the long-term clinical follow-up of the use of GIC
root canal sealers during root canal treatment are
scarce, and clinical follow-up is limited to 18 months.
In a study performed by Friedman et al. (1995), the
healing rate for teeth treated with Ketac-Endo was in the
range reported in previous studies with other sealers.

One of the findings on Ketac-Endo was that, contrary
to other sealers (Augsburger & Peters 1990), it was not
resorbed after periradicular extrusion (Friedman et al.
1995), confirming its low tissue solubility.

Root-end filling material
Conventionally setting, resin-based and cermet GIC for-
mulations have been used as root-end filling materials.
As GICs are sensitive to moisture at the start of their
set and as avoiding moisture contamination in the peri-
radicular region is not achieved easily, the application
of GICs demands precise handling and placement pro-
dcedures.

In some cases, GICs have also been used at the apical
end of extremely shortened root canals, when a post-
space is needed after root-end resection (De Moor &
De Bruyne 2000).

Sealing ability
In vitro evaluation Glass ionomer cements used as
root-end filling materials have been tested in various
in vitro studies, with and without varnish, and have been
compared mainly to amalgam (Friedman 1991). Again,
because of the limitations of the methodology, the results
have been contradictory. GICs provided a better seal
(Schwartz & Alexander 1988, Zetterqvist et al. 1988,
Pissiotis et al. 1991, Aktener & Pehlivan 1993, Alhadainy
et al. 1995, Pretorius & van Heerden 1995, Gerhards &
2000), an equal seal (Olsen et al. 1990, Friedman et al.
1991a, Roth 1991, Danin et al. 1994, Sutimantanakul
et al. 2000, Siqueira et al. 2001) or a worse seal
(King et al. 1990, Danin et al. 1992, Biggs et al. 1995,
Sutimantanakul et al. 2000, Siqueira et al. 2001, Reister
et al. 2002) than other root-end filling materials. When
conventionally setting GICs were compared after appli-
cation of a varnish, a better seal was ensured
(Barkhordar et al. 1989, Aktener & Pehlivan 1993, Özata
et al. 1993); the resin-modified formulations scored better
than the conventional cement, and both rated better
than cermet cements (Özata et al. 1993, Rosales et al.
1996).

In vivo evaluation In general, the performance of GIC
has been comparable to that of amalgam (Friedman
et al. 1991b, Trope et al. 1996, Chong et al. 1997c), in con-
trast to the failure of GIC to seal infected root canals in
an earlier study (Pitt Ford & Roberts 1990).
Clinical evaluation  In spite of the previously mentioned contradictory results, it has been shown that, when peri-
radicular surgery with a root-end filling of Chemfil (De Trey, Zürich, Switzerland) was performed on teeth with
necrotic pulps and periapical pathosis without prior root canal treatment, satisfactory healing 1 year post-
operatively occurred (Damin et al. 1999). Also Ketac-Silver used as a retrograde filling material performed well
on the long term (Böhler 2000).

Follow-up
The long-term success of GIC as a root-end filling mate-
rial has been confirmed in several studies (Zetterqvist
to amalgam root-end fillings, GICs appear to perform
as well. The moist environment does not seem to be detri-
mental to the surface (Jesslén et al. 1995) and GICs seem
to be less susceptible to moisture than expected. This
has been shown both in vitro (De Moor & Verbeeck
1998) and in vivo (Friedman et al. 1991b).

Repair of perforations and root
resorption defects

Perforation repair
Root perforation is an undesirable complication of root
canal preparation and often leads to tooth extraction
(Fuss & Trope 1996). Successful treatment depends
mainly on immediate sealing of the perforation and pre-
vention of infection (Fuss & Trope 1996). In addition to
factors related to the perforation itself, such as time
elapsed since the perforation occurred and size and loca-
tion of the perforation (Lemon 1992, Fuss & Trope
1996), the repair material is also of importance (Fuss
& Trope 1996).

In vitro evaluation
Although in vitro studies alone cannot support the clin-
cal choice of materials, a variety of methods and materi-
als for perforation repair in vitro (surgical and nonsurgical) successfully tested GICs for sealing perfora-
tions (Alhadainy & Himel 1994, Himel & Alhadainy
& Abdalla 1998).

Clinical evaluation
(2000) and Breault et al. (2000) described the success-
ful repair of perforations with GIC. From these cases,
GIC appeared to be a suitable material for repair of
perforations or near perforations, where it acted as a
substitute for dentine.

Repair of root resorption cavities
Thorough debridement and cleaning of the resorption
cavity are essential for a good prognosis (Gutmann &
Harrison 1994). Moreover, long-term success is also
influenced by the use of a biocompatible restorative
material (De Moor et al. 2002). As previously stated,
because of the long setting reaction (setting continues
for more than 1 year; Wilson & McLean 1988), hydration
of GICs during the initial setting influences the long-
term properties through contact with the moist environ-
ment (Sen et al. 1996, Kontakiotis et al. 1997, Taylor et
al. 1997, Wu et al. 1997). Nevertheless, contemporary chemi-
cally cured GICs appear to perform well; Ketac-Fil (Espe,
Seefeld, Germany) used for the repair of resorption
defects gave satisfactory results for at least 4 years (De
Moor et al. 2002).

Treatment of vertically fractured teeth
Vertical fractures occasionally occur in vital teeth, both
intact and those with large restorations, because of
excessive occlusal forces or traumatic injuries. In endo-
dontically treated teeth, vertical fractures are more fre-
quency (Bender & Freedland 1983, Soerenson & Martinoff
1984, Hansen et al. 1990). In a vertically fractured tooth,
the fracture line becomes infected resulting in bone loss
along the fracture line (Walton et al. 1984). Consequently,
to successfully treat a fractured tooth and to eliminate
the infection, the fracture line needs to be eliminated
or, when a complete fracture is present, the tooth seg-
ments must be bonded together. A biocompatible environ-
ment should be maintained to obtain reattachment of
periradicular tissues (Trope & Rosenberg 1992).

In vitro evaluation
As a result of their adhesive properties, GICs have been
proposed for bonding root segments. Friedman et al.
(1993b) described the ability of Ionos glass ionomer
bone cement (Ionos, Seefeld/Oberbay, Germany), to bond
two segments together, to be less than that of bonding
agents and cyano-acrylate cement. Their findings were
based on the in vitro resistance to the repeated fracturing
of roots, which were previously fractured and bonded.
Also the use of Ketac-Endo, instead of AH 26, as a sealer
did not increase the resistance to root fracture in vitro
in human maxillary canine teeth, although both were
significantly stronger than roots whose canals were instrumented but not obturated (Cobankara et al. 2002). On the other hand, immature roots could be reinforced in vitro by placing a RMGIC in the canal after the apical 2 mm of the canal had been filled with gutta percha and AH 26 (Goldberg et al. 2002). Moreover, an advantage of GICs is that they can be used without etching, the latter being detrimental to the cementum and periodontal ligament (Hammarstrom et al. 1986). In this respect, it was seen that GICs can maintain a bond in a wet environment and withstand thermocycling better than Gluma (Bayer Dental, Leverkusen, Germany; Sorensen 1991). The biocompatibility of GIC may also offer opportunities for periodontal reattachment (Dragoo 1997). Treatment success depends on this reattachment and on prevention of periodontal tissue breakdown (Trope & Rosenberg 1992).

Clinical evaluation

Stewart (1990) strengthened incompletely fractured teeth by filling the canals with a modified GIC assumed to flow into the fracture line. One-year follow-up showed that the teeth were still comfortable.

Barkhordar (1991) described a case of a mesiodistal fracture in a maxillary first premolar. The fracture was initially treated with calcium hydroxide for 6 months in order to encourage the natural healing of the periodontal area and consequent resolution of the pockets. Silver-reinforced GIC was then used as a root canal sealer and condensed in the root canal. At the 2-year recall, satisfactory healing was present.

Trope & Rosenberg (1992) described a vertical fracture in a maxillary left second molar, which, 1 year after bonding the extracted segments together with a glass ionomer bone cement (Espe, Seefeld, Germany) and replantation, was still functioning normally.

Selden (1996) reported on the repair of incomplete vertical fractures in six teeth. After 1 year, all had failed, whether or not GIC had been used apart from 4-META, and despite elimination of all lateral occlusal contacts.

Coronal seal


In vitro evaluation

Although there is no clinical evidence, GICs perform well as a coronal filling material in vitro compared to other materials. Placement of GIC in the canal orifices and on the floor of the pulp chamber in multirotted teeth clearly diminished the coronal ingress of microorganisms from the access cavity of the filled root canals (Carman & Wallace 1994, Chailertvanitkul et al. 1997, Barthel et al. 1999, Barthel et al. 2001). In one study, using the fluid filtration method, GIC 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, Ketac-Fil GIC, placed in conditioned cavities, leaked less than Kalzinol (DeTrey, Zürich, Switzerland) and Cavit-W (Espe, Seefeld, Germany); while placed in unconditioned cavities, Ketac-Fil was almost equally effective as Kalzinol and more effective than Cavit-W after a 1-month experimental period (Liem 1990). Only one study showed a contrary result (Beckham et al. 1993).

Conclusion

Glass ionomer cements are bioactive and adhesive materials with a therapeutic action: they act as antimicrobial materials with a high degree of biocompatibility. In spite of their critical handling characteristics, there is substantial evidence for their use as a root-end filling material. Both soft tissue and bone compatibility make GICs suitable as root filling material during endodontic surgery. GICs used as a root canal sealer, however, have mostly been investigated in vitro and their use remains a matter of debate as a result of the inconclusive findings on their sealing ability and antimicrobial activity. The use of GICs in the repair of perforations or root resorption cavities and as temporary restoration during endodontic therapy, despite having been extensively investigated with success in vitro, requires further in vivo and clinical investigation. The repair of vertically fractured teeth with GICs has been described in a limited number of cases. The results remain contradictory and require further substantiation.

References


