The Benefits and Limitations of Glass-Ionomer Cements and Their Use in Contemporary Dentistry

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Abstract

Since the advent of glass-ionomer cement as a dental restorative material, the number of clinical applications has steadily increased as both the efficiency and improved clinical outcomes for patients have been realized.

Glass-ionomer cements provide tooth-coloured restorations with a low technique sensitivity. They bond chemically to sound and caries-affected tooth structure and release levels of fluoride that protect cavosurface margins from recurrent caries attack. In a clinical environment, a more predictable bond is achieved by pretreating teeth with 37 % phosphoric acid than 20 % polyacrylic acid.

The ion exchange layer between glass-ionomer cement and dentine facilitates the remineralization of caries-affected dentine into fluorapatite that provides a caries-resistant base beneath a glass-ionomer cement restoration or lining.

Auto-cure glass-ionomer cements can be used to restore carious lesions in a tooth where the cusps are not undermined and the restoration does not involve a high-wear area such as a centric stop. Resin-modified glass-ionomer cements should be limited as restorative materials to sites that are not subject to occlusal forces, and photo-curing is able to penetrate to the base of the restoration to minimize any residual unpolymerized HEMA.

Photo-cured resin-modified glass-ionomer cements are well suited as lining materials, luting agents and dental adhesives. As dental adhesives, resin-modified glass-ionomer cements eliminate the effects of polymerization shrinkage stress of composite resins and provide a caries-resistant zone around the perimeter of the restoration.

When composite resins and auto-cure glass-ionomer cements are combined to form a "sandwich restoration", the use of a resin-modified

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glass-ionomer cement adhesive as a "co-cure" intermediary between the two materials provides a time-efficient technique that effectively triples the bond strength between glass-ionomer cement and composite resin.

Since the advent of glass-ionomers as a dental restorative material, the number of clinical applications has steadily increased as dentists have discovered both the efficiency and improved clinical outcomes for patients that can be achieved with this material.

3.1 Clinical Benefits

From a clinician's point of view, glass-ionomer cements have a low technique sensitivity and can be efficiently applied over a wide range of clinical situations. There is also a popular perception amongst dentists that glass-ionomer cements protect teeth from recurrent caries more than composite resins (Forsten et al. 1994). The caries protection ability of glass-ionomer cements is now well established in the dental literature (McComb et al. 2002; Hicks et al. 2003).

3.1.1 Adhesion

Glass-ionomer cements chemically bond to tooth structure by ionic bonding. Although relatively weak compared to the mechanical bond strengths of resin-based adhesives, glass-ionomer cements will bond to both sound and (slightly less strongly) to caries-affected tooth structure (Lenzi et al. 2013).

3.1.2 Ion Exchange Layer and Fluorapatite Formation

The ion exchange layer between glass-ionomer cement and dentine in fact extends further into both tooth structure and the glass-ionomer cement than first observed (Wilson and McLean 1988). Electron probe microanalysis (EPMA) studies have shown penetration of over 75 μm of calcium and phosphorous ions into glass-ionomer cements and fluoride, strontium and aluminium ions into dentine, after two weeks of placing an auto-cure glass-ionomer overlay (Knight et al. 2007a). It can be postulated that the depth and amount of ion exchange could be expected to increase further over time. The penetration of fluoride ions into the dentine facilitates the transformation of carbonated apatite to fluorapatite (Fig. 3.1).

3.1.3 Fluoride Release

EPMA studies have demonstrated in vitro that fluoride released from glass-ionomer cements into demineralized dentine penetrates deeply into the underlying dentine at concentrations of about 5000 ppm (Ngo et al. 2006). Aqueous fluoride concentrations as low as 600 ppm have been shown to inhibit fluoride-resistant *Streptococcus mutans* bacteria (Brown et al. 1980) (Fig. 3.2).

3.1.4 Remineralization

The penetration of strontium, calcium and fluoride from glass-ionomer cements into dentine (Knight et al. 2007a, b) indicates that these ions are available to assist with remineralization of any demineralized dentine remaining beyond the restorative interface.

The combination of dentinal tubular fluid and ion penetration from auto-cure glass-ionomer cements into demineralized dentine creates an environment that predisposes to fluorapatite formation and increase in hardness of the demineralized tooth structure (Fig. 3.3).

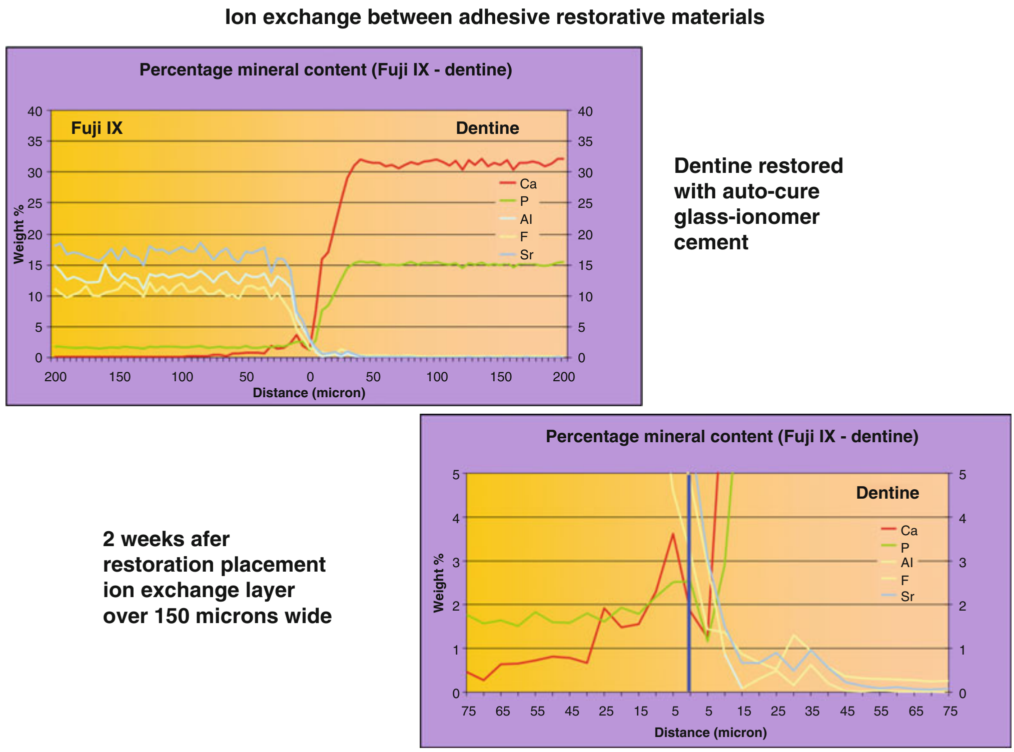


Fig. 3.1 Shows specific ion penetration between glass-ionomer cement and dentine after 2 weeks (Courtesy of Dr. Geoff Knight)

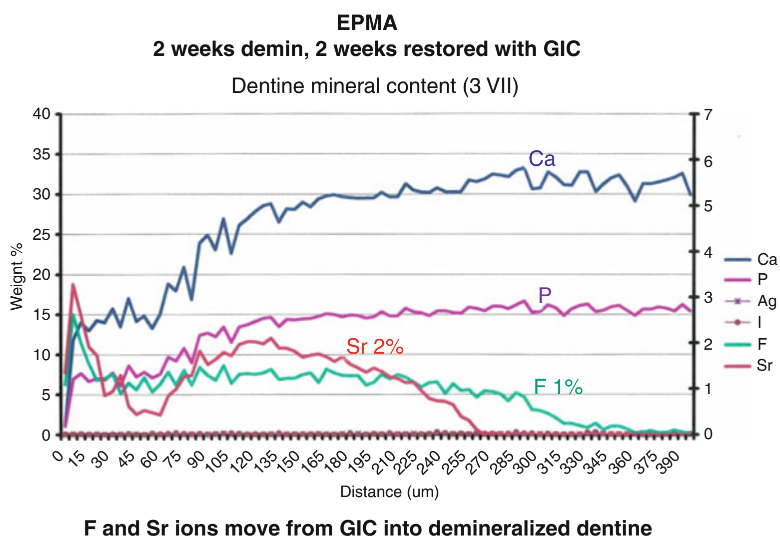


Fig. 3.2 This specimen was demineralized in an demineralizing solution (mimicking caries) onto which an auto-cure glass-ionomer cement restoration was placed. The specimen was examined 2 weeks after placement of the glass-ionomer. EPMA measurement of ion penetration from glass-ionomer cement into demineralized dentine. Note the concentration of fluoride ions at 1 % (about 5000 ppm) to the depth of demineralization, 300 µm into the dentine (Courtesy of Dr. Geoff Knight)

3.1.5 Marginal Caries Protection

Both auto-cure and resin-modified glass-ionomer cements protect the margins of restorations from caries up to depths of 0.25 mm (Knight et al. 2007b; Tantbirojn et al. 2009) while composite resins do not (Fig. 3.4).

3.1.6 Gingival Biocompatibility

Although there is conjecture in the literature about the effects that composite resin and glass-ionomer surfaces have on oral biofilm formation, a survey of the clinical observations of a group of dentists found that gingival inflammation associated with glass-ionomer cement restorations was rarely seen, whereas it was often seen with composite resin restorations (Forsten 1998).

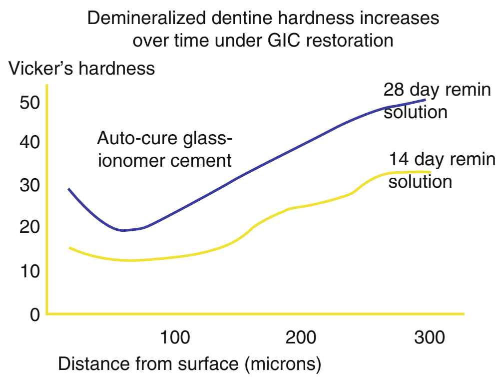


Fig. 3.3 Increase in Vickers hardness of demineralized dentine in a remineralizing solution of artificial saliva (to simulate the oral cavity) under a glass-ionomer cement restoration between 14 and 28 days (Courtesy of Dr. Geoff Knight)

3.1.7 Contouring

Unlike composite resins, amalgams or indirect restorations, glass-ionomers are relatively soft and easy to contour with either low- or high-speed instruments, especially in difficult access areas or at cervical margins.

3.1.8 Aesthetics

The aesthetics of the newer auto-cure glass-ionomer cements are approaching that of resin-modified glass-ionomer cements. In the aesthetic zone, requiring high aesthetics, composite resins are better suited. However, beyond this zone, most clinicians find that the aesthetics of glass-ionomer cements meet their patient's requirements.

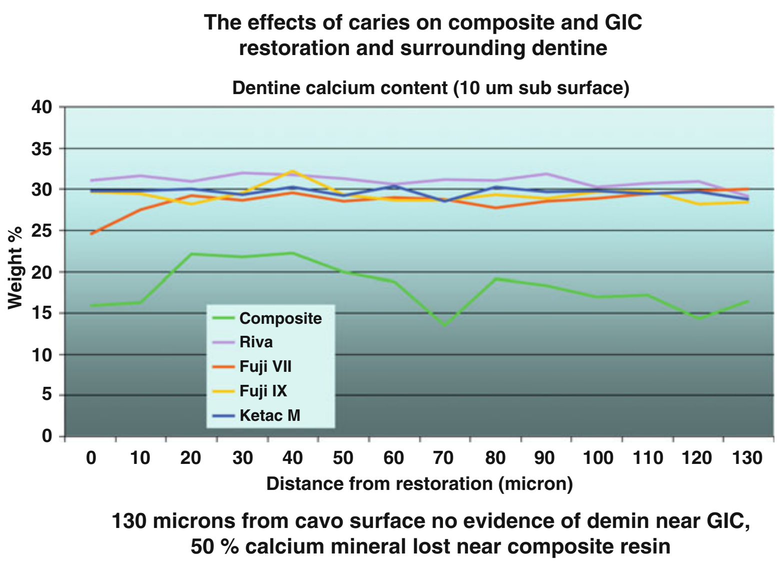


Fig. 3.4 EPMA of subsurface dentine after a 2-week challenge by *Streptococcus mutans* (simulated chemostat caries study) demonstrating 50 % loss of subsurface calcium adjacent to a composite resin restoration, while there has been no calcium loss from dentine restored with glass-ionomer cements (Courtesy of Dr. Geoff Knight)

3.2 Limitations of Glass-Ionomer Cements

3.2.1 Wear Resistance

The low wear resistance of glass-ionomer cements is often cited as a reason to exclude them as an occlusal restorative material. While the surface wear of resin-modified glass-ionomer cements clinically is significant, the restorative auto-cure glass-ionomer cements have an excellent record of low occlusal wear and marginal integrity, providing that they are not placed over occlusal surfaces that involve centric stops (Knight 1992; Lazaridou et al. 2015).

3.2.2 Buffering Oral Acids

Glass-ionomer cements act as buffers to changes in oral pH that will cause their slow degradation in areas where saliva is unable to wash oral acids away. This can result in the surfaces of the glass-ionomer cements being degraded and lost (Nicholson et al. 2000).

In such circumstances, when glass-ionomer cement and composite resin are placed to form an "open-sandwich" restoration, the glass-ionomer cement component of the restoration can be "washed out" to create the effect of proximal recurrent caries. This is possibly the reason why clinicians suggest that they observe proximal caries associated with these restorations (Tyas 2005). While caries may not be a problem, food packing certainly is, and the use of "open-sandwich" restorations should be discouraged as a clinical procedure and a "closed-sandwich" restoration should be placed instead (Figs. 3.5 and 3.6).

3.2.3 Residual HEMA (2-Hydroxyethylmethacrylate)

Resin-modified glass-ionomer (RMGIC) restorations have relatively good aesthetics. However, they should be limited to shallow restorations,

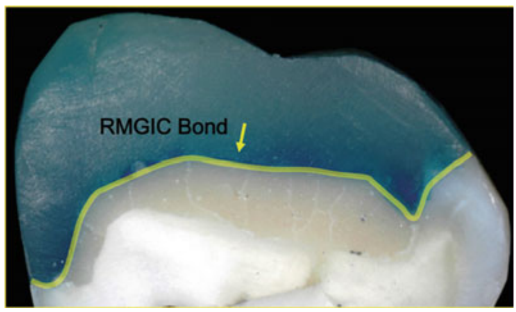


Fig. 3.6 Shows a "closed-sandwich" proximal restoration that prevents loss of proximal glass-ionomer cement (Courtesy of Dr. Geoff Knight)

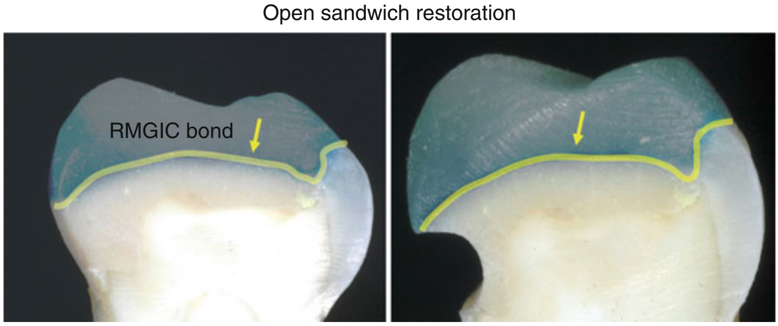


Fig. 3.5 Demonstrates the potential consequences of interproximal plaque acids on the glass-ionomer cement in an "open-sandwich" restoration (Courtesy of Dr. Geoff Knight)

away from occlusal loads as they have poor wear resistance, e.g. in cervical restorations.

Furthermore, these materials are quite opaque compared to composite resins, and there is limited penetration of light to the base of RMGIC restorations during photo-curing that can leave unpolymerized HEMA remaining at the restorative interface. This predisposes to water uptake from the tooth into the restoration and penetration of unpolymerized HEMA from the restoration into the dentinal tubules and eventually into the pulp (Watson 1997).

Light-cured resin-modified adhesives and luting agents, however, are applied as thin films over tooth surfaces that will result in much higher levels of polymerization of the HEMA upon photo-curing.

3.3 Clinical Applications

3.3.1 Surface Preparation

Glass-ionomer cements adhere as a relatively weak ionic bond (about 2.5 MPa) to any clean tooth surface irrespective if it is enamel, dentine or cementum and sound or carious (Lenzi et al. 2013). The bond strength may be enhanced by removing the surface bioload using either conditioning for 10 s with 20 % polyacrylic acid or etching for 5 s with 37 % phosphoric acid (Van Meerbeek et al. 2003).

3.3.2 Condition or Etch?

Traditionally, manufacturers have instructed clinicians to condition teeth with 20 % polyacrylic acid for 10 s prior to placing glass-ionomer cements and have shown a slightly superior bond achieved in vitro with conditioning compared to etching. In addition, the conditioner contains the same components as the liquid used in glass-ionomer cements, and hence, any residue should not interfere with the bonding process; on the other hand, it is said that etching removes mineral content from dentine that reduces the bond strength (McLean 1992).

Much of this published work has been carried out in vitro, and there are significant clinical differences when applied to the oral environment.

Firstly, most hand-pieces are oiled prior to autoclaving, resulting in a spray of oil over the tooth surface from the hand-piece during cavity preparation. The bond strength of dentine surfaces contaminated with oil and conditioned with polyacrylic acid is half that of a non-contaminated surface (Matos et al. 2008). However, etching removes the oil from the dentine surface; dentine with oil contamination that has been etched has the same bond strength as etched non-contaminated dentine (Matos et al. 2008).

Furthermore, a recent paper has shown that RMGIC bonding agents are equally effective, irrespective of whether they are etched or conditioned (Hamama et al. 2014).

Finally, as the fluoride ions from a glass-ionomer cement penetrate the etched dentine surface and combine with dentinal tubular fluid, the dentine will remineralize to form a caries-resistant layer of fluorapatite.

3.4 Auto-Cure or Resin-Modified Glass-Ionomer Cements?

Auto-cure glass-ionomer cements are better suited as restorative materials than resin-modified glass-ionomers as they have better occlusal wear and do not have the problems associated with residual HEMA found at the base of resin-modified glass-ionomer cement restorations.

3.5 Auto-Cure Glass-Ionomer Cements

3.5.1 Fissure Protection

The use of composite resins to fissure seal occlusal surfaces deemed to be at risk from caries has long been advocated by many in the dental profession.

As teeth form in a "biological soup", when they first erupt into the mouth, the hydroxyl apatite crystals are contaminated with carbonate groups that make them more prone to acid breakdown at a higher pH than teeth that have been erupted for some time. After eruption, the outer layers of apatite are subjected to a series of demineralization and remineralization cycles, which in the presence of fluoride, will form a layer of fluorapatite crystals that require a lower pH for demineralization and hence are more caries resistant than a newly erupted tooth (Chow and Vogel 2001).

Sealing a fissure with composite resin on a recently erupted tooth prevents the transformation from carbonated apatite to fluorapatite, leaving the tooth potentially more susceptible to caries if the seal was lost. A tooth that has been in the mouth and subjected to multiple demineralization and remineralization cycles will be far more resistant to microbial attack.

Protecting a fissure with auto-cure glass-ionomer cement has the benefit of, firstly, demineralizing the outer apatite crystals due to the low pH of the uncured glass-ionomer. Secondly, after curing when the pH returns to neutral and in the presence of a high concentration of fluoride ions, demineralized apatite crystals will remineralize as fluorapatite.

Eventually, when the glass-ionomer has worn from the surface, the remaining enamel will be able to resist caries attack as well, if not better, than a mature tooth that has been subjected to multiple remineralizing cycles in a high-fluoride environment.

3.5.1.1 Technique

- Etch the surface to be protected for 5 s with 37 % phosphoric acid, wash and dry thoroughly.
- Isolate the tooth with cotton rolls.
- Apply an auto-cure glass-ionomer over the surface and "puddle" into the fissures with a disposable mini-brush.
- Place a 3 x 2 cm film of a "freezer bag" over the surface and have the patient close in maximum intercuspation. This will force the glass-ionomer into the fissures and maximize the amount that can exist within the occlusion, substantially increasing the area to be protected and the time the glass-ionomer will remain upon the occlusal surface before being worn away (Fig. 3.7).

3.5.2 Management of Cervical Hypersensitivity

The low-viscosity auto-cure glass-ionomer cements are well suited for protection from cervical hypersensitivity by isolating the tooth sur-

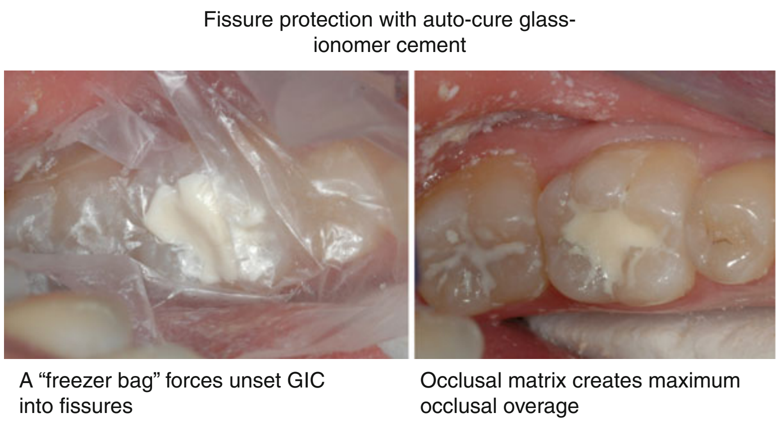


Fig. 3.7 Placement of a 3 × 2 cm piece of freezer bag over a glass-ionomer cement when fissure sealing will force the cement into the fissures and defines the occlusal envelope allowing the maximum amount of glass-ionomer cement coverage of the occlusal surface (Courtesy of Dr. Geoff Knight)

face from the oral environment and releasing fluoride that may well further help encourage desensitization.

3.5.2.1 Technique

- Clean the surface to be treated ideally with 37 % phosphoric acid for 5 s; depending upon the level of sensitivity, this may require prior administration of a local anaesthetic.
- Isolate the area with cotton rolls.
- Mix the low-viscosity auto-cure glass-ionomer and place the unset material on a mixing pad.
- Using a small disposable mini-brush, paint over the relevant areas identified with the hypersensitivity. Distribution of the glass-ionomer cement may be aided by blowing air gently into the interproximal spaces.
- Allow the glass-ionomer to cure.
- A second application of the glass-ionomer may occasionally be required.

3.5.3 Luting Cements

Both auto-cure and resin-modified glass-ionomer cements can be used as luting cements. They are radiopaque and have reasonable adhesion (about 10 MPa) and a relatively high-fluoride release that protects margins from recurrent caries (Tantbirojn et al. 2009).

Auto-cure luting cements have a film thickness of about 20 μm and resin-modified luting cements as low as 10 μm.

Auto-cure luting cements are suitable for metal-based restorations or posts. Resin-modified luting cements have similar properties and benefit from a controlled setting time.

Resin-modified luting cements will bond to both metallic and ceramic surfaces at bond strengths of about 7 MPa. Resin-modified luting cements are best applied to translucent restorations that will facilitate photo-cure polymerization of the HEMA within the cement.

3.6 Auto-Cure Glass-Ionomer Cement as a Restorative Material

The choice of the type of restoration technique depends upon the site of the lesion and the state of the tooth to which it is to be applied. If the lesion occurs in a region of a tooth where the surrounding cusps are well supported and not involving a centric stop, a wear-resistant glass-ionomer cement restoration may be used. When adjacent cusps are undermined and susceptible to occlusal loads, or if the centric stops occur on the occlusal surface, then a composite resin or combined composite resin/glass-ionomer cement restoration may be more appropriate (Figs. 3.8 and 3.9).

3.6.1 Occlusal Restorations with Supported Cusps: OI-Type Cavity

These are small cavities that do not involve centric stops and can be placed using auto-cure glass-ionomers.

Cavity classification

Site	Supported cusps I	Unsupported cusps II	Missing cusps III
Occlusal "O"			
Proximal "P"			
Cervical "C"			

Based upon the site and anatomical integrity of the surrounding tooth

Fig. 3.8 This table, developed by the author, shows a classification for restorations based upon the site of a lesion and the anatomical integrity of the surrounding tooth structure; i.e. if the surrounding cusps are supported and centric stops not involved, then a wear-resistant auto-cure glass-ionomer cement restoration is indicated: if surrounding cusps are not supported, then a composite resin or glass-ionomer composite "sandwich" restoration is required (Courtesy of Dr. Geoff Knight)

Occlusal cavity with supported cusps

Site	Supported cusps I	Unsupported cusps II	Missing cusps III
Occlusal "O"	●		
Proximal "P"			
Cervical "C"			

Type "OI" cavity restored with auto-cure glass-ionomer cement

Fig. 3.9 Traditional Class I cavity: this classification is for a small occlusal cavity with well-supported surrounding cusps suitable for placing a wear-resistant auto-cure glass-ionomer cement. OI-type cavity (Courtesy of Dr. Geoff Knight)

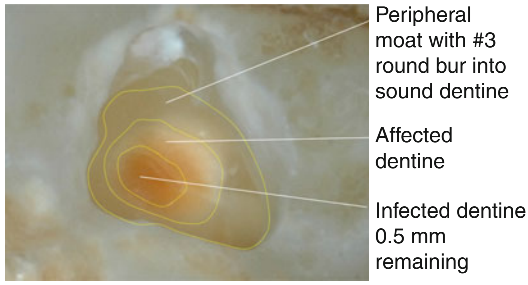


Fig. 3.10 Cavity preparation. Remove caries to just above the infected dentine layer as shown, leaving a 0.5 mm layer of carious dentine at the base of the preparation surrounded by affected (remineralizable) dentine. Prepare a moat around the periphery of the cavity into sound dentine using a no. 3 round bur (Courtesy of Dr. Geoff Knight)

3.6.1.1 Technique

- Caries removal: as glass-ionomer cements release bactericidal levels of fluoride, a conservative preparation to just above the affected dentine layer is recommended, leaving a 0.5 mm layer of carious dentine at the base of the preparation (Knight et al. 2007a; Ngo et al. 2006; Brown et al. 1980).
- Cavity preparation is completed by preparing a moat around the dentino-enamel junction using a size no. 3 round slow-speed bur to aid retention and assure a biological seal into sound dentine. This acts as a further preventive measure against recurrent caries.
- After cavity preparation, etch the preparation for 5 s with 37 % phosphoric acid (to remove hand-piece oil and other debris), wash and dry with oil-free air.
- Isolate with cotton rolls.
- Place the glass-ionomer cement into the cavity (preferably with a capsule) from the base of the cavity upwards to minimize air inclusions and to slightly overfill the cavity.
- Place a 3 x 2 cm piece of "freezer bag" over the restoration and ask the patient to close into maximum intercuspation until the glass-ionomer cement cures. This forces the glass-ionomer cement into the cavity and creates an occlusal matrix that minimizes contouring of the cured restoration.
- In small cavities, the only adjustment required can be done with a sharp excavator.
- In larger restorations that involve more of the occlusal surface, it may be necessary to contour the inclined planes of the restoration parallel to those of adjacent teeth to compensate for lateral and protrusive movements of the mandible during mastication
- Covering the restoration with an isolating varnish film is a matter of the clinician's choice (Fig. 3.10).

3.6.2 Occlusal Restorations with Unsupported Cusps: OII-Type Cavity

These cavities involve more of the occlusal surface such that cusps are either unsupported or involve centric stops. Glass-ionomer cement restorations do not have the shear strength to support these cusps and are subject to high levels of wear on surfaces involving centric stops. In such circumstances, the preferred restorative technique is a "sandwich" technique, described by John McLean, where glass-ionomer cement

Occlusal cavity with unsupported cusps

Site	Supported cusps I	Unsupported cusps II	Missing cusps III
Occlusal "O"		●	
Proximal "P"			
Cervical "C"			

Type "OII" cavity restored with auto-cure glass-ionomer cement with composite resin overlay

Fig. 3.11 Traditional Class I cavity: this classification is for a larger occlusal cavity when the surrounding cusps are unsupported or the restoration involves a centric stop indicating a composite resin or glass-ionomer composite "sandwich" restoration. OII-type cavity (Courtesy of Dr. Geoff Knight)

replaces dentine and composite resin replaces enamel (McLean 1992) (Fig. 3.11).

3.6.2.1 Technique

- Caries removal is similar as for a small occlusal restoration: leave 0.5 mm layer of carious dentine and prepare a moat into sound dentine around the dentino-enamel junction using a no. 3 round bur.
- As the cusps are unsupported, it is advisable to protect them using an occlusal overlay preparation with a high-speed large round diamond bur.
- After cavity preparation, etch the preparation for 5 s with 37 % phosphoric acid (to remove hand-piece oil and other debris), wash and dry with oil-free air.
- Isolate with cotton rolls.
- Place the glass-ionomer cement into the cavity (preferably using a capsule), filling from the base of the cavity upwards to minimize air inclusions up to the dentino-enamel junction.
- Prepare a resin-modified glass-ionomer adhesive bond and either wait until the auto-cure glass-ionomer has set or place the bond directly over the uncured glass-ionomer and the exposed cavosurface margin walls (Knight et al. 2006). (This procedure is called "co-curing" and discussed later within this chapter.)

Occlusal cavities with unsupported cusps

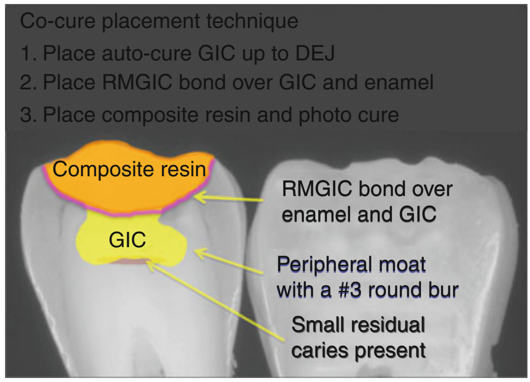


Fig. 3.12 During cavity preparation, the cusps are protected by forming a cusp overlay on the occlusal surface. The technique of bonding composite resin to auto-cure glass-ionomer cement with resin-modified glass-ionomer cement bonding adhesive is called "co-curing", enabling chemical adhesion of about 7 MPa between the two materials (Knight et al. 2006) (Courtesy of Dr. Geoff Knight)

- Insert an increment of composite resin over the freshly set or unset glass-ionomer to slightly overfill the cavity.
- Burnish the margins with a ball burnisher.
- Place a 3 x 2 cm piece of "freezer bag" over the restoration and ask the patient to close into maximum intercuspation onto the uncured composite resin.
- While the patient remains in occlusion, photo-cure the restoration from the buccal aspect for 5 s.
- Ask the patient to open and photo-cure for a further 10 s.

If the composite resin has been placed onto the uncured glass-ionomer, the heat generated from the polymerization of the composite will initiate a cascade setting reaction within the glass-ionomer cement, causing a complete cure within 40 s (Knight et al. 2006) (Fig. 3.12).

- As these restorations involve most of the occlusal surface, it will be necessary to contour the inclined planes of the restoration parallel to those of adjacent teeth to compensate for lateral and protrusive movements of the mandible during mastication.
- After contouring, polish the composite resin to a high gloss to minimize patient discomfort and plaque accumulation (Fig. 3.13).

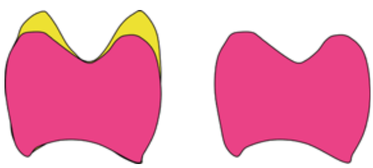
3.6.3 Proximal Restorations with Supported Cusps: PI-Type Cavity

These restorations are usually associated with unrestored proximal caries.

Breaking through the marginal ridge destroys the structural integrity of the tooth and weakens cusps that eventually lead to fracture.

A "tunnel" or slot restoration will maintain this structural integrity and is the most conservative and efficient way to manage such lesions (Knight 1992). If the lesion is visible on either the facial or lingual aspect of the tooth, slot (Morand and Jonas 1995) restorations are preferable; if the lesion is not visible, then a tunnel restoration is indicated (Knight 1984; Hunt 1984). As neither of these restorative techniques involve a centric stop, both are suitable for restoration by auto-cure glass-ionomer cements (Fig. 3.14).

Adjusting occlusion after maximum intercuspation



- Maximum intercuspation does not allow for lateral or protrusive movements
- Look at the incline planes of adjacent teeth in that segment of the arch
- Contour the incline planes parallel to adjacent teeth
- Check bite for occlusal interferences

Fig. 3.13 Following photo-curing of the occlusal surface, the inclined planes of the restoration require to be contoured parallel to the inclined planes of adjacent teeth to facilitate lateral and protrusive movements within the dentition (Courtesy of Dr. Geoff Knight)

Proximal lesion with supported cusps

Site	Supported cusps I	Unsupported cusps II	Missing cusps III
Occlusal "O"			
Proximal "P"	●		
Cervical "C"			

Type "PI" cavity restored with auto-cure glass-ionomer cement

Fig. 3.14 Traditional Class II cavity: this classification is for initial proximal lesions (irrespective of size) where the marginal ridge remains intact and surrounding cusps are supported, indicating a wear-resistant auto-cure glass-ionomer cement restoration. PI-type cavity (Courtesy of Dr. Geoff Knight)

3.6.3.1 Technique

Slot Restorations

- Access the lesion where it is visible with a water-cooled high-speed bur.
- Use a slow-speed round bur (nos. 3 to 6 depending on the extent of caries) to conservatively remove the carious dentine, leaving the affected dentine if practicable.
- Prepare a moat around the dentino-enamel junction into sound dentine with a no. 3 round bur at the perimeter of the cavity to aid retention and ensure a biological seal into sound dentine to prevent recurrent caries.
- Etch the preparation for 5 s, wash and dry the preparation.
- Isolate with cotton rolls.
- Insert a sectional matrix or Mylar strip into the proximal area and wedge the matrix against the preparation with a suitably sized GP point.
- Mix a capsulated auto-cure glass-ionomer cement and insert to the depth of the preparation.
- Slowly extrude the glass-ionomer cement into the cavity, withdrawing the capsule to avoid air bubbles until the cavity is slightly overfilled.
- Fold the matrix band or Mylar strip over the exposed part of the preparation and hold in place until the glass-ionomer has cured.
- Remove the GP point and matrix or Mylar strip and remove any flash of glass-ionomer that may be present.
- Covering the restoration with an isolating varnish film is a matter of the clinician's choice (Figs. 3.15, 3.16 and 3.17).

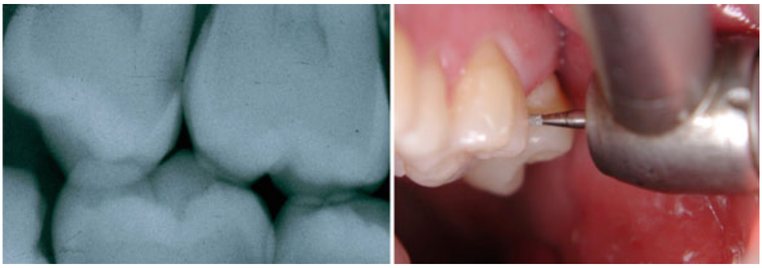


Fig. 3.15 Slot preparation when the lesion is visible from the buccal aspect using a high-speed bur, taking care to avoid the adjacent proximal tooth surface (Courtesy of Dr. Geoff Knight)

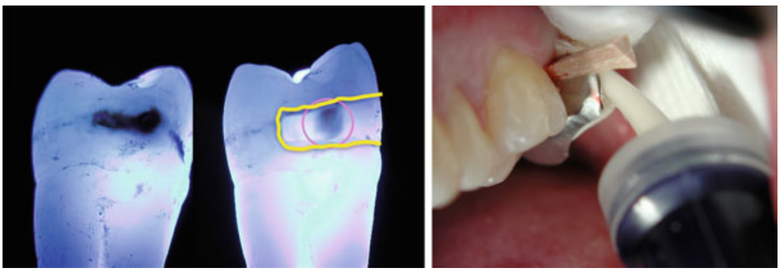


Fig. 3.16 After initial caries removal with a slow-speed round bur, a moat is prepared around the perimeter of the slot with a no. 3 round bur into sound dentine. The nozzle of the GIC capsule is inserted to the depth of the cavity and cement slowly extruded as the nozzle is withdrawn (Courtesy of Dr. Geoff Knight)

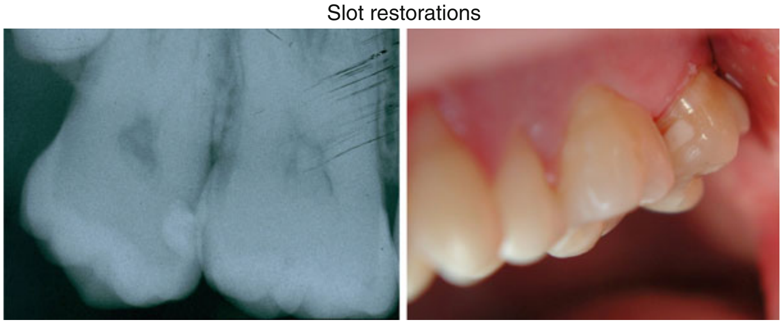


Fig. 3.17 The completed restoration maintaining the structural integrity of the tooth (Courtesy of Dr. Geoff Knight)

Tunnel Restorations

- Prepare a "T" cavity in the enamel above the lesion with a water-cooled high-speed bur 2 mm in from the marginal ridge, extending 2 mm facially, 2 mm lingually and 2 mm over the occlusal surface. This will conservatively maximize both mechanical and visual access to the preparation.

- Choose a slow-speed round bur depending on the size of the lesion and start removing dentine above the lesion by running the bur along the dentino-enamel margin until the lesion is reached.
- Once the caries has been accessed, gently loop the bur around the proximal lesion, staying at the dentino-enamel junction and limiting tooth removal to tactile detectable softened dentine.
- Run the bur around the enamel margins of the proximal cavitation to remove any unsupported enamel.
- With a no. 3 round bur, create a moat into sound dentine at the dentino-enamel junction, starting either facially or lingually and running the bur below the cavitated enamel and up the other side of the preparation to biologically seal the restoration, preventing recurrent caries.
- Etch with 37 % phosphoric acid for 5 s, wash and dry the preparation.
- Isolate with cotton rolls.
- Insert a Mylar strip into the interproximal space and withdraw it facially until there is about 0.5 cm extending beyond the lingual aspect of the tooth.
- With a pair of scissors, cut away the facial strip, leaving about 0.5 cm of it protruding.
- Firmly wedge the proximal matrix against the preparation with a suitably sized GP point.
- Mix a capsulated auto-cure glass-ionomer cement and insert to the depth of the preparation.
- Slowly extrude the glass-ionomer cement into the cavity, withdrawing the capsule to avoid air bubbles until the cavity is slightly overfilled.
- Ask the patient to commence closing slowly into maximum intercuspation and just prior to tooth contact; fold the matrix over the occlusal aspect of the cavity using a periodontal probe or a similar plastic instrument.
- The patient should remain closed in this position until the glass-ionomer cement has set.
- When the glass-ionomer cement has set, remove the GP point and the matrix band along with any flash visible on the proximal surfaces.
- Minimal contouring to remove occlusal interferences is usually required.
- Covering the restoration with an isolating varnish film is the clinician's choice (Figs. 3.18, 3.19, 3.20 and 3.21).

3.6.4 Proximal Restorations with Unsupported Cusps (Fig. 3.22)

Soon after auto-cure glass-ionomer cements first started to be used as a restorative material, McLean advocated the concept of a "sandwich"

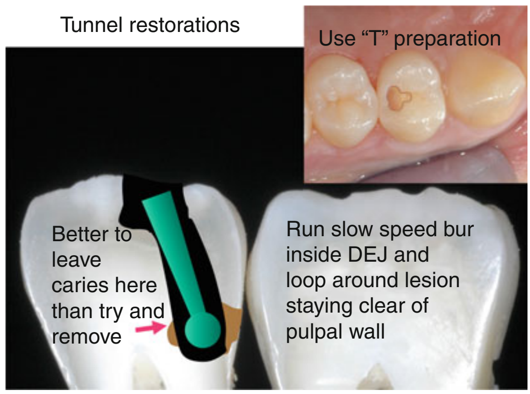


Fig. 3.18 Prepare a conservative "T" preparation in the enamel with a high-speed diamond bur. Following this, access the lesion with a slow-speed round bur running along the dentino-enamel junction until the caries is reached, looping the bur slightly below the point where the lesion has broken through the enamel (Courtesy of Dr. Geoff Knight)

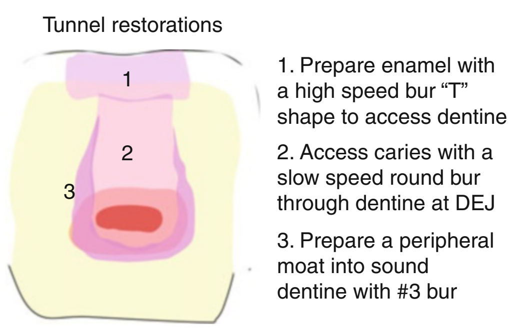


Fig. 3.19 After removing caries around the lesion along the dentino-enamel junction, take a no. 3 round slow-speed bur and prepare a moat into sound dentine at the perimeter of the preparation (Courtesy of Dr. Geoff Knight)

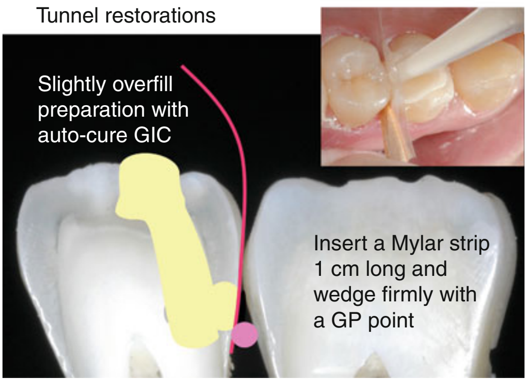


Fig. 3.20 Insert a 1-cm-long Mylar strip interproximally and wedge it firmly with a GP point followed by slightly overfilling the cavity with auto-cure glass-ionomer cement (Courtesy of Dr. Geoff Knight)

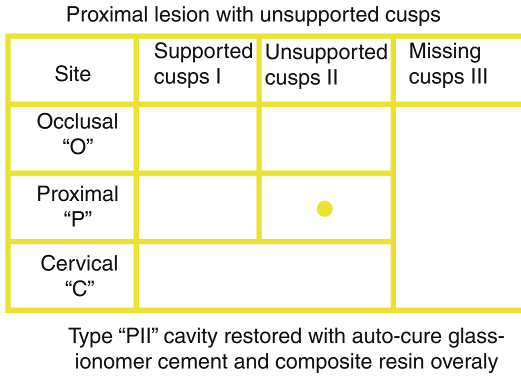


Fig. 3.22 Traditional Class II cavity: this classification is for proximal lesions where the marginal ridge is no longer present; cusps are unsupported, indicating a composite resin or glass-ionomer composite "sandwich" restoration. PII-type cavity (Courtesy of Dr. Geoff Knight)

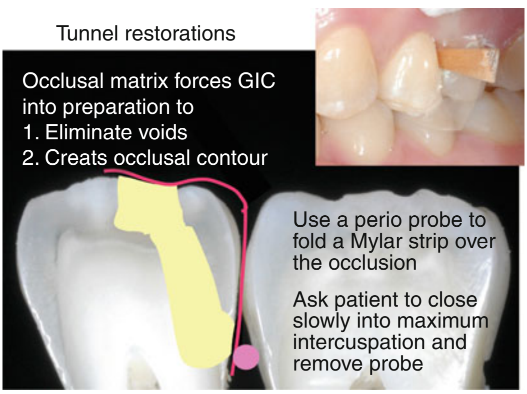


Fig. 3.21 Ask the patient to close slowly into maximum intercuspation and just prior to contact; fold the Mylar strip over the occlusal surface with a periodontal probe or similar instrument. This forces the glass-ionomer cement into the preparation, eliminating voids and creates an occlusal anatomy that minimizes contouring after the glass-ionomer has set (Courtesy of Dr. Geoff Knight)

restoration (McLean 1992) where dentine was replaced with glass-ionomer cement and enamel was replaced with composite resin. The two materials were bonded together by first waiting for the glass-ionomer cement to cure and then etching the set glass-ionomer with phosphoric acid for 10 s, after which resin bond was applied to the glass-ionomer surface followed by composite resin. The weak resulting bond was in the order of 2 MPa (Knight et al. 2006) and prone to debonding in areas where moderate tensile forces were applied to the restoration. A much higher bond can be achieved between auto-cure glass-ionomer cements by placing a layer of resin-modified glass-ionomer cement adhesive between the glass-ionomer and composite resin.

This resin-modified bonding system can be applied to the auto-cure glass-ionomer cement either before or soon after the glass-ionomer cement has cured to achieve a bond strength of about 7 MPa (Knight et al. 2006), which is the bond strength at cohesive failure of auto-cure glass-ionomer cement. In other words, the bond achieved in this manner is greater than the forced required for cohesive failure of the glass-ionomer cement.

When the composite resin is applied to the uncured glass-ionomer cement and subsequently photo-cured, the exothermic setting reaction of the composite resin heats up the surface of the auto-cure glass-ionomer and causes a cascade setting reaction within the glass-ionomer, significantly reducing the setting time and thus the clinical time required to place the restoration (Knight et al. 2006). This procedure is called "co-curing" and is discussed in depth later within this chapter.

"Open-sandwich" restorations may lead to food packing and are generally clinically unsatisfactory (Welbury and Murray 1990). A "closed-sandwich" technique is preferred where a layer of auto-cure glass-ionomer cement is laid down as a base but not extending onto the proximal surfaces. A thin layer of resin-modified cement bonding agent is present at the margins to afford some protection from recurrent caries, and the glass-ionomer cement remains available to help arrest proximal caries if they proceed past the layer of overlying composite resin.

With these factors in mind, the technique for placing a closed-sandwich restoration is described below.

3.6.4.1 Technique

- Access the lesion with a water-cooled high-speed bur.
- If caries are present, use a slow-speed round bur (nos. 3 to 6 depending on the extent of caries) to conservatively remove the carious dentine, leaving the affected dentine.
- Prepare a moat around the dentino-enamel junction into sound dentine with a no. 3 round bur to form a biological seal. This is particularly important on the floor of the proximal box where dentinal tubules run parallel to the cavity floor. Creation of a moat means that the ends of the dentinal tubules will be blocked with either auto-cure glass-ionomer or a resin-modified dentine bonding agent.
- If bleeding is present on the proximal gingivae, a small amount of a saturated solution of trichloroacetic acid (TCA) may be applied with a periodontal probe onto the tissues as a powerful haemostatic agent. When using this product, clinicians are advised to have an antidote of a saturated solution of sodium bicarbonate on hand in case any acid is inadvertently spilled onto the patient's skin, where it will cause an uncomfortable and long-lasting caustic burn.
- Etch the preparation with 37 % phosphoric acid for 5 s, wash and dry.
- Isolate with cotton rolls.
- Prior to applying a proximal matrix, place a layer of auto-cure glass-ionomer cement over the dentinal surfaces up to the dentino-enamel junction. If no enamel is present on the proximal floor, bring the glass-ionomer to a feather-edge at the margin.
- Mix a resin-modified glass-ionomer adhesive, and apply this over the glass-ionomer cement (either cured/set or uncured/setting) and the remaining cavity walls.
- Place a preferred matrix system and wedge as required.
- Insert a small amount of composite resin onto the floor of the proximal box and photo-cure for 10 s (making sure there is an adequate contact of the matrix band with the adjacent tooth).
- Place a further increment of resin-modified glass-ionomer adhesive over the composite resin and cure for 10 s.
- Place the final increment of composite to slightly overfill the remaining cavity space, and photo-cure for a further 10 s.
- Remove the matrix and contour the composite restoration to fit within the occlusal envelope.
- Carry out final contouring and polish the restoration (Figs. 3.23, 3.24 and 3.25).

3.6.5 Silver-Sintered Auto-Cure Glass-Ionomer Cements

Originally looked upon as a means of strengthening auto-cure glass-ionomer cements, silver and gold particles were sintered into the glass particles to form the powder component of the resto-

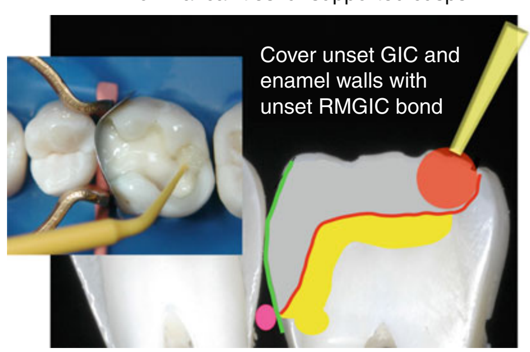


Fig. 3.23 The auto-cure glass-ionomer cement is placed up to the dentino-enamel junction and just short of the margin of the proximal floor. Observe the moat at the dentino-enamel junction margin. Cover the set or unset auto-cure glass-ionomer cement with a thin layer of resin-modified glass-ionomer adhesive (Courtesy of Dr. Geoff Knight)

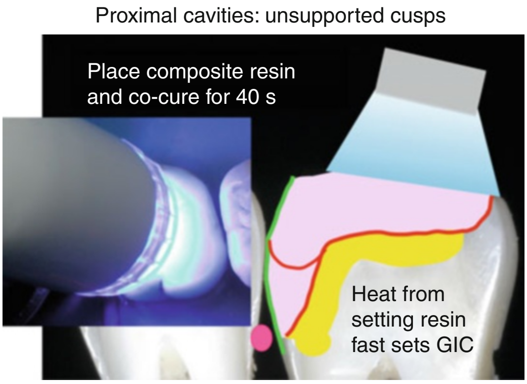


Fig. 3.24 After creating a proximal contact with the composite resin and curing it, fill the remainder of the cavity with composite resin and photo-cure. If the auto-cure glass-ionomer cement has not yet set, curing for 40 s combined with the exothermic setting reaction of the composite will cause a cascade setting reaction within the glass-ionomer, saving valuable clinical time (Courtesy of Dr. Geoff Knight)

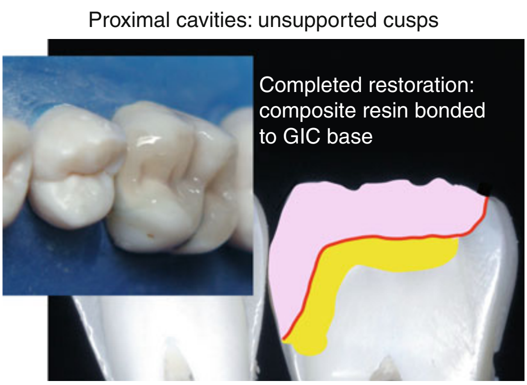


Fig. 3.25 Completed closed-sandwich restoration with the auto-cure glass-ionomer cement and the composite resin chemically bonded with resin-modified glass-ionomer adhesive (Courtesy of Dr. Geoff Knight)

ration. The gold proved too expensive, but the silver version has persisted. Another version is simply to mix amalgam particles into the existing glass-ionomer powder.

The poor aesthetics of these products have reduced their clinical acceptance; however, the high radiopacity makes them suitable for cores, and when used as long-term intermediate restorations, they seem to stay in the cavity well beyond the predicted life expectancy, possibly due to the silver particles acting as a surface lubricant and minimizing the traumatic effects of occlusion.

3.6.6 Managing Endodontically Treated Teeth in a Collapsing Dentition

Many older patients experience collapse of their dentitions as endodontically restored teeth decoronate and leave exposed roots at the gingival margins. The extraction of these teeth adds unnecessary trauma to a frail individual, and they can be managed either by being covered by a denture or left exposed within the dentition by covering the root stumps with auto-cure glass-ionomer cement.

The release of fluoride from the glass-ionomer inhibits caries formation, and minimal cavity preparation is required to produce a smooth surface restoration that prevents tongue lacerations from a jagged cavity margin.

3.6.6.1 Technique

- Minimally prepare the root surface to gain some undercuts if possible.
- Etch for 5 s, wash and dry thoroughly.
- Isolate the cavity with cotton rolls.
- Apply a layer of resin-modified dental adhesive and photo-cure.
- Apply a second layer, but do not photo-cure.
- Apply an increment of auto-cure glass-ionomer cement to slightly overfill the preparation.
- Contour the glass-ionomer with the applicator brush used for the adhesive.
- Photo-cure the auto-cure glass-ionomer and the adhesive for 40 s.

The resin-modified adhesive will triple the bond strength of the glass-ionomer cement, and the energy from the curing light will reduce the normal curing time of the auto-cure glass-ionomer cement (Fig. 3.26).

3.6.7 Resin-Modified Glass-Ionomer Cements

3.6.7.1 Resin-Modified Glass-Ionomer Cement as a Restorative Material

Resin-modified glass-ionomer cements are well suited as luting cements and tooth adhesives

Salvaging broken down root-filled teeth

1. Minimal tooth preparation, etch, wash and dry
2. Apply RMGIC bond and photo-cure, reapply bond
3. Place GIC over unset bond and photo cure

Fig. 3.26 Salvaging a decoronated tooth that has been root-filled with an auto-cure glass-ionomer cement restoration preserves the alveolar ridge and can be incorporated under a denture or left to protect the gingiva from hard food particles (Courtesy of Dr. Geoff Knight)

where thin layers can be photo-cured to polymerize the HEMA present within the cement. In deep cavities, the possibility of unpolymerized HEMA at the floor of the cavity can result in absorption of fluid from the tooth into the restoration or permeation of free HEMA into the dentine and pulp where postoperative sensitivity may develop (Watson 1997).

The clinical use of resin-modified glass-ionomer cements as a restorative material should be limited to shallow cervical restorations where high aesthetics are required and core build-ups in nonvital teeth where there is adequate remaining tooth structure. Resin-modified glass-ionomer cements are well suited as dental adhesives, thin cavity lining materials and luting of translucent ceramic restorations.

3.6.7.2 Cavity Liners

Resin-modified glass-ionomer cements have been successfully used as cavity liners for many years. In thin layers, the free HEMA is mostly polymerized to create an adhesive, bactericidal (Duque et al. 2009), thermally protective and radiopaque liner for use under composite resin or amalgam restorations.

3.6.8 Dental Adhesives

3.6.8.1 Bonding Composite Resin to Tooth Structure

When resin-modified glass-ionomer cements are used as dental adhesives, they are able to eliminate the polymerization shrinkage stress found at the restorative interface between composite resin and tooth structure. Polyacrylic acid is a highly elastic molecule capable of absorbing moisture from the environment and expanding to compensate for the polymerization shrinkage stress generated by the photo-initiation of the composite resin (Naoum et al. 2014). Resin-modified glass-ionomer cements also provide (Forsten et al. 1994) enhanced marginal protection from caries compared to resin adhesives. Capsulated resin-modified glass-ionomer cement adhesives have been shown to resist marginal staining equally well as resin-based adhesives (Tantbirojn et al. 2009) (Figs. 3.27 and 3.28).

3.6.9 Co-curing: Bonding Auto-Cure Glass-Ionomer Cements to Composite Resin

The sandwich technique as described by McLean (1992) required adhering the freshly set glass-ionomer cement to composite resin by first etching the glass-ionomer cement with 37 % phosphoric acid, washing and drying the surface, before applying a layer of unfilled resin as a bonding agent between the resin and composite. The bond strength generated by this technique was about 2 MPa.

Resin-modified glass-ionomer cements will chemically bond either freshly cured or uncured glass-ionomer cements to composite resin (Knight 1994). The resin component in the adhesive bonds to the composite, and the glass-ionomer cement component bonds to the auto-cure glass-ionomer. The bond strength of these bonds exceeds 7 MPa which is the cohesive failure strength of the auto-cure glass-ionomer (Knight et al. 2006) (Figs. 3.29, 3.30 and 3.31).

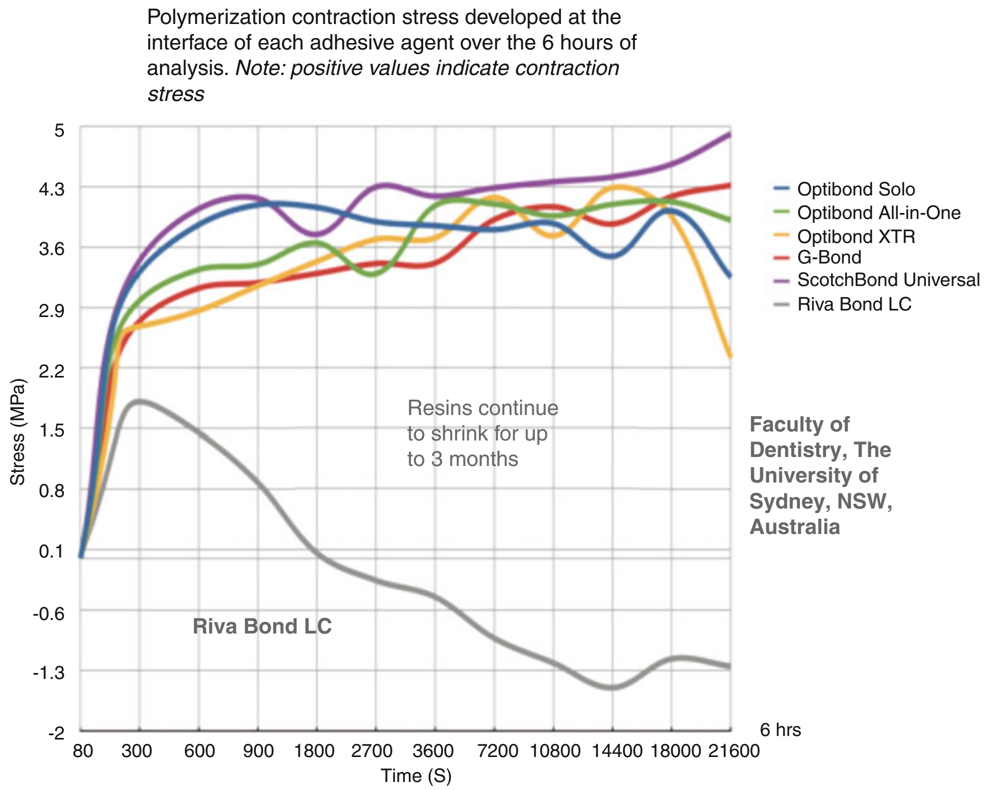


Fig. 3.27 Chart showing the reduction in polymerization shrinkage stress over 6 h at the margins of a composite resin restoration when a resin-modified glass-ionomer adhesive (Riva Bond LC) is used compared to resin-based adhesives (Reprinted from Naoum et al. (2014), with permission from John Wiley & Sons)

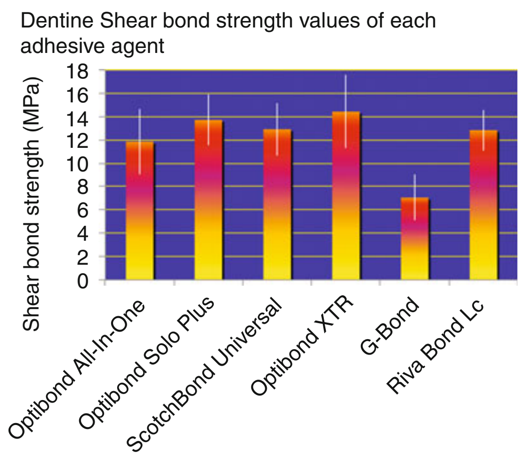


Fig. 3.28 Chart showing the comparisons of the shear bond strength to dentine of various dental adhesives (Reprinted from Naoum et al. (2014), with permission from John Wiley & Sons [Faculty of Dentistry, The University of Sydney, NSW, Australia])

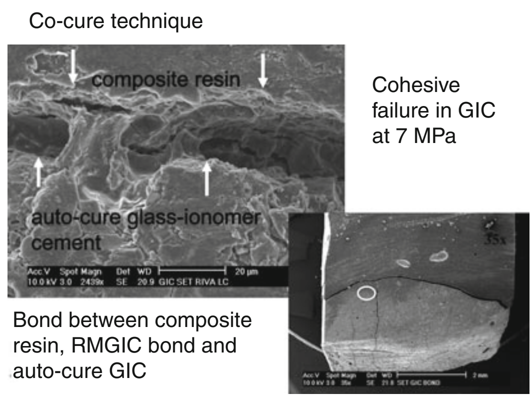


Fig. 3.29 Scanning electron micrograph showing the bond interface between set auto-cure glass-ionomer cement and composite resin using a resin-modified glass-ionomer adhesive at the interface (area indicated in the lower magnification micrograph). Note cohesive failure occurred within the auto-cure glass-ionomer (Courtesy of Dr. Geoff Knight)

3.6.10 Bonding Auto-Cure Glass-Ionomers to Tooth Structure

Resin-modified glass-ionomer bonding agents are capable of increasing the bond strength of auto-cure glass-ionomer cements to dental enamel and dentine. An uncured layer of resin-modified bonding agent is applied over a photo-cured layer followed by the auto-cure glass-ionomer and photo-curing of the combined materials for 40 s. The resin-modified glass-ionomer will photo-cure at the margins and dark-cure beneath the glass-ionomer cement. The bond strength exceeds the cohesive failure of the auto-cure glass-ionomer cement (7 MPa). Increasing the curing time to 40 s transfers heat from the curing light into the auto-cure glass-ionomer, encouraging the setting reaction (Knight et al. 2006) (Figs. 3.32, 3.33 and 3.34).

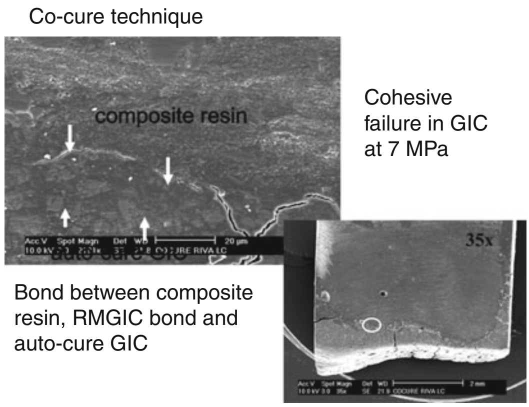


Fig. 3.30 Scanning electron micrograph showing the bond interface between unset (co-cured) auto-cure glass-ionomer cement and composite resin using a resin-modified glass-ionomer adhesive at the interface (area indicated in the lower magnification micrograph). Note how the glass-ionomer and composite resin interface has merged almost undetectably with the resin-based glass-ionomer cement adhesive and that cohesive failure occurred within the auto-cure glass-ionomer (Courtesy of Dr. Geoff Knight)

3.6.11 Resin-Modified Glass-Ionomer Bonding Agents Used as a Carrier for Medicaments Under Restorations

As resin-modified adhesives are water-soluble resin-based materials, they can be used as vehicles to apply medicaments at the base of a restoration. Metallic oxides such as zinc can be

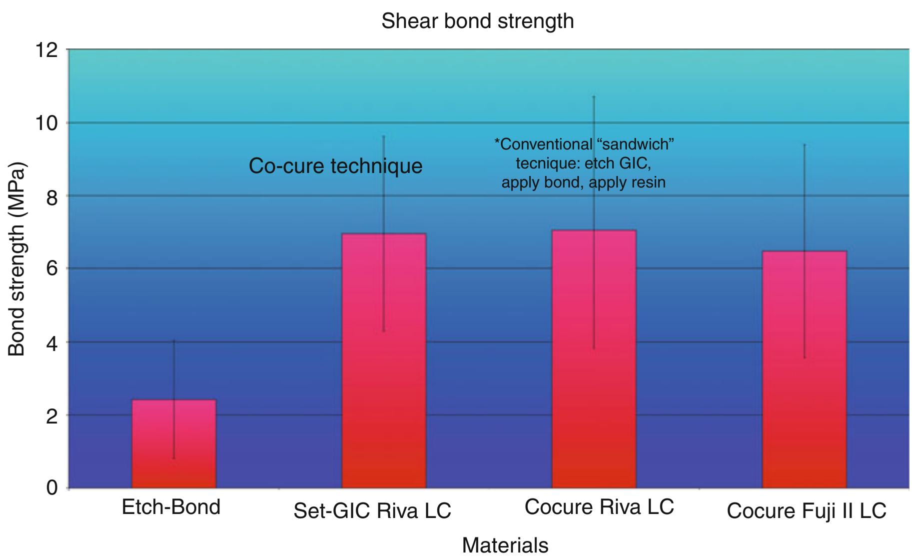


Fig. 3.31 Chart showing the bond strengths of various adhesive techniques between auto-cure glass-ionomer cement and composite resin. There is no statistical difference in the strengths between set and unset (co-cured) glass-ionomer cements as all samples failed cohesively within the glass-ionomer (Courtesy of Dr. Geoff Knight)

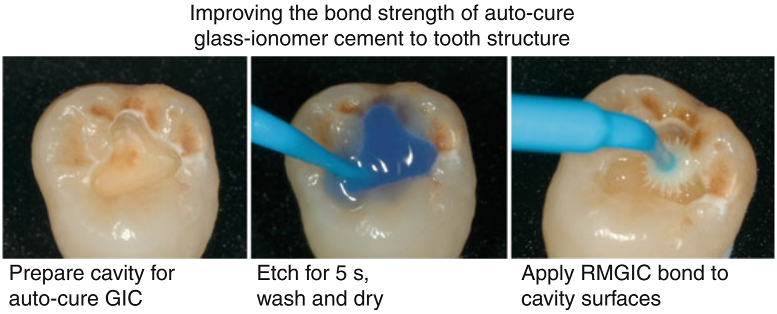


Fig. 3.32 Improving the bond strength between auto-cure glass-ionomer cement and tooth structure. This figure shows the preparation of the cavity and first layer of resin-modified glass-ionomer cement adhesive (Courtesy of Dr. Geoff Knight)

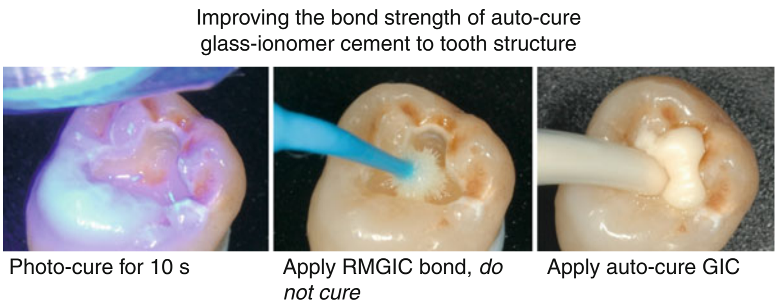


Fig. 3.33 Improving the bond strength between auto-cure glass-ionomer cement and tooth structure. This figure shows photo-curing the first layer and applying the second layer of adhesive followed by the auto-cure glass-ionomer cement (Courtesy of Dr. Geoff Knight)

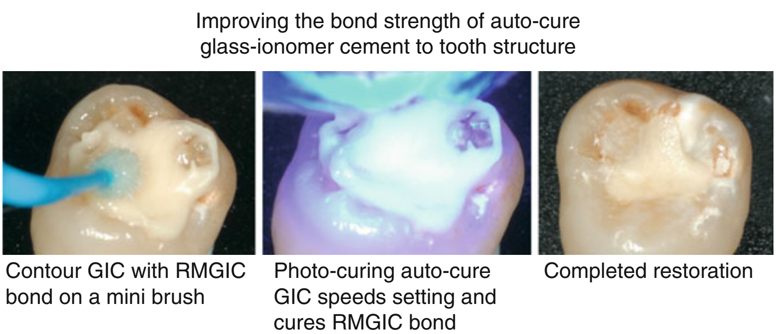


Fig. 3.34 Improving the bond strength between auto-cure glass-ionomer cement and tooth structure. This shows the photo-curing of the adhesive and auto-cure glass-ionomer cement for 40 s to speed the setting time due to heat from the curing light (Courtesy of Dr. Geoff Knight)

incorporated to act as a disinfectant, and small amounts of Ledermix® (Haupt Pharma GmbH, *Wolfratshausen*, Germany) powder can be mixed into the unset bond to create a light-cured version of the liquid/powder combination that has been used for many years as an anti-inflammatory lining beneath deep restorations (Figs. 3.35, 3.36, 3.37 and 3.38).

3.6.12 Bonding Amalgam to Enamel and Dentine

Resin-modified adhesives can be used under dental amalgams to create a chemical bond between the tooth and amalgam. Furthermore, this seals the amalgam and helps protect margins from recurrent caries.

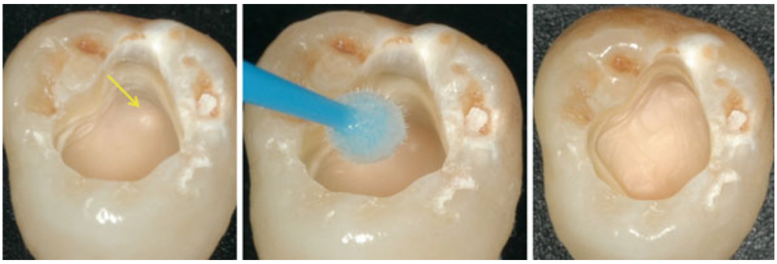


Fig. 3.35 Using a resin-modified glass-ionomer adhesive as a vehicle to apply medicaments to a tooth. This figure shows identification of a small exposure and applying TCA to manage any bleeding (Courtesy of Dr. Geoff Knight)

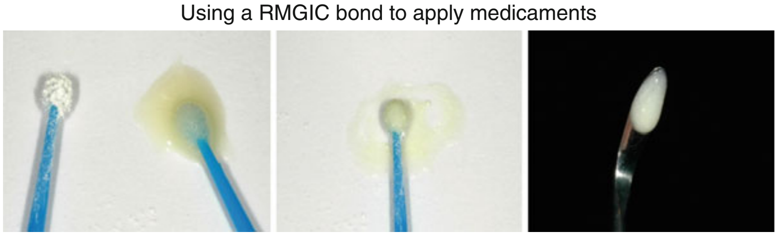


Fig. 3.36 Using a resin-modified glass-ionomer adhesive as a vehicle to apply medicaments to a tooth. This shows the technique for incorporating the medicament into the resin-modified glass-ionomer adhesive (Courtesy of Dr. Geoff Knight)

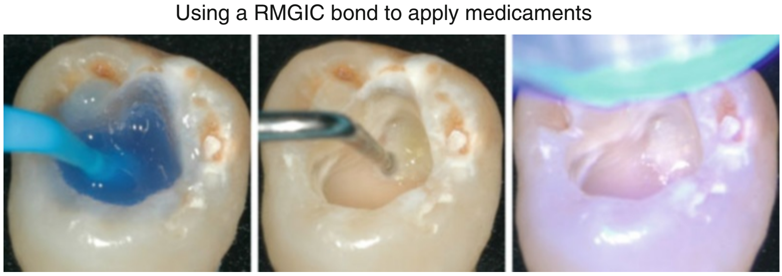


Fig. 3.37 Using a resin-modified glass-ionomer adhesive as a vehicle to apply medicaments to a tooth. This figure shows medicament application to the tooth (Courtesy of Dr. Geoff Knight)

Fig. 3.38 Using a resin-modified glass-ionomer adhesive as a vehicle to apply medicaments to a tooth. The application of resin-modified glass-ionomer cement adhesive and final placement of the restoration are shown here (Courtesy of Dr. Geoff Knight)

Conclusion

Glass-ionomer cements are finding an expanding role within dentistry as restorative agents, lining materials, luting cements and dental adhesives.

The biomimetic properties of all glass-ionomer cements enable far more conservative cavity preparations either in the management of small initial lesions or being incorporated in combination with composite resin in the management of much more extensive restorations.

The introduction of resin-modified glass-ionomer cement adhesives has resolved many of the inherent problems associated with polymerization shrinkage stress of composite resins and has further enabled the improvement of the bond of auto-cure glass-ionomer cement to tooth structure.

As the dental industry strives for a biomimetic, aesthetic and structurally robust replacement for dental amalgam, it would seem that the answer will certainly incorporate some glass-ionomer cement technology.

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