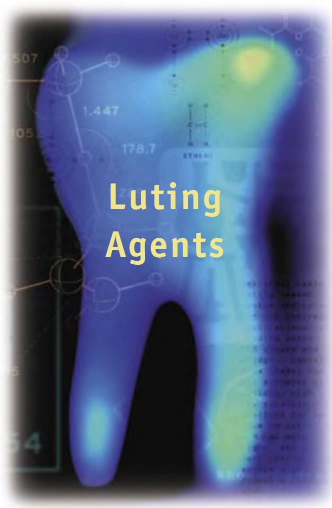

Selection of Luting Agents, Part 1

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Abstract

The clinical success of indirect restorations is dependent on multiple factors that include preparation design, mechanical forces, restorative material selection, oral hygiene, and selection of a proper luting agent. The selection of the luting agent is dependent on the specific clinical situation, the type of restoration utilized and the physical, biologic, and handling properties of the luting agent.

Although it is important to choose the best luting agent for each clinical situation, far greater variations in physical properties result from improper manipulation of a given luting agent than exist between different types of cements.[1] One study listed loss of retention as the third-leading cause of prosthetic replacement, with failure occurring after only 5.8 years in service.[2]

The primary purpose of the luting procedure is to achieve a durable bond and to have good marginal adaptation of the luting material to the restoration and tooth. Conventional cements have always relied upon retention and resistance forms in tooth preparations; Adhesive-type luting agents offer the clinician an added advantage by bonding to the tooth structure.[2]

Three main types of conventional "cements" are commonly used, zinc phosphate and the polyelectrolyte cements polycarboxylate, and glass ionomer cements. Because of its long history of successful clinical use, zinc phosphate is considered the gold standard against which all other luting agents are compared because of its long clinical history of successful use.

Currently, two additional types of luting agents have gained considerable popularity. These include the resin-modified glass ionomer cements and resin cements.[1] The resin cement category includes light-cured, dual-cured and chemically cured agents.

The purpose of this article is to discuss the ideal attributes of a luting agent and make clinical recommendations for their use.

The practicing clinician has many choices with regard to luting agents. No currently available luting agent is ideal for all situations and a careful choice needs to be made based on scientific rationale.

Ideal attributes of a luting agent are noted in (**Table 1**). These will be discussed in reference to currently available luting agents.

Adhesion to Tooth Structure

The primary function of a dental cement is to seal the restoration to the tooth. This would occur if the cement would biomechanically or biochemically adhere to the prepared tooth. Zinc phosphate, which has been the most popular luting agent for the past 100 years, does not chemically bond either

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to the tooth structure or the restorative material. However, when freshly mixed, zinc phosphate has a very low pH. This acidity allows for excellent wetting of the tooth and for micromechanical attachment to the prepared dentine. Retention depends on careful design of the tooth preparation and the quality of fit of the restoration. Several microleakage studies have demonstrated significant linear penetration of silver nitrate from the external margin along the restoration/tooth interface after crown cementation with zinc phosphate cement. The significance of this microleakage will be discussed later in the article (**Figure 1**).[4,5]

The polyacrylic-based cements bond to both enamel and dentine and are also claimed to have some affinity for metal and ceramic surfaces. This category of tooth adhesive cements includes polycarboxylate and the glass ionomer, and resin-modified glass ionomer cements. Although they have some ability to bond to metals, they do not provide adequate bond strengths to metal or ceramic in some of the more demanding situations encountered.[6,7]

Polycarboxylate cements exhibit chemical adhesion to the tooth through interaction of free carboxylic acid groups with calcium. It is reasonable to assume that because of this adhesion, polycarboxylate cements would exhibit less microleakage. However, microleakage studies demonstrate they leak just as much as zinc phosphate. The glass ionomer cements form an ionic bond to the tooth as a result of chelation of the carboxyl groups in the acid with the calcium and phosphate ions in the apatite of dentine and enamel.[7]

The resin-modified glass ionomer cements also form much stronger bonds to dentine than does zinc phosphate cement. There is sufficient data to warrant their use as an alternative to zinc phosphate in luting full-coverage restorations.[8,9] Their adhesion to enamel and dentin is similar to glass ionomer cement. An added advantage is that these cements are able to bond to composite resin.

Table 1

Desirable properties of a luting agent

1. Adhesion to restorative material
2. Adequate strength to resist functional forces
3. Lack of solubility in oral fluids
4. Ability to achieve a low-film thickness under cementation conditions
5. Biocompatibility with oral tissues
6. Possession of anticariogenic properties
7. Radio-opaque
8. Relative ease of manipulation
9. Esthetic/color stability

With the advent of predictable dentin bonding, the resin cements can bond to both tooth structure and restorative material. Adhesion to enamel occurs through micromechanical interlocking of the resin to the hydroxyapatite crystals and the rods of etched enamel.

Resin to dentin adhesion is obtained by infiltration of resin into etched dentin producing a micromechanical interlock with partially demineralized dentine, which underlies the hybrid layer. Adhesion to dentine requires multiple steps beginning with the application of an acid conditioner to remove the smear layer, open and widen tubules and demineralize the top 2-5 microns of dentine. The acid dissolves and extracts the apatite material and opens channels around the collagen fibers. These channels provide an opportunity for micromechanical retention. An optimal 2-5 micron zone of demineralization has been described with a 15-second application for conditioner. Prolonged application results in a deeper demineralization zone which resists resin infiltration. If complete infiltration of the collagen by the primer does not occur, the collagen within the deeper demineralized layer will be left unprotected and subject to future proteolysis and breakdown. After demineralization, a wetting agent, such as HEMA (hydroxyethyl methacrylate), is applied. HEMA is bifunctional and hydrophilic, which allows it to bond to the dentine, and it is also hydrophobic which allows it to bond to the adhesive.[10,11]

It is reasonable to assume that luting agents that present stronger bonds to tooth structure will also demonstrate less microleakage. This has been verified by both in vitro and in vivo studies.[4,5] Restorations cemented with resin and resin-modified GIC exhibit reduced microleakage when compared to zinc phosphate cement. Conventional glass ionomers also demonstrate significantly less microleakage than zinc phosphate cements. What is the clinical significance of reduced microleakage? A recent in vivo

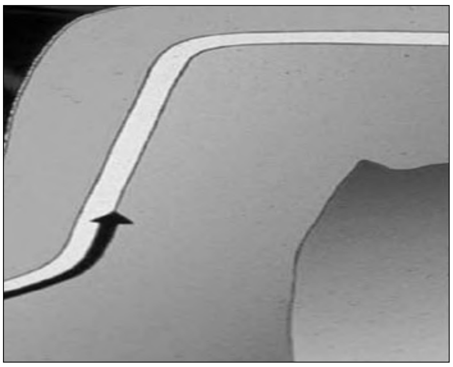

Figure 1. Leakage pathway of cast crown.

study evaluated microleakage with cast gold crowns cemented with zinc phosphate. The study evaluated eight restorations that had provided a mean service of 22 years. The teeth required extraction for periodontal reasons. When conventional tests were done on these teeth, the typical microleakage associated with zinc phosphate was demonstrated. However, there was no evidence of recurrent caries, sensitivity, or pulpal degeneration. This data calls into question the clinical significance of microleakage studies.[12] There is no evidence that improved adhesion to tooth structure improves the clinical performance of dental cements for cast restorations. However, one must be careful not to extrapolate this to the bonded restoration where adequate seal may play a major role in the survival of the restoration.

Adhesion to Restorative Material

It is also thought that a strong bond to the restoration is desirable. With conventional cements this would not be an advantage because when the crown loses retention, it is normally seen that the cement is retained within the crown. With regard to ceramic restorations luted with resin-based cements, there is controversy whether one should achieve a stronger bond to the restorative substrate by silanating the ceramic or not.

The research on silanization reports higher bond strengths to the ceramic.[13] It reports chemical bonding between the ceramic and the resin composite. Use of silane improves the wettability and contributes to the covalent bond formation between porcelain and resin composite. It also theoretically supports reinforcement of the ceramic through chemical bonding, theoretically decreasing the likelihood of fracture.

Those against silanization argue that a greater bond strength to the ceramic is not required, the micromechanical bond to the etched ceramic is adequate. Increasing the bond to the restorative substrate results in uniaxial shrinkage of the cement toward the restoration and significant contraction gaps develop at the tooth cement interface. These gaps are thought to result in microleakage and continue to be a source of sensitivity.[14]

If the practitioner decides to silanate, a number of variables need to be considered. When using silane, one mix and two mix silanes are available. The silane coupling agents contain a high volume of various solvents. Improperly sealed or open containers will allow evaporation of the solvents and increase the concentration of the coupling agent. If this occurs, the silane may act as a separating medium reducing the bond strength between the ceramic and the composite.

Various authors have also evaluated the effect of silanization of porcelain on the bond strength to composite. The general trend observed was that application of a silane coupling agent resulted in improved bond strength. The heat treatment showed increased bond strength, and it was demonstrated that delaying the time between silanization and bonding resulted in increased bond strength.[15] From a practical perspective, delaying the bonding time is not feasible.

Other studies have also investigated the effect of the post-silanization drying time with a stream of warm air to determine if this could increase the tensile bond strength of composite to ceramic over that produced by room temperature drying.[16] Higher bond strengths were achieved with warm air and the failure mode was cohesive within the composite. The results of the study concluded that use of a miniature blow dryer is effective in enhancing bond strength of ceramic to composite than drying at room temperature.

Silane must be used appropriately. Imperative procedures include properly sealed containers to prevent evaporation of solvent, heat drying following applications, and a delay in bonding time. Those who do not use silane must exercise proper care in etching the ceramic with hydrofluoric acid after clinical try-in and remove ceramic precipitates that form on the internal surface of the restoration.[17] These residues have a potential to reduce the bond strength of the ceramic to the composite (**Tables 2**, **3**).[18]

Indirect composites were introduced as an inlay/onlay material in an attempt to improve the mechanical properties over direct restorative materials. However, there is no clinical evidence to show that an improvement in physical properties translates to an improvement in long-term clinical success. A number of studies have evaluated adhesion between the resin cement and the inlay/onlay material. Anecdotally, many clinicians have observed debond-

Table 2

Reasons in favor of using silane

Advantages

1. Higher bond strengths to ceramic
2. Provides chemical bonding
3. Reinforcing the ceramic decreasing propensity of fracture

Table 3

Reasons against using silane

Disadvantages

1. Don't need a higher bond strength to ceramic
2. Potential for postoperative sensitivity
3. Silane improperly used can act as a separating medium.

ing between the luting resin and composite inlay.

Microsandblasting of the composite surface is a prerequisite for optimal bonding.[19] Indirect composites are also secondarily cured and studies have shown that this curing causes a significant reduction in availability of the bonds and a consequent reduction in bond strength to composite.[20] One author evaluated the adhesive bond strength of resin cements to resin composites with and without secondary curing and with and without microsandblasting.[18] The results of the study showed that secondary curing only without sandblasting resulted in a decreased bond strength to the resin cement. Sandblasting improved the bond strength. The greatest bond strengths were achieved without secondary cure and with sandblasting.[21] When using these types of restorations, microsandblasting of the fit surface should always be performed prior to bonding.

The authors have also evaluated various surface treatments of indirect resin composites prior to luting (microfilled and hybrids).[18] The effect of hydrofluoric acid, phosphoric acid, microsandblasting, and combinations were investigated. The results of the studies showed that phosphoric acid and hydrofluoric acid alone did not produce sufficient roughness to create mechanical retention. In fact, the use of the hydrofluoric acid degraded the surface of the composite. With microfilled composites, the glass particles were embedded in the resin and were unavailable for etching. Hybrids had higher bond strengths with etching than did microfills. The highest bond strengths were achieved when microsandblasting followed by etching with phosphoric acid. The microsandblasting roughens the surface and the phosphoric acid cleans any debris (**Table 4**, **Figures 2-6**).

Resin-bonded fixed partial dentures have an undeserved poor reputation in the minds of many practitioners who believe that such prostheses have a relatively short life span. This reputation has resulted from improper teaching and execution of this restorative service.[1] It has been shown that with proper resistance and retention form that long-term clinical service of resin-bonded fixed partial dentures is at least equal to conventional cemented prostheses.[22]

Various methods to develop adhesion between a prosthesis and a tooth have been developed. Initially the approach was macroretentive but gradually adhesive procedures involving micromechanical and chemical bonding became available.[23,24]

Another approach is the use of adhesion promoters such as silica coating, tin plating, tribochemical coatings, and metal primers, which have been developed to improve the bond between metal and the more conventional Bis GMA or urethane dimethacrylate resins. An important consideration in adhesion is whether one is seeking to bond a base metal alloy or a precious metal alloy.

For the resin-bonded fixed partial dentures, the metal is etched, which removes one of the phases and provide micromechanical retention. This provides a surface onto which composite resin can adhere. The composite luting resins are very similar to composite resin restorative materials in that they consist of Bis GMA, or urethane dimethacrylate resins, and a glass filler. Where these resins are different is that they are a two-paste system, which are either chemically or dual-cured. The filler particle size is less and the filler loading tends to be slightly less in order to ensure a lower film thickness.

One of the drawbacks of the technique is the reluctance of clinicians and laboratory technicians to use to beryllium containing Ni-Cr alloys. Nonberyllium containing Ni-Cr alloys do not etch as well.

Table 4

Pretreatment of indirect composite prior to bonding

- Secondary curing causes reduction in availability of bonds.
- Microsandblasting improved the bond strengths.
- Highest bond strengths are achieved with microsandblasting followed by cleaning with phosphoric acid.

Figure 2. Recurrent caries beneath amalgam restoration patient requested esthetic alternative.

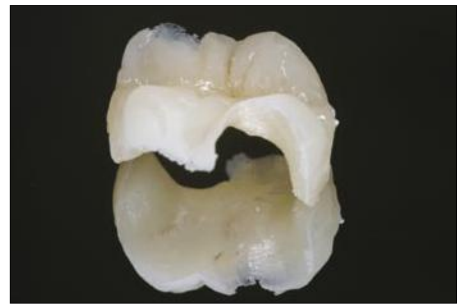

Figure 3. Indirect composite restoration.

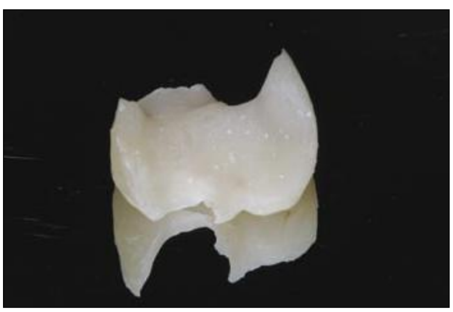

Figure 4. Fitting surface of indirect composite microsandblasted to improve bond strength.

Figure 5. Thirty-seven percent phosphoric acid used to clean debris on fit surface.

Figure 6. Indirect composite on No. 2.

Precious metal alloys also cannot be etched since they have a relatively homogenous microstructure, hence it is not possible to use the etching technique for resin bonding with these alloys.

Because of the trend to move away from beryllium-containing alloys, laboratories had to find some other means of bonding to the alloy. The problem is Bis GMA and UDME resins do not bond well to etched metal surfaces and rely primarily on micromechanical and physical adhesion. In order to improve the adhesive bond to metal, a variety of composite resins have been developed in which the resin component has been modified to be able to bond chemically to the metal surface, these luting agents are referred to as chemically adhesive luting resins to differentiate them from the Bis GMA resins C&B superbond is one example (based on carboxylic monomer 4 META).

Another luting agent which has been modified to contain a phosphate monomer is Panavia 21 from Kuraray (MDP methacryloxyethylphenyl phosphate). Resin bonding is facilitated by the high affinity of the carboxylic acid or phosphoric acid derivative containing resins for the metal oxide on the base metal alloy, they can provide a durable bond to nickel chromium alloys. They have low affinity for precious metal alloys, such as gold and palladium, due to lack of surface oxide coating.

Adequate Strength to Resist Functional Forces

Many clinicians believe that increased strength of the luting agent will increase the retention of the castings on the teeth. Scientific evidence for this belief is lacking and it is becoming increasingly clear that crown retention is a function of resistance and retention form coupled with accuracy of fit of the casting. Clinical experience with provisional luting agents and resin-bonded fixed partial dentures support this belief.[1]

There are substantial differences in strength between the different groups of luting agents. The question always arises, if it is stronger, does it mean it is better?

Figure 7. Short clinical crowns, which would lack resistance and retention form if prepared for full-coverage restorations.

Figure 8. Preparations must provide adequate resistance and retention form.

Cement strengths are generally compared using the parameters of compressive strength and diametral tensile strength, with the latter being considered more important to clinical performance. Compressive strength tests are done with cylindrical samples and diametral tensile tests are done using disc-like samples. Neither of these tests evaluates the cement in the mode, in which it is used, which is a thin film of 25 microns. Testing will reveal that zinc phosphate has the lowest compressive and diametral tensile strength while resin cements have values which are much higher. The clinical significance of these values can be questioned. If the clinician is confronted by preparations with a short wall height, can the strength of resin cements be used to provide long-term retention for restorations?

Increased strength of cements will not increase retention of castings cemented on prepared teeth (**Figures 7, 8**). It may provide retention for the prostheses in the short term but eventually the cement will undergo fatigue failure and the prosthesis will decement. Increasing the strength of the cement will not compensate for lack of retention and resistance form.[1]

Many clinicians have experienced delivering a definitive restoration with a provisional cement only to find that the restoration is very difficult to remove. These provisional cements have much inferior physical properties than the permanent cements, yet still retain the casting in place over the long term. This calls into question the value of increased strength.

Lack of Solubility in Oral Fluids

Significant differences in solubility exist between the different luting agents. The literature on solubility demonstrates the necessity of relying too heavily on in vitro data to predict clinical performance. Tests are done in which the cement sample is immersed in a solute for 24 hours and the weight loss of the sample is recorded or an increase of the cement component in the solute is measured. Under these conditions, zinc phosphate appears to be the least soluble and glass ionomer the most soluble. However clinical studies show the opposite to be true.[24-26] The difference between in vitro and vivo studies can be explained by patient variability and timing of the test. Tremendous variability can exist between patients in terms of their potential to dissolve cement with some dissolving much cement and others dissolve none. The timing of the test is also critical. Glass ionomer cement is quite soluble within the first 24 hours and perform poorly in a 24-hour test. However after the initial 24 hours, glass ionomers are quite resistant to dissolution and hence perform very well in a long-term clinical test. The latter is more clinically significant.[1]

The issue should not be the solubility of the cement but rather the fit of the restoration. With excellent fitting restorations solubility is secondary.

Ability to Achieve a Low–Film Thickness Under Cementation Conditions

Film thickness is influenced by a number of factors including particle size of the powder, cementation force and technique, viscosity and the use of specific techniques such as diespacing, venting, or placement of escape channels.

ADA stipulations state that luting agents must achieve a film thickness of no more than 25 microns under the conditions of the specification test. With this test, a mix of cement is compressed between two glass slabs with a specified amount of force, and then the increase in thickness of the two slabs is measured. This increase in thickness is designated film thickness. Most luting agents can achieve the required film thickness under the specifications of the test but the same luting agent may produce excessive casting elevations when the restorations are luted in place.[27,28] What the clinician must understand is that values reported in trade journals may not be representative and film thickness is more than just a material property. Ultimately, it's how the practitioner manipulates the luting agent rather than the physical property of the luting agent itself.

Biocompatibility With Oral Tissues

When luting agents are used they will invariably contact a large area of dentin, hence the susceptibility to producing postoperative sensitivity or pulpal inflammation is a very important consideration.

An ideal luting agent would not be harmful to the dental tissues. It was long thought that cements containing phosphoric acid cause pulpal inflammation as a result of their low pH. For many years clinicians applied copal varnish over the prepared tooth to protect the pulp from the acidity of zinc phosphate cement. Research has challenged this long-held belief and it is likely that all commonly used dental cements elicit no long-term pulpal response and hence meet the criteria for biocompatibility.[29]

Postoperative sensitivity has also been rightly or wrongly attributed to the luting agent used. Clinical symptoms such as sensitivity after crown cementation are more likely because of microleakage than pulpal inflammation resulting from damage caused by the luting agent. Well-controlled clinical trials using a strict protocol for cementation have demonstrated that the sensitivity is clearly operator-related and can essentially be prevented with proper technique.[30,31]

A concept which has been introduced during the last few years is the idea of "immediate dentin sealing." This has been primarily advocated for adhesive-type restorations. It has been demonstrated that effective adhesion can be achieved by immediately applying the adhesive following tooth preparation.[32] Following application of the adhesive and curing, an impression is made. It appears that immediate dentine bonding has several advantages by sealing the dentinal tubules prior to impression-making:

- No contamination of the dental tissues by impression material or cement,
- Stabilization of the adhesive layer prior to subjecting the adhesive interface to stresses, and
- Reduction of postoperative sensitivity.

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It appears to be a perfectly rational way to seal and protect the dentino-pulp complex, prevent sensitivity, and bacterial leakage during the provisional phase.

Possession of Anticariogenic Properties

Many luting agents have been described as having anticariogenic properties. A number of these have been marketed on this premise. Many manufacturers claim that their specific brand of cement releases fluoride, but the clinical efficacy of such claims has not been investigated.

The fact that a material contains fluoride does not necessarily endow it with anticariogenic properties. Sufficient concentrations of fluoride must be released over a period of time, and the material itself should not suffer from any significant degradation. Of the conventional cements, the glass ionomers have been reported to have long-term fluoride release and cariostatic activity of these cements has been proposed.[33] However, even if fluoride is released, one must question just how much fluoride is released from the margins of a well-fitting restoration, and whether this amount of fluoride has any significant impact. Scientific studies have been inconclusive in showing that the thin film of cement at the margin of a restoration has any significant clinical therapeutic value as a cariostatic agent.

Radio-opacity

An ideal luting agent should be radio-opaque to enable the practitioner to distinguish between the cement, the tooth, and the restoration. Combinations of composite luting cements/and or glass ionomers may show gap-like features because of difference in radio-opacity. It is important that dental cements have greater opacity than dentine.

It is impossible radiographically to detect excess luting agent if the material is radiolucent. In practice, luting agents come in a wide range of radio-opacities.

One study showed zinc phosphate to be the most radio-opaque. The dual polymerized and conventional glass ionomer showed the same as human enamel. The RMGI are intermediate between enamel and dentine. The autopolymerizing luting agents had similar radio-opacity to dentine and were the lowest.[34]

Relative Ease of Manipulation

One of the most important attributes of any dental material is that it be user friendly and relatively easy to manipulate.

It is important that cements be mixed according to manufacturer's recommendations and with meticulous attention to detail, far greater variations occur from improper mixing rather than selection of type of cement. Cements may be handmixed or come in pre-dosed capsules or syringes. The auto-mix cartridges are an advantage because they allow a consistency of mix, convenience, and less clean up is required. Disadvantages include greater expense and the inability to vary the viscosity.

Amongst the conventional luting agents, zinc phosphate appears to be the least technique-sensitive. A specific protocol is required with the use of zinc phosphate, and as long as these recommendations are followed long-term success will be achieved.[1]

Polycarboxylate cements are also more technique-sensitive. They exhibit a thixotropic behavior where an apparently viscous mix flows readily under pressure. However, they exhibit a rapid increase in film thickness that may impede proper seating of a casting. During setting, polycarboxylate cements go through a rubbery stage, and at this time should remain undisturbed during setting to prevent it from being pulled away from under the margins.

One disadvantage of polycarboxylate cements is they exhibit plastic deformation and thus the cement is not suited for use in areas of high masticatory stresses or in cementation of long-span prostheses.[35] Their use is confined to single units in low stress areas. These cements may also be used to secure long-term provisional restorations.

Resin cements are extremely technique-sensitive because of their inherent polymerization shrinkage and their sensitivity to moisture. Using resin cements with restorations that have subgingival margins is problematic. Removal of the excess becomes difficult because of the hardness of the cement and its adhesion to the tooth.

Resin-modified glass ionomer cements are less technique-sensitive than the resin cements and in auto-mix cartridges, can prove to be an extremely efficient way of delivering cast restorations. One of the disadvantage of RMGIC is the hydrophillic nature of the polyhema, which results in increased water sorption and subsequent plasticity and hygroscopic expansion. The continual water resorption does have deleterious effects. Potential for substantial dimensional change contraindicates their use with all-ceramic type restorations.

The working time and setting time are considerations in the choice of luting agent, the longer working time being needed for long-span prostheses vs. single-unit restorations. With conventional luting agents, the working time can be varied by utilizing techniques such as slaking, incremental mixing, use of a chilled slab, and mixing over a wide area to dissipate the heat of the exothermic reaction.

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With resin cements there is a choice between dual-cured and light-cured resins.

The light-cured resins have some purported advantages in that working time is increased, the ability to remove excess, and reduced finishing time. Dual-cured cements have traditionally been used when ceramic thickness did not allow light penetration for maximal conversion of the luting cement. Disadvantages of dual-cured cements include porosity from mixing, reduced working time, degree of conversion, and color instability due to amine degradation. One author investigated both dual- and light-cured cements in regard to conversion rate under cerec inlays.[36]

The following parameters were evaluated: the effect of ceramic thickness, use of a light reflecting wedge, and varied the time of curing. Following curing, Vickers hardness at the pulpoaxial wall was measured. It was concluded that dual-cured cements offered no advantages over the light-cured cements, provided an extended curing mode 120 seconds was used. One question which often arises is curing of the luting agent beneath excessive thicknesses of ceramic. An alternative approach to avoid excessive thicknesses of ceramic is to build the tooth up in composite material.

The Young's modulus of composite is more like dentin as opposed to ceramic, which is a more enamel-like material. The core of the tooth may be built up to minimize thickness of ceramic in the definitive restorations. Traditionally, clinicians removed tooth structure to eliminate undercuts so that the preparation would allow a single path of insertion. Today, clinicians are able to block out undercuts with composite and avoid the unnecessary destruction of tooth tissue so that a single path of insertion may still be realized. In this manner, the thickness of ceramic can be optimal for use of light-cured resins.[37]

Another category of luting agents that has recently been introduced is the auto-adhesive group. It is not the purpose of this article to describe the different mechanisms of adhesion of resin cements but briefly just to describe the three categories.

Etch and rinse, self-etch adhesive along with a low-viscosity resin composite, and the self-etch, which also includes the self-adhesive resin. This third category of resin cement is becoming very popular with practitioners because of the reduced chairtime and a simpler application protocol. It combines the adhesive and resin in one product eliminating the need for pretreatment of both tooth and restorative material prior to cementation.

The adhesive properties are based on acidic monomers that demineralize and infiltrate the tooth substrate resulting in micromechanical retention. A secondary reaction of this cement is to provide chemical adhesion to hydroxyapatite.

Several other purported advantages from manufacturers include:

- It is dual-cured and achieves a bond to tooth structure similar to that achieved by multistep adhesives,
- Mechanical properties are supposedly superior to zinc phosphate and glass ionomer cements,
- It has excellent moisture tolerance and manufacturers state that a rubber dam need not be used, and
- Little risk of postop sensitivity because the dentin is not etched, the smear layer is not removed, and the dentinal tubules remain closed. The multistep of etching, priming, and bonding are not required so there is little risk of overdrying, overly moist dentin and generation of nanoleakage by inadequate preparation of the primer and bonding system.

One group of authors evaluated the microtensile tensile bond strength of RelyX Unicem(3M Espe) to enamel and dentin.[38] The experimental protocol also evaluated the interaction of this material with dentin by means of high resolution electron microscopy. The authors compared the microtensile bond strength to enamel and dentine with and without etching after 24-hour water storage compared to the bonding effectiveness of the control cement Panavia F (Kuraray). The interface between the dentine and the luting agent was also examined with a scanning electron microscope.

There is no ideal luting agent for all procedures; and choice is dependent on physical properties, technique sensitivity and evidence base.

The results showed that microtensile bond strength was significantly lower than that of the control cement to etched enamel, while there was no significant difference to dentin. Acid etching raised the microtensile bond strength to that of the control cement but was detrimental to the dentine bonding effectiveness. This was due to inadequate infiltration of the collagen mesh.

SEM evaluation showed that Rely X cement interacted only superficially with enamel and dentine, and application, using some pressure, is required for close adaptation of the cement to the cavity wall. There was negligible chemical bonding.

Esthetics and Color Stability

Esthetics, although not a major consideration with metal and metal ceramic restorations does become an issue with translucent porcelain restorations. Light transmission and color stability of the luting agent are important in this regard. Expanded kits of resin cements with tints, opaques, and multiple shades are tailored to anterior ceramic restorations and supposedly allow subtle shade corrections to be made. Caution should be exercised in this approach. In practice, the color of a try-in paste may differ significantly from the luting agent. Of three shades of three bands tested by one author, all but two had easily detectable color differences.[39] For anterior esthetic restorations, color of the restoration should be developed with intrinsic characterization techniques and the restorations bonded with a universal luting agent.

Color stability over time should be considered.[40,41] The amine accelerator necessary for dual cured polymerization can cause the color to change over time. This in itself may be another reason for choosing light-cured resins over dual-cured when bonding esthetic restorations.

Clinical Recommendations

There is no ideal luting agent for all procedures; and choice is dependent on physical properties, technique sensitivity and evidence base. The type of restoration being fabricated also has an important role in the selection of a luting agent with the requirements of bonded restorations being very different to that of cast restorations.

Physical properties of a luting agent, although somewhat important, cannot be used as the sole basis for selecting a cement based on discussions earlier.

Two criteria to look at would be evidence-base and technique-sensitivity. It is reasonable to make the statement that unless a specific indication for a given luting agent exists, the least technique-sensitive material should be utilized.

The following is a brief summary of clinical recommendations. A more detailed analysis of luting of all ceramic restorations will follow in Part 2 of the article.

Gold Castings and Metal Ceramic Restorations

There are a number of luting agents available when seating a well-fitting cast restoration.

■ Zinc phosphate would be considered for its long clinical history of use. Also, it has a long working time when correctly mixed zinc phosphate materials are indicated for multiunit fixed-partial dentures, as well as full-arch restorations.

■ Glass ionomer could be used but the variables of the mixing procedure should be controlled.

■ Glass ionomer does have a shorter setting time in comparison to zinc phosphate.

■ Resin-modified glass ionomer cement is also appealing because of its user friendly nature. The auto-mix delivery systems make dispensing and clean up much easier. From a practical perspective, it is easier to mix than zinc phosphate cement. Long-term clinical data also warrants its use.

Polycarboxylate cements should only be used for single-unit restoration. Plastic deformation over time limits their use when luting fixed-partial dentures. With polycarboxylate cements, the setting reaction proceeds rapidly and the mixing should be completed within 30 to 40 seconds.

Dowel and Cores

It appears from what has been discussed that luting of cast dowels should be carried out with zinc phosphate. Glass ionomers should not be used because they do not attain adequate strength in their early setting stage, and frequently such dowels do not fit the canal space with precision. This may result in excessive film thicknesses of GIC, which may weaken it.

There is a tendency to go toward bonding of cast dowel and cores. Excellent retention can be obtained using the proper technique. This technique would involve etching the internal of the canal, applying a hema-based primer and then the activated monomer.[42] The activated monomer is applied to the dowel, which is then coated with adhesive resin and then the dowel is inserted. However, if retrieval of the dowel is required for endodontic retreatment, it becomes a difficult endeavor. Practitioners should exercise caution in this approach.

Resin-Bonded Fixed-Partial Dentures

Chemical cured resin cements such as Panavia should be used. The chemical cure is essential because it's virtually impossible to expose the cement to an adequate amount of light to enable it to set. The cement should be opaque to mask the color of the metal that may alter the shade of the abutment teeth.

Porcelain Veneers

The luting agent of choice here is light-cured resin cement. Dual-cured cements exhibit color instability over time and can affect the esthetics of the restoration in the long term. This luting agent should also be radio-opaque (**Figures 9-14**).

The type of composite to use also requires consideration.

■ Heavily filled composites are desirable. The viscosity of these can be reduced by warming the carpule of composite contained in a clear, plastic, waterproof bag in hot water. The concern with this is that seating may be a little more difficult and the risk of fracture with excessive seating force exists. The advantage of using a slightly heavier filled composite is that it makes clean up much easier for the operator.

■ Composites with low filler content have worked very well in the past but excess is more difficult to control and increased time is required for clean up.

Ceramic Inlays/Onlays

The advantages of light-cured resins have been discussed previously. There is easier clean up, command set, and a homogenous mix. With dual-cured resins, there is limited working time and the possibility of porosity on mixing. Excessive bulk of ceramic can be avoided by building the tooth up with composite prior to preparation so that optimal thicknesses of ceramic are attainable.

Figure 9. Preoperative composite veneers on teeth Nos. 8 and 9.

Figure 10. Teeth Nos. 8 and 9 prepared and dentin immediately sealed.

Figure 11. Porcelain restorations etched with 10 percent hydrofluoric acid for 90 seconds.

Figure 12. White chalky color denotes formation of ceramic residues following etching. These residues must be removed to improve bond strengths. Precipitates removed by placing veneers in ultrasonic bath for three to four minutes. Internal of veneer should have a clean surface.

Figure 13. Veneers bonded under rubber dam isolation.

Figure 14. Final postoperative situation with ceramic veneers on Nos. 8 and 9 and composite restoration on No. 10.

All-Ceramic Crowns

■ Luting of all-ceramic crowns is dependent on the substrate that is being utilized.

■ Ceramic restorations available today are either etchable or non-etchable based on the core material.

■ Etchable are the silica-based ceramics feldspathic, leucite-reinforced, and glass ceramics.

■ Non-etchable are the nonsilica-based ceramics such as aluminum oxide, zirconium oxide. Part 2 of this article will discuss in detail luting protocols for these types of restorations.

Luting agents possess varied, complex chemistries that affect their physical properties, longevity and suitability in clinical situations. It appears that a single agent is not suitable for all applications. Physical properties should not be a sole criteria for selection because improvement in many of the apparently important physical properties has not automatically resulted in an improvement in clinical performance.

To date, no single luting agent can completely compensate for the shortcomings of preparation retention and resistance form or ill-fitting, low-strength restorations. Practitioners must be aware of the virtues and shortcomings of each type of luting agent and select them appropriately. CDA

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